



AEROSPACE RECOMMENDED PRACTICE

ARP5794™

REV. A

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Superseding ARP5794

Centrifugal Aircraft Fuel Pump Requirements,
Design and Testing, Aerospace Standard

RATIONALE

This Aerospace Recommended Practice is intended to provide general guidelines for the design, development, and qualification of aircraft, tank mounted fuel booster pumps. This revision adds references to SAE documents ARP594 and ARP6385 which provide additional details on proper methods for thermal, mechanical, and electrical safety design of pump components.

1. SCOPE

This specification covers the general design, testing, and safety requirements for aircraft tank mounted fuel booster pumps used for engine fuel feed, transfer, and jettison.

1.1 Purpose

This document is intended to provide guidance for the proper design, testing, and certification of aircraft, tank mounted fuel pumps. References to key considerations for safety compliance to all applicable industry regulations are directly discussed or references are provided to other SAE documents. This document is meant to complement a Procurement Agency's detail technical specification for a given design application or use. This document was developed as the replacement document for MIL-P-5238C, which was made inactive in 1996.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue negotiated between Seller and Procurement, except where specific revisions have been called out on selected specifications. In this case the cited revision or a letter revision shall apply. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2175	Castings, Classification and Inspection of
AMS3216	Fluorocarbon (FKM) Rubber High Temperature - Fluid Resistant Low Compression Set 70 to 80
AMS-A-21180	Aluminum Alloy Castings, High Strength

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Documents
Document Sharing Hub

AMS-P-5315	Acrylonitrile-butadiene (NBR) Rubber for Fuel-Resistant Seals 60 to 70
AMS-QQ-P-416	Plating, Cadmium (Electrodeposited)
AMS-R-83485	Rubber, Fluorocarbon Elastomer, Improved Performance at Low Temperatures
AIR4246	Contaminants for Aircraft Turbine Engine Fuel System Component Testing
ARP594	Fuel Pump Thermal Safety Design
ARP1401	Aircraft Fuel System and Component Icing Test
ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP5316	Storage of Elastomer Seals and Seal Assemblies Which Include an Elastomer Element Prior to Hardware Assembly
ARP6385	Aircraft Fuel Pump Mechanical and Electrical Safety Design
ARP8615	Fuel System Components: General Specification For AS5202 Port or Fitting End, Internal Straight Thread, Design Standard
AS5440	Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For
AS8879	Screw Threads - UNJ Profile, Inch Controlled Radius Root with Increased Minor Diameter
AS50881	Wiring Aerospace Vehicle
SAE J1926-1	Connections for General Use and Fluid Power - Ports and Stud Ends with ASME B1.1 Threads and O-Ring Sealing - Part 1: Threaded Port with O-Ring Seal in Truncated Housing

2.2 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

Y14.24	Types and Applications of Engineering Drawings
Y14.34	Associated Lists
Y14.35	Revision of Engineering Drawings and Associated Documents
Y14.100	Engineering Drawing Practices

2.3 Military Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-737-8000, <http://quicksearch.dla.mil/>.

MIL-DTL-25988	Rubber, Fluorosilicone Elastomer, Oil-&-Fuel-Resistant, Sheets, Strips, Molded Parts, and Extruded Shapes
MIL-DTL-83133	Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)
MIL-H-8891	Hydraulic Systems, Manned Flight Vehicles, Type III Design, Installation and Data Requirements for, General Specification for

MIL-PRF-6855	Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes
MIL-S-7742	Screw Threads, Standard, Optimum Selected Series, General Specification for
MIL-STD-129	Military Marking for Shipment and Storage
MIL-STD-202	Test Method Standard Electronic and Electrical Component Parts
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-882	System Safety
MIL-STD-889	Dissimilar Metals
MIL-STD-31000A	Technical Data Packages

2.4 Other Publications

Title 14, Code of Federal Regulations – Aeronautics and Space, Section 25.981, Fuel Tank Ignition Prevention

ASTM D910	Standard Specification for Aviation Gasolines
FAA AC20-115	Airborne Software Development Assurance Using EUROCAE ED-12() and RTCA DO-178()
FAA AC20-152	RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware
FAA AC 20-155	Industry Documents to Support Aircraft Lightning Protection Certification
FAA AC 20-158	The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment
FAA AC 25.981-1C	Federal Aviation Administration Advisory Circular – Fuel Tank Ignition Source Prevention Guidelines
FAA AC 25.1309	System Design and Analysis
FAA AC 20-136	Aircraft Electrical and Electronic System Lightning Protection
FAR 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
FAR 25	Airworthiness Standards: Transport Category Airplanes
FAR 27	Airworthiness Standards: Normal Category Rotorcraft
FAR 29	Airworthiness Standards: Transport Category Rotorcraft
RTCA DO-160	Environmental Conditions and Test Procedures for Airborne Equipment

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions shall be provided by the procurement activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Detail Specification

A detail specification providing design and performance requirements shall be submitted by or mutually developed between the procurement agency and the contractor. It is recommended that the detail specification reiterate all basic requirements of this specification except where the procurement agency has taken exception. In cases of conflict, the detail specification shall take precedence over this document.

