SAE Aerospace
An SAE International Group

AEROSPACE INFORMATION REPORT

SAE AIR5490

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Carbon Brake Contamination

RATIONALE

AIR5490 has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This document provides information on contamination and its effects on brakes having carbon-carbon composite friction materials (carbon). Carbon is hygroscopic and porous, and therefore readily absorbs liquids and contaminants. Some of the contaminants can impact intended performance of the brake. This document is intended to raise awareness of the effects of carbon brake contamination and provide recommendations for its prevention. Although not addressed in this report, contaminants can cause problems with other landing system components including tires.

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 in effect on the date of the purchase order. 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 1424 Deicing/Anti-Icing Fluid, Aircraft SAE Type I
AMS 1428 Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV
AMS 1431 Compound, Solid Runway and Taxiway Deicing/Anti-icing
AMS 1435 Fluid, Generic, Deicing/Anti-icing, Runways and Taxiways

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AIR5490

2.2 Military Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MILPRF-83282	Hydraulic Fluid
MIL-PRF-5606	Hydraulic Fluid
MIL-PRF-87257	Hydraulic Fluid

3. DEFINITIONS:

Airplane Anti-Icing/Deicing Fluids: Chemical solutions applied to the exterior of an aircraft for the purpose of preventing and removing frozen deposits of frost, ice, and snow prior to take-off.

Airplane Hydraulic Fluids: Oils used in struts and hydraulic systems.

Airplane Lubricants: Greases and oils, particularly that are applied to landing gear components.

Airplane Wash Fluids: Cleaning solutions applied to the airplane and/or its components.

Carbon Brake: A brake that uses friction material composed of a carbon-carbon composite. This is usually in the form of a carbon fiber preform densified with additional carbon as matrix.

Catalytic Oxidation: Oxidation that is accelerated by a catalyst.

Cleaning Solvents: Chemical degreasers and paint stripping agents.

Fire Extinguishing Agents: Foam, dry chemicals, and solutions used to extinguish fires.

Disinfectants: Chemicals applied to aircraft to kill biological organisms for limiting the spread of diseases.

Hygroscopic: Absorbs liquids.

Runway Anti-Icing/Deicing Solids and Fluids: Chemical solutions applied to a runway surface for the purpose of preventing and removing frozen deposits of frost and ice.

Temperature Indication Markers: Crayons with specified melting points used to determine brake temperatures.

4. BACKGROUND:

The aerospace industry has had a number of brake problems occur on different airplane models that have been traced back to carbon friction material contamination. As mentioned above, carbon is particularly susceptible to contamination. Carbon brakes usually operate at temperatures higher than their steel brake counterparts. Operating temperatures may be high enough to boil off the contaminant. In this case, the impact on performance may be temporary. In other cases, the temperatures required to boil off the contaminant far exceed normal brake operating temperatures. In these cases, the impact on performance can be permanent, lasting the carbon disc life without maintenance intervention. Performance impact can range from temporary suppression of the friction coefficient to brake failure due to loss of carbon disc strength.

5. POTENTIAL TYPES AND SOURCES OF BRAKE CONTAMINATION:

Sources for potential carbon brake contamination are:

a. Runway anti-icing/deicing solids and fluids
b. Airplane anti-icing/deicing fluids
c. Airplane wash fluids
d. Airplane lubricants
e. Airplane hydraulic fluids including phosphate ester based fluids
f. Fire extinguishing agents
g. Cleaning solvents
h. Disinfectants containing sodium, potassium, calcium, citric acid and other uninhibited compounds
i. Temperature indication markers applied directly to carbon
j. Sea water

5.1 Classifications of Contaminants Found in Service:

5.1.1 Catalytic Agents: The catalysis mechanism is fairly well understood. Elements from contamination absorb into pores of unprotected carbon, which catalyze oxidation at temperatures (800 to 1200 °F) that are common for normally operated carbon brake friction material. Some common catalysts include:

a. Sodium from seawater, or aircraft cleaners or anti-icers/deicers that do not contain phosphate.

b. Potassium acetate ($KC_2H_3O_2$), calcium or magnesium from anti-icers/deicers.

c. Sodium, calcium or potassium containing cleaning agents typically found in airplane, landing gear, engine, and wheel well cleaners.

d. Potassium containing fire extinguishing agents.

e. Temperature indicating sticks have also been reported as a potential source for catalysis. In some cases it has been severe enough to induce pressure plate structural failures.

