AWB 28-1 Issue 1, Fuel Tank Safety

Fuel Tank Safety

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Introduction

Following the accident to Flight TWA 800, the influences on fuel tank safety have been widely discussed to establish means by which fuel tank explosions can be prevented in future. The National Transportation Safety Board (NTSB) investigation into the TWA 800 accident determined that the probable cause of the accident was an explosion of the centre wing fuel tank resulting from ignition of the flammable fuel/air mixture in the tank. The NTSB recommendations were, among others, to make improvements to the safety of fuel tank designs by reducing the probability of creating an ignition source within the tank.

In June 2001, the new FAA regulations related to fuel tank ignition prevention came into force. This requirement package includes new Fuel Tank Safety design requirements. FAR 25.981(a) requires a demonstration that the probability of ignition sources meets specific Safety Objectives.

In addition, SFAR No. 88 requires these Safety Objectives to be met by (most of) the current aircraft fleet registered in the U.S. To achieve that aim, the aircraft TC and STC holders are required to conduct a safety review of the airplane fuel tank system to determine that the design meets the requirements of FAR 25.901 and FAR 25.981(a) and (b), and to create a new airworthiness limitation section associated to fuel tank ignition prevention. If the design does not meet these requirements, the TC or STC holder must develop design changes to the fuel tank system on an improved maintenance program to meet these requirements.

This is an important safety issue that has considerable implications on the standard practices and inspections that are used in maintaining fuel tanks in Australian registered aircraft. CASA is actively participating in the worldwide program and will keep the Australian aviation industry advised of advances or any special requirements resulting from the activities of other National Airworthiness Authorities (NAA's).

This AWB is envisaged as the first in a series of advisory material dealing with general information on this subject that will be promulgated to the industry.

CASA will be supporting the new rules relating to the design of fuel tanks and a fuel tank safety review of existing fuel tank installations.

Applicability

These proposed requirements will apply to aircraft certificated in the transport category (FAR/JAR Part 25), and the recommendations contained in this AWB and proposed by the new rule should be reviewed by:

- Those persons responsible for maintenance in aircraft fuel tanks, and
- Those persons involved in developing a system of maintenance for an aircraft.

Whilst not every aspect detailed in this advisory material may be appropriate for every fuel tank installation the principles and precepts will provide a sound foundation and understanding of the philosophies involved with fuel tank maintenance and the possible causes of fuel tank explosions.

The safety assessment of fuel tank design will be carried out by the manufacturers of Part 25 certificated aircraft and will most probably require an inspection of the fuel tank installation by service bulletin and a review of the aircraft's maintenance records.

For other than Part 25 certificated aircraft CASA recommends maintenance personnel pay particular attention to the items addressed in Paragraphs 5 and 6 of this AWB. These recommendations are not intended to replace any manufacturers instructions but to complement them.

Reference material

There are a number of reference documents relating to the fuel tank safety issue, however the definitive FAA document FAA AC 25.981B provides a list of related documents. This AC may be downloaded direct from the FAA website http://www.faa.gov/RegulatoryAdvisory/ac_index.htm

Fuel Tank Safety - Fuel Tank Ignition Sources

In service history has shown that ignition sources have developed in aircraft fuel tanks due to failure modes or factors that may not have been considered at the time of original certification of the aircraft.

There are three primary phenomenon's that can result in ignition of fuel vapours in aeroplane fuel tanks they are:

- Electrical arcs;
- Friction sparks resulting from mechanical contact of rotating equipment in the fuel tank;
- Hot surface ignition; and
- Auto ignition.

The conditions required to ignite fuel vapours from these ignition sources vary with pressures and temperatures within the fuel tank and can be affected by sloshing or spraying of fuel in the tank. Due to the difficulty in predicting fuel tank flammability and eliminating flammable vapours from the fuel tank, design practices have assumed that a flammable fuel air mixture exists in aircraft fuel tanks and require that no ignition sources be present.

Any components located in or adjacent to a fuel tank must be qualified to meet standards that assure, during both normal and failure conditions, ignition of flammable fluid vapours will not occur. This is typically done by a combination of design standards, component testing and analysis. Testing of components to meet explosion proof requirements is carried out for various single and combinations of failures to show that arcing, sparking, auto ignition or flame propagation from the component will not occur. Testing for components has been accomplished using standards and component qualification tests.

The focus of the re-evaluation of the aircraft fuel system should be to identify and address potential sources of ignition within fuel tanks and by possible external influences, which may not previously have been considered to be unsafe features.

Fuel Tank Safety - Maintenance Practices

Each operator should review aircraft service records, flight logs, inspection records, and component supplier service records to assist in establishing any unforeseen failures, wear or other conditions that could result in an ignition source within the fuel system. In addition, changes to components, and the use of PMA parts following certification may have been done without consideration of possible effects of the changes to the requirements to preclude ignition sources. Therefore, results of reviewing this service history information and a review of changes to components from the original type design should be documented as part of the fuel tank review and safety analysis. Whilst the aircraft manufacturer will be responsible for the integrity the fuel system designed by them, they are not responsible for any effects that may be caused by the installation of additional fuel tanks fitted by STC or CAR 35 approved modification or alternate components fitted through the PMA process.