3.1.1 Fuels

The detail specification shall state the principal fuel type and other alternate fuels expected to be encountered in use. In normal operations, it shall be assumed that the fuels contain various quantities of dissolved and free water, salts, gases, solid contaminants and maximum aromatic levels permitted by the applicable fuel specifications. This document is based on pumps for use with hydrocarbon based jet fuels and additives. Typical primary fuels are Jet A, Jet A-1, JP-8, TS-1, and Chinese No.3. Typical alternate fuels are JP-4, JP-5, and Jet B. As new fuel types and new additives are developed, properties such as lubricity, viscosity, and flammability limits will need to be addressed in the detail specification.

3.1.2 Temperature

The detail specification shall state the applicable minimum and maximum temperatures for the fuel and surrounding ambient environment. In the event that the detailed specification does not provide temperature limits, the following guidelines are recommended:

Environmental Conditions: For continuous operation, the ambient temperature may vary between -65 °F (-54 °C) to +131 °F (+55 °C). For temperature soaking, the ambient temperature may vary between -94 °F (-70 °C) to +149 °F (+65 °C). Thermal limits for short term operation must be defined by the procurement agency.

Fuel Temperatures: Coldest fuel temperature shall be 3 °C above the freezing point of the fuel and hottest fuel temperature shall be +131 °F (+55 °C).

3.1.3 Input Power

The detail specification shall state the input power type, including minimum and maximum voltages, frequencies for electrical power as defined for the air vehicle. Additionally, power quality and switching transients shall be identified. MIL-STD-704, RTCA DO-160, or other specifications may be cited as necessary. For hydraulic power, the minimum and maximum hydraulic system pressures shall be stated.

3.2 Performance

The detail specification shall include specific performance requirements as shown by charts, tables or as needed. The minimum data shall include electrical characteristics (power input, voltage, current), inlet pressure, fuel flow, output pressure, temperature, air saturation levels in the fuel (if using unweathered fuel), and the maximum operational altitude (or as a function of altitude). The pumps shall demonstrate satisfactory performance when subjected to the applicable tests of 4.2.2. (Fuel quality shall be defined in individual paragraphs, see 3.2.3 for fuel definitions.)

3.2.1 Sea Level Performance

The detail specification shall state the output performance requirements at sea level with specified fuel type, temperature, flow, fuel inlet pressure, and input power conditions. Detail specification shall state whether performance criteria are applicable to weathered and/or unweathered fuel (see 3.2.3 for fuel definitions).

3.2.2 Altitude Performance

The detail specification shall state the output performance requirements at required altitudes with specified fuel type, temperature, flow, fuel inlet pressure, and input power conditions. Detail specification shall state whether performance criteria are applicable to weathered and/or unweathered fuel (see 3.2.3 for fuel definitions).

3.2.3 Altitude Climb Performance

Where applicable, the detail specification shall establish the minimum pump output requirements during and/or following the harshest set of operating conditions that occur during altitude climb at a temperature no less than 110 °F (43 °C) using unweathered fuel, or as specified in the detail specification. The fuel temperature selected for this test shall reflect the maximum possible fuel temperature based upon hot day operation.

Unweathered fuel is defined as new fluid that has not been previously used for any test or as used fuel that has been properly reconditioned to be certifiable to meet the minimum properties of its defining specification. This includes at a minimum: density, kinematic viscosity, vapor pressure, and air solubility. Air solubility may be equal or less than 100% saturated if agreed to in the detail specification. Weathered fuel is defined as any test fuel that does not meet the requirements of unweathered fuel.

3.2.4 High Temperature Performance

The detail specification shall state the output performance requirements at specified altitudes, ambient and interface temperatures with specified fuel type, temperature, flow, fuel inlet pressure, and input power conditions.

3.2.5 Low Temperature Performance

The detail specification shall state the output performance requirements at specified altitudes, ambient and interface temperatures with specified fuel type, temperature, flow, fuel inlet pressure, and input power conditions.

