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AEROSPACE INFORMATION REPORT

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CONSIDERATIONS ON ICE FORMATION IN AIRCRAFT FUEL SYSTEMS

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Revised

FOREWORD

During the past several years incidents and accidents have occurred in the operation of military and civil aircraft which have been attributed to the formation of ice in the engine fuel supply system resulting in intermittent or complete starvation of fuel flow.

Earnest effort has been applied by many airframe, engine, and accessory manufacturers and civil and military agencies to study the problem and to evolve corrective measures, but by its very nature the problem has been difficult to identify and analyze.

This report is based substantially on the conclusions reached at a combined Air Force-BuAer-Industry conference held in 1959, but the information has been reviewed and up-dated by the SAE Committee AE-5 to represent the best summary of opinion available today from fuel system engineering personnel and is being published for use as a guide in future consideration of the subject.

1. INTRODUCTION :

1.1 Ice formation in aircraft fuel systems results from the presence of water in two forms: dissolved or undissolved. One condition of undissolved water is entrained water such as, water particles suspended in the fuel as a result of mechanical agitation of free water or conversion of dissolved water through temperature reduction. Another condition of undissolved water is free water which may be introduced as a result of refueling or the settling of entrained water that collects at the bottom of a fuel tank in easily detectable quantities separated by a continuous interface from the fuel above. Dissolved water or water in solution with petroleum fuels constitutes a relatively small part of the total potential water in a particular system; the quantity dissolved being dependent on fuel temperature and the existing pressure and the water solubility characteristics of the fuel.

1.2 Entrained water will settle out in time under static conditions and may or may not be drained, depending on the rate at which it is converted to free water. In general, it is not likely that all entrained water can ever be separated from fuel under field conditions. The settling rate depends on a series of factors including temperature, quiescence and droplet size. The droplet size will vary depending upon the mechanics of formation. Usually the particles are so small as to be invisible to the naked eye, but in extreme cases can cause slight haziness in the fuel.

1.3 Free water can be drained from a fuel tank if sump provisions are adequate. Water in solution cannot be removed except by dehydration or by converting it, through temperature reduction, to entrained, then to free water.

1.4 Water strictly in solution, is not a serious problem in aircraft fuel so long as it remains in solution. Entrained and free water are potentially the most dangerous because of the possibility of more water available for collection on the surfaces of the system. Further, entrained water will freeze in cold fuel and tend to stay in suspension longer since the specific gravity of ice is approximately the same as that of hydrocarbon fuels.

1.5 The elimination of toleration of undissolved water must be examined from the standpoint of these major elements of the fuel supply:

- The bulk storage and ground handling equipment.

- The airframe and engine fuel supply system.

Pertinent considerations of these elements to reduce the icing hazard follow.

2. FUEL CONDITIONING REQUIREMENTS FOR GROUND HANDLING:

2.1 Undissolved Water: There should be no undissolved water detectable at fuel ambient temperature. The presence of less than 5 parts per million above that to saturate the particular fuel at the fuel ambient temperature is considered to comply with this requirement.

2.2 Solid Contaminant: Should not exceed maximum of 0.2 milligram per liter (95% by weight to be equal to or less than 10 microns.)

2.3 Control techniques should be established and implemented to insure continuous compliance with the requirements of 2.1 and 2.2 above at point of delivery to aircraft. Field kits are now available to do this.

2.4 Fuel should be delivered to the aircraft near atmospheric temperature to reduce the tendency of the fuel to dissolve additional water from the atmosphere.

3. AIRFRAME AND ENGINE FUEL SYSTEM ICING INFLUENCES AND CONSIDERATIONS:

3.1 AIRCRAFT OPERATIONAL CONDITIONS TENDING TO FAVOR ACCUMULATION OF FREE WATER OR RETENTION WITHIN THE AIRCRAFT FUEL SYSTEM

3.1.1 Descent from high altitude (condensation).

3.1.2 Cold weather operation (maintenance problem below 32°F).

3.1.3 Any decrease in fuel temperature (tends to release water from solution) as a result of:

- Servicing aircraft with relatively warm fuel.
- Prolonged flight at altitude.
- Temperature cycling above and below freezing.

3.1.4 High ambient humidity (during flight and on ground).

3.1.5 Temperature cycling of fueled aircraft on ground.

3.1.6 Prolonged exposure to above conditions.

3.1.7 Improper water drainage procedure.

3.2 DESIGN FEATURES WHICH TEND TO MINIMIZE ICING PROBLEM WITHIN THE AIRFRAME AND ENGINE FUEL SYSTEMS

3.2.1 Water Drainage Provisions:

3.2.1.1 Provisions for 100% water drainage in "at rest" attitude by design and by procedure.

3.2.1.2 Provisions for adequate accessibility for ground maintenance.

3.2.1.3 Provisions for ease of operation for ground maintenance.

3.2.1.4 Prominent and clearly defined markings for ground maintenance.

3.2.2 Component Design:

3.2.2.1 Selection of appropriate materials.

3.2.2.2 Development of non-critical fuel servos and fuel control devices.

3.2.2.3 Elimination of unnecessary screens and filters from the aircraft and engine fuel systems consistent with all other safety of flight criteria.

3.2.2.4 Mandatory use of by-passes around screens and filters.

3.2.2.4.1 Reliable design of by-pass element.

3.2.2.4.2 By-pass element located to prevent backwashing of sediment.

3.2.2.4.3 Multiple by-pass elements in principal filter. (Safety-of-flight consideration).

3.2.2.5 Impending bypass or bypass warning device on principal filter or screen.

3.2.2.6 Use of ice collecting protective devices.

3.2.2.7 Insulation provisions where practical.

3.2.2.8 Adequate access to interior of fuel tanks for inspection and cleaning.

3.2.2.9 Incorporation of adequate water sump capacity.

3.2.3 Icing Prevention or Control Measures to be Considered:

3.2.3.1 Anti-icing

3.2.3.2 De-icing

3.2.3.3 Additives

3.2.3.4 Optimum use of available heat

3.2.3.5 Environmental location of components

3.3 CONTAMINATION AND WATER - DESIGN OPERATIONAL CONDITIONS

3.3.1 Contamination (since the size and capacity of the fuel filter is an important consideration in the icing problem, this information is included here for reference).

3.3.1.1 Contaminant: per specification MIL-E-5007B.

3.3.1.2 Duration:
Aircraft: per model specification inspection period.
Engine: 150 hours (recommended) or as per engine model specification.

3.3.1.3 Qualification test:
Aircraft: per specification MIL-F-17874A or WCLP-59-1.

3.3.2 Water

3.3.2.1 Amount: for aircraft and engine, use fuel conditioning procedure per WADC Exhibit WCLP-59-1 or MIL-F-17874A as guide.

3.3.2.2 Qualification test: for system and components use fuel conditioned per WADC Exhibit WCLP-59-1 or MIL-F-17874A as basis for negotiated tests contingent on mission time, environment, etc., applicable to model in question.

NOTE: Difficulty in reproducing test results has been experienced when handling large quantities of conditioned fuel.