During maintenance pay particular attention to:

Ignition Sources

Electrical Arcs and Sparks

Ignition sources from electrical arcs can occur as a result of electrical component and wiring failures, direct and indirect effects of lightning, HIRF / EMI, and static discharges.
Note : The level of electrical energy necessary to ignite fuel vapours is defined in various standards. The generally accepted value is 0.2 millijoules.

Friction Sparks

Rubbing of metallic surfaces can create friction spark ignition sources. Typically this may result from debris contacting a fuel pump impeller or an impeller contacting the pump casing.

Hot Surface Ignition

Guidance provided in FAA AC25-8 "Auxiliary Fuel Systems Installations" has defined hot surfaces which come within 30°C of the autogenous ignition temperature of the fuel air mixture for the fluid as ignition sources. It has been accepted that this margin of 30°C supported compliance to FAR 25.981(a). Surface temperatures not exceeding 200°C have been accepted without further substantiation against current fuel types.

Components in-service experience

The following sections intend to present a list of faults, which have occurred to fuel system components. By its nature it cannot be an exhaustive list, but it is attempting to provide a list of some discrepancies found in fuel systems and fuel system components.

Pumps

Pump inducer failures have occurred resulting in ingestion of the inducer into the pump impeller and generation of debris into the fuel tank;
Pump inlet check valves have failed resulting in rubbing on pump impeller;
Stator windings have failed during operation of the fuel pump.

Subsequent failure of a second phase of the pump caused arcing through the fuel pump housing;

Thermal protective features incorporated into the windings of pumps have been deactivated by inappropriate wrapping of the windings;
Cooling port tubes have been omitted during pump overhaul;
Extended dry running of fuel pumps in empty fuel tanks, violation of manufacturers recommended procedures, are suspected of causing failures in two incidents;
Use of steel impellers that might produce sparks if debris enters the pump;
Debris has been found lodged inside pumps;
Pump power supply connectors have corroded allowing fuel leakage and electrical arcing;
Electrical connections within the pump housing have been exposed and designed with inadequate clearance to pump cover resulting in arcing;
Re-settable thermal switches resetting at higher trip temperature;
Flame arrestors falling out of their respective mounting;
Internal wires coming in contact with the pump rotating group, energising the rotor and arcing at the impeller / adapter interface;

- Poor bonding across component interfaces;
- Insufficient ground fault current capability;
- Poor bonding of components to structure;
- Loads from the aeroplane fuel feed plumbing were transferred;
- Premature failure of fuel pumps thrust bearings allowing steel rotating parts to contact the steel pump side plate;
- Wiring to Pumps located in metallic conduits or adjacent to fuel tank walls; and
- Wear of Teflon sleeving and wiring insulation-allowing arcing to conduit causing an ignition source in tank, or arcing to the tank wall.

Fuel Pump Connectors

- Electrical arcing at connections within electrical connectors has occurred due to bent pins or corrosion.

Fuel Quantity Indication System (FQIS) Wiring

- Degradation of wire insulation (cracking);
- Corrosion (copper sulphate deposits) at electrical connectors;
- Unshielded FQIS wires that have been routed in wire bundles with high voltage wires;
- Corroded and loose terminations; and
- Excessive strain on the wiring.

For repairing wiring, it is recommended practice to replace the wiring or harness unless the manufacturer specifically approves a repair.

Fuel Quantity Indication System Probes

- Corrosion and copper sulphide deposits have caused reduced breakdown voltage in FQIS wiring;
- FQIS wiring clamping features at electrical connections on fuel probes has caused damage to wiring and reduced breakdown voltage; and
- Contamination in the fuel tanks including: steel wool, lock wire, nuts, rivets, bolts; and mechanical impact damage, caused reduced arc path between FQIS probe walls.

Bonding Straps

- Corrosion, inappropriately attached connections (loose or improperly grounded attachment points);
- Static bonds on fuel system plumbing connections inside the fuel tank have been found worn due to mechanical wear of the plumbing from wing movement, and corrosion;
- Bonding points that have been improperly sealed after access;
- Worn and frayed bonding jumpers; and
- Incorrect bonding jumpers (manufactured from incorrect material).

Failed or aged seals

Seal deterioration may result in leaks internal or external to fuel system, as well as fuel spraying.

Minimizing electrical hazards within fuel tanks

When carrying out routine maintenance within fuel tanks or fuel systems pay particular attention to all normal housekeeping tasks such as but not limited of:

Cleanliness:

Removal of any loose material, rivets, swarf, hardware, excess sealant, etc

Inspection of:

All plumbing for damage, security, possible sources of abrasion and chaffing;
Quick disconnect fittings are secure and in good condition;
Plumbing is not distorted by clamps;
Wiring for any signs of degradation or overheating;
Wire routing is appropriate and properly secured;
Connectors are properly torqued and if appropriate lock wired;
Where a connector has been disturbed inspect both the male and female connections for damage;
Insulation material deterioration;
Cable support for adequacy or potting for deterioration;
Contacts for damage and corrosion clean with an approved agent prior to reassembling;
Bonding jumpers and bonding points for damage, correct sealing, corrosion, correct material and terminals;
Fuel Pumps are correctly mounted and secure;
Fuel system vents and vent heating elements, check the condition and security including any flame trap that may be installed and that the vent is unobstructed.