3.2.6 Reprime Requirements

The pump shall be capable of self-priming within the time period outlined by the detailed specification, following a period when the inlet is uncovered and then re-submerged in fuel. This time period will vary based upon the engine/aircraft requirements at altitude. For pumps with remote inlets, the detail specification shall specify the required re-prime times at required altitudes, along with inlet line volume, geometry, and lift requirements. This capability shall exist up to the maximum operating altitude of the aircraft. The pump performance, depth of inlet submersion, fuel type (per 3.1.1), fuel condition (weathered/unweathered), and temperature (per 3.1.2) shall be in accordance with the detail specification. Other details such as pump attitude, tank pressurization, time running with the inlet uncovered, pump shut downs, changes in altitude while running dry or shut off, upstream or downstream components that may impact the ability of the pump to re-prime, etc., shall be defined in the detail specification.

3.2.7 Negative G and Inverted Operation

The pump shall be capable of being operated under negative G conditions or during inverted flight, as defined in the detailed specification. The pump output under these conditions shall be in accordance with the detail specification. Designs that use dual inlets must have performance requirements defined in the detail specification for combined and single inlet submerged operations for both normal and inverted attitudes.

If there are no acceptance criteria in the detailed specification, it shall be considered that the pump shall sustain the required maximum fuel flow. This performance shall be demonstrated by tests. The duration of each test condition should be a minimum of 7 seconds between 0 and -1 G, with a total accumulation of 20 seconds of negative acceleration operation. Minimum fuel level for negative acceleration sustained operation as prescribed herein shall be defined.

3.2.8 Start-Up

The rate of power input, acceleration, and output during start-up shall be stated in the detail specification. At any point during or following the climb of 3.2.3, when a non-operating pump is started, it shall develop the required flow and pressure within 5 seconds (or at a time specified in the detail specification) after power is applied. The required pressure must be defined in the detail specification as full performance pressure or some percentage of full performance pressure (i.e., pressure switch activation pressure).

3.2.9 Pump Down

The pump shall be capable of maintaining rated flow and pressure at any altitude and temperature, as defined in the detailed specification, up to the point where the fuel level is no greater than 2 inches (51 mm) above the top of the pump

inlet (or another value defined in the detailed specification). The required fuel level shall reflect the minimum fuel sustainable for aircraft operation. To ensure installation similarity, the detailed specification shall define the height of pump's fuel inlet above the tank floor.

For dual inlet pumps, this requirement applies to each inlet. Uncovering of one inlet shall not deteriorate the pump down performance of the other inlet in either the normal or the inverted position. Pump down performance at less than the required pressure, and the minimum fuel level where the pump continues to transfer fuel, shall be in accordance with the detail specification.

3.2.10 Variations in Power Input

The pump assembly shall demonstrate compatibility with all the variations in the aircraft power supply system(s), without overspeed, overheating, stopping, or other failure. The minimum requirements are per RTCA DO160, MIL-STD-704, AS5440, MIL-H-8891, or as defined in the detail specification. Any specific requirements relative to current ripple must be outlined in the detail specification. The ability of a 3-phase AC motor driven pump to start and operate on 2 phases shall be specified by the procurement agency.

3.3 Design

3.3.1 Envelope and Weight

The detail specification shall state the applicable requirements for envelope and weight. The detail specification shall explicitly state if the weight requirement includes fluid weight.

3.3.2 Components

The pump shall consist of a centrifugal pump and a driving motor, assembled as an integral unit. The motor may be electric or hydraulic as required by the detail specification.

The pump may include motor control electronics, integral or as a separate assembly. Qualification testing requirements for the control electronics are included within this document (e.g., vibration, shock, temperature limits, etc.), and design requirements for the control electronics must be specified in the detail specification (e.g., voltage or current de-rating limits, redundancy, etc.).

3.3.3 Standards and Specifications

Standards and specifications for commodities and services not specified herein and the order of precedence shall be selected in accordance with the detail specification.

3.3.4 Materials and Processes

Materials and processes used shall be suitable for the purpose, and shall conform to applicable specifications. Subject to procurement agency approval, materials and processes may be selected using industry or contractor specifications or standards. Selection of materials and processes shall include consideration of the temperatures, fluids, fuel vapors, standard fuel additives, contaminants, sparking, humidity, salt fog, and other materials and all conditions likely to be encountered in service.

3.3.4.1 Fungus Proof

Materials that are nutrients for fungi shall not be used where it is practical to avoid them. Where used and not hermetically sealed, they shall be treated with a fungicidal agent acceptable to the procurement activity; however, if used in a hermetically sealed enclosure, fungicidal treatment will not be necessary.

3.3.4.2 Elastomers

Elastomeric materials shall conform to AMS-P-5315, MIL-PRF-6855, MIL-DTL-25988, AMS3216, or AMS-R-83485.

