



AEROSPACE RECOMMENDED PRACTICE

ARP6385™

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Aircraft Fuel Pump Mechanical and Electrical Safety Design

RATIONALE

This document is a continuation of the safety information presented in ARP594, which covered the thermal aspects of fuel pump safety design. Other failure modes in FAA AC 25.981-1C fall under the umbrellas of mechanical and electrical design. This new document will address these key elements and, when used in combination with ARP594 and ARP5794, will represent a basis for the proper pump design and testing and support certification of an airframe fuel pump installation.

ARP6385 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

The requirements presented in this document address the key considerations for mechanical and electrical safety in aircraft fuel pump design. Document sections focus on understanding safety relative to an electrically motor driven fuel pump assembly acting as an ignition source for explosive fuel vapors within the airplane tank.

1.1 Purpose

This Aerospace Recommended Practice (ARP) provides fuel booster pump design considerations commensurate with industry requirements for prevention of ignition of explosive fuel vapors and the confinement of spark-initiated explosions by means of mechanical and electrical design features. Guidelines are presented for proper design of fuel pumps and systems to meet the intent of 14CFR 25.901(c), Amendment 25-40 or later, and 14CFR 25.981, Amendment 25-102 or later and FAA AC 25.981-1C for in-tank ignition sources and the general safety requirements of MIL-STD-882. In addition, recommendations are presented for proper assembly, testing, and repair/overhaul to verify safe fuel pump design that prevents mechanical and electrical arcs and sparks.

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 Buyer. 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, supercedes 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.

ARP594 Fuel Pump Thermal Safety Design

ARP4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

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<https://www.sae.org/standards/content/ARP6385/>

Documents

Document Sharing Hub

ARP5794 Centrifugal Aircraft Fuel Pump Requirements, Design and Testing, Aerospace Standard

ARP8615 General Specification For Fuel System Components

2.2 Military Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

MIL-STD-882 System Safety

2.3 Other

Federal Aviation Administration Advisory Circular – Fuel Tank Ignition Source Prevention Guidelines, Document Number AC 25.981-1C.

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

RTCA DO160, Environmental Conditions and Test Procedures for Airborne Equipment

ASTM E659 Standard Test Method for Autoignition Temperature of Chemicals

3. RELATED REQUIREMENTS FROM 14CFR 25.981, FAA AC 25.981-1C, AND MIL-STD-882

3.1 Introduction

For commercial fuel pumps, the governing regulations for fuel tank safety are provided in 14CFR 25.981 [Amendment 125]. Detailed guidance to demonstrate compliance for fuel tank ignition prevention is provided in FAA AC 25.981-1C. There are four primary phenomena that can result in ignition of fuel vapors within an airplane fuel tank. These categories are as follows:

- Electrical Arcs and Sparks
- Filament Heating
- Friction Sparks
- Hot Surface Ignition or Auto-ignition

For military applications, safety guidance is provided by MIL-STD-882, which does not delineate failure categories but focuses on the System Safety Process of identifying, assessing, documenting, and reducing safety risks. The risks are categorized by severity and probability and ranked in a Risk Assessment Matrix. The focus is on risk reduction through design improvements, warning devices, signage, procedures, training, and personal protective equipment. In addition to the criteria set forth in MIL-STD-882, the design guidelines presented in FAA AC 25.981-1C should be considered for military products to provide the safest product.

3.2 Definitions

ARC FAULT CIRCUIT BREAKER: A device that provides circuit breaker protection by detecting electrical arcing faults and interrupts electrical power to the circuit.

AUTO-IGNITION TEMPERATURE: The minimum temperature at which an optimized flammable vapor and air mixture will spontaneously ignite when heated to a uniform temperature in a normal atmosphere without an external source of ignition. Refer to ASTM E659 for information on standard autoignition test procedures.

CRITICAL DESIGN CONFIGURATION CONTROL LIMITATIONS: A type of Airworthiness limitations that define those features of the design that must be maintained to ensure that ignition sources will not develop within the fuel tank. These parameters must be verified prior to initial installation in the aircraft and also during maintenance and overhaul as determined by the Component Maintenance Manual. (Other types of fuel tank system Airworthiness limitations may include mandatory replacement times, inspection intervals, and related inspection procedures.)

ELECTRICAL ARCS: Electrical arcs occur between electrodes which are in contact with each other and carry excessive current which results in melting at the contact points. This may result in electric arc plasma and/or ejection of molten or burning material. The term thermal sparks is used interchangeably with electrical arcs.

ELECTRICAL SPARKS: A spark that is initiated by a potential difference which causes an electrical breakdown of a dielectric, such as a fuel/air mixture, produced between electrodes which are initially separated, with the circuit initially carrying no current. The term voltage sparks can be used interchangeably with electric sparks.