3.3.4.3 Wiring

All wiring shall be fuel resistant, and, other than windings, shall be in accordance with AS50881, or equivalent.

3.3.4.4 Metals and Surface Treatments

Metals shall be of the corrosion-resistant type or suitably treated to resist corrosion due to fuels, standard fuel additives, fuel contaminants, FAME (Fatty Acid Methyl Ester), salt fog, or atmospheric conditions likely to be met in storage or normal service. The use of any protective coating that will crack or scale with age or extremes of climatic and environmental conditions shall be avoided. The effect of surface treatments on material properties such as fatigue strength shall be considered.

3.3.4.4.1 Dissimilar Metals

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

3.3.4.4.2 Magnesium

Magnesium or alloys thereof shall not be used in contact with fuel.

3.3.4.4.3 Copper

Copper shall not be used in contact with fuel except for stator electrical windings or rotors with suitable protective coating or DC commutators.

3.3.4.4.4 Cadmium

Cadmium shall not be used in contact with fuel, unless specifically approved for a specific application by the procurement agency. Where plating is used (not in contact with fuel) it shall be in accordance with AMS-QQ-P-416, Type II, Class 2.

3.3.4.4.5 Aluminum Castings

Aluminum castings shall be in accordance with AMS-A-21180 or other industry specifications. Inspection of castings shall be in accordance with AMS2175, AMS-A-21180, or an equivalent specification. Classification shall be determined based on application and approved by procurement activity.

3.3.4.4.6 Other Castings

Other castings shall be inspected in accordance with AMS2175, classification determined based on application and approved by procurement activity.

3.3.5 Lubrication

The pump and motor assembly shall not require any scheduled maintenance for lubrication and shall be suitable for operation with all intended fluids.

3.3.6 Thermal Safety

3.3.6.1 Dry Operation

The pump shall be capable of dry running per the discussion below. The number and duration of dry run cycles, as well as the required test altitudes and ambient temperatures shall be defined by the procurement agency in the detail specification. The procurement agency shall also specify the pre-dry run condition of the pump, such as transitioning from wet to dry (i.e., pump down) or completely dry (i.e., installation of a new pump). Temperature limits of pump surfaces in contact with the aircraft structure shall be as specified in the detailed specification. Position of the check valves (open or closed) on inlet and discharge ports is to be specified in detail specification.

In systems where dry running is not anticipated or minimal, a dry run time up to 8 hours may be specified. Recent fuel system advances including auto-shut off, fuel system management, or thermal temperature cutoffs, may preclude dry running as a normal operational mode. In systems where long dry running cycles are expected either as a normal operational condition or as a result of a single point (component or system) failure mode, a longer dry run time may be specified in the procurement specification. Refer to ARP594 and ARP6385 for information regarding design and testing methods related to dry running. The detail specification shall explicitly state allowable limits of any deterioration in performance. In no case shall any dry run pump failure result in an unsafe failure mode or compromise pump safety compliance to FAA AC 25.981-1C.

Examples of unsafe failure modes are as follows:

1. Any wear on surfaces which serve as part of the explosion proof path.
2. A hot spot on the pump that could ignite the fuel vapors in the tank. The peak temperature shall not exceed 400 °F (204 °C) on any portion of the housing in contact with the unprotected fuel tank ullage or other flammable vapor zones.
3. Electrical failures such as failure of the insulation and wiring system.

3.3.6.2 Thermal Shut Off

The detail specification shall specify either non-resetting thermal fuses or automatic resetting thermal shut off provisions.

3.3.6.2.1 Non-Resetting Thermal Fuses

If thermal fuses are required, they shall be integrally mounted to the critical location(s) on the stator where the hottest temperatures will result during operation based upon pump assembly orientation and variable fuel levels (based upon operating condition). The thermal fuses shall not be replaceable without replacement of the stator assembly. The activation temperature of the thermal fuse shall be chosen to prevent the exterior surface of the control volume surrounding the explosion proof cavity from reaching the maximum allowable temperature in the adjacent zones. One fuse shall be used for each AC motor phase. One fuse shall be used in DC motor driven pumps.

3.3.6.2.2 Automatic Resetting Thermal Shut Off

Where an integral automatic dry cut-off feature is required to meet the dry operation requirements of 3.3.6.1, it shall be capable of 10000 cycles of operation without failure or causing degradation of pump performance. Thermal safety shall be in accordance with ARP594.

3.3.7 Stop and Restart

For any design using electronic switching, the detail specification shall identify the design requirement for start and stop cycles. Stop is defined as power removed from the pump or the pump can be in standby mode with power applied.

3.3.8 Inrush Current

The detail specification shall identify the allowable limits for inrush current magnitude and transient time when power is applied to the pump assembly.