ELECTRO-STATIC DISCHARGE: ESD is the sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown.

EXPLOSION PROOF: Components designed and constructed such that an internal arc/spark or explosion is contained and will not ignite flammable vapors or liquids surrounding the component under any normal or abnormal operating condition.

FILAMENT HEATING: Filament heating occurs when current is passed through a metallic material. Testing has shown that a small level of current when passed through steel wool will ignite a flammable mixture.

FRICTION SPARKS: A heat source in the form of a spark that is created by mechanical contact, such as trapped metallic debris contacting with rotating components.

GROUND FAULT INTERRUPTER: A device that provides circuit breaker protection by detecting an electrical current leak to ground condition and interrupting the electrical supply.

HOT SHORT: Electrical energy introduced into equipment or systems as a result of unintended contact with a power source of a different type or voltage, i.e., 115 VAC applied to 28 VAC equipment. Causes could be incorrect installation or damaged insulation on adjacent wires.

HOT SURFACE IGNITION: The initiation of a flame due to a fuel/air mixture coming in contact with a surface which exceeds the fuel's auto ignition temperature. The Hot Surface Ignition Temperature (HSIT) is dependent on many factors including surface geometry, ambient pressure, air flow, how the fuel comes in contact with the surface, as well as fuel and air temperature.

IGNITION SOURCE: A source of sufficient energy to initiate combustion of a fuel/air mixture. Surfaces that exceed the auto-ignition temperature of the flammable vapor under consideration are ignition sources.

MAXIMUM ALLOWABLE SURFACE TEMPERATURE: A surface temperature within the fuel tank that provides a safe margin under all normal and failure conditions, which is at least a delta of 50 °F (27.8 °C) below the lowest expected auto-ignition temperature of the approved fuels. For example, the auto-ignition temperature for kerosene based fuels under static sea level conditions is 450 °F (232.2 °C). This results in a maximum allowable surface temperature of 400 °F (204.4 °C) for an unaffected component surface.

3.3 Relevant Fuel Pump Failure Modes

Table 1 provides a list of potential failure modes applicable to fuel pumps as related to in-tank ignition safety.

Table 1 - Fuel pump failure modes related to safety compliance

Failure Category	Description of Design Issue or Failure Mode
Friction sparks (NOTE: Impeller reference includes main hydraulic impeller as well as secondary impellers used in liquid rings)	Ingestion of pump inlet components into the pump impeller releasing debris into the fuel tank.
	Pump inlet housing degradation, allowing the pump inlet check valve to contact the impeller.
	Premature failure of fuel pump radial or thrust bearings allowing unintentional contact between rotating and stationary parts – if these parts are made of sparking material.
	Use of metal impellers (i.e., steel or other sparking metals) that may produce friction sparks if debris enters the pump.
	Debris lodged inside pumps.
Electrical arcs and sparks	Failure of one or more phases of the stator winding during operation of the fuel pump motor resulting in arcing phase to phase or arcing through the pump housing.
	Arcing due to the exposure of electrical connections within the pump housing that have been designed with inadequate clearance to the pump cover.
	Pump power supply connectors have corroded resulting in fuel leakage and electrical arcing.
	Electrical connections within the pump housing have been designed with inadequate insulation from the metallic pump housing, resulting in arcing.
	Internal wires coming in contact with the pump rotating group, energizing the rotor and arcing at the impeller/adaptor interface.
	Loss or degradation of bonding across component interfaces due to wear or corrosion.
	Insufficient ground fault current protection capability.
	Loss or degradation of bonding of pump components to structure.
	Electrical arcing at connections within electrical connectors due to bent pins or worn contacts.
	Fuel leakage and subsequent fuel fire outside of the fuel tank caused by corrosion of electrical connectors inside the pump motor which led to electrical arcing through the connector housing (connector located outside the fuel tank).
	Selection of improper insulating materials in connector causing degradation of the material because of contact with fuel that is used to cool and lubricate the pump motor.
Hot surface ignition or auto-ignition	Wear of teflon sleeving and wiring insulation on wires in metallic conduits located inside fuel tanks, allowing arcing from wire through the conduits into fuel tank ullages.
	Damage to insulation on wiring routed adjacent to the fuel tank exterior surfaces that resulted in arcing to the metallic fuel tank surface.
	Omission of cooling port tubes between the pump and the motor assemblies during pump overhaul.
	Extended dry running of fuel pumps in empty fuel tanks, which was contrary to the manufacturer's recommended procedures.
Filament Heating	Thermal switches aging over time resulting in a higher trip temperature.
	Locked rotor or dragging rotor condition caused by debris, damaged or deformed inlet screens, or incorrect mechanical clearances.
	Electrically conductive FOD or contamination causing heat generation between pins of an electrical connector.
	Poor bonding of internal components to structure.