5.1.1 (Continued):

f. Disinfectants/Anti-viral agents - In response to the outbreak of Foot and Mouth disease in Europe, operators have been directed to apply disinfectants or anti-viral agents to aircraft landing gear. Many of these products have catalytic effects on carbon-carbon friction material.

NOTE: Contamination with phosphate-ester based brake fluid has actually reduced oxidation rates of unprotected carbon brake disk materials. These results were interpreted as cases where sodium (Na) or other catalytic impurities already in or on the carbon were combined as phosphates during oxidation, and thus removed from carbon surfaces where they normally would have catalyzed carbon oxidation. However, brake fluids do affect brake performance and should not be intentionally applied to carbon friction surfaces.

5.1.2 Friction Modifiers: Fluids that affect the coefficient of friction, aggravate the effect of adsorbed/absorbed water, or affect the friction interface in such a way as to impact brake vibration and brake performance. These would include airplane and runway anti-icers/deicers, cleaning fluids, lubricants, hydraulic fluids, and fire extinguishing agents. Runway and airplane deicing/anti-icing, airplane and component cleaning, airplane hydraulic system servicing or leaks, and fire extinguishing have all been found to be potential sources of carbon contamination.

6. PERFORMANCE IMPACT:

6.1 Oxidation/Structural:

Catalytic oxidation from sodium and potassium containing fluids have been implicated in some structural failures of disc drive regions. For example, accelerated matrix oxidation has been observed in stator drive lugs contaminated with potassium acetate deicer. This was confirmed both visually and through chemical analysis. Numerous laboratory studies have confirmed the catalytic effect of the alkali metals on carbon oxidation in the typical operating temperature range of carbon brakes. Fluids have been compared for effects on carbon during oxidation tests by soaking coupons in solutions and drying at an elevated temperature. Relative comparisons of catalysis action can be made from these tests. Normally, if oxidation is visible, significant structural degradation has occurred.

6.2 Vibration:

The presence of foreign contaminants on friction surfaces can result in variation in friction coefficient causing aggravation of squeal vibration in brakes. An increase in friction coefficient is possible with some contaminants and would affect brake whirl vibration stability. Alkali metal and silicon containing materials will be more chemically stable than, for example, hydrocarbons and may affect friction properties for long periods of time.

6.3 Friction Coefficient:

As mentioned above, friction coefficient can be impacted by contamination. Both increases and decreases in friction coefficient have been reported. Humidity also has an impact on carbon friction coefficient. Humidity can exaggerate the effects of contamination on friction coefficient. For example, the drying effect of braking may temporarily appear to restore friction coefficient in a contaminated brake, only to see the effect return when humidity is reabsorbed into the carbon. One military operator reported a weak brake, where the pilot was unable to achieve a reasonable deceleration rate problem traced the cause to an aircraft cleaner. Another military aircraft experienced runway over-runs reportedly due to brake contamination.

Modified friction coefficients from contamination can also lead to uneven braking or over heating of other brakes where friction between brakes becomes imbalanced.

6.4 Brake Wear:

Carbon contamination with sodium and potassium containing materials can result in accelerated wear of friction surfaces. In-service laboratory observations have confirmed this result indicating an increase in brake wear of up to three times normal wear rates. Of the materials tested, some runway deicing agents, having a higher level of sodium and potassium content in comparison to aircraft deicing fluids, were shown to have the most detrimental effect. The level of increase in brake wear was also shown to be a function of the frequency of exposure to contamination and can result in even or unevenly distributed accelerated wear depending on the exposure or path of ingress of contaminating agents into the brake assembly.

7. DETECTION METHODS:

Because oxidation can so severely attack a carbon-carbon composite, it often can be visually detected. An oxidized area will often appear pitted, porous, soft, and straw-like.

One method used to detect excessive internal porosity caused by oxidation has been detection of reduced conductivity. A hand-held eddy current meter of the type used to sort metal alloys has been found to provide such a detection capability. Detection of carbon contamination on an airplane is extremely difficult. If a carbon brake is known to be contaminated, it can be designated for removal. Often, contaminated carbon will show visual effects of staining. Also, severe cases of contamination will also manifest itself by emitting a strong odor from the carbon that can be detected when the wheel is removed or when the brake is in the shop for overhaul. A severely contaminated brake may also smoke when the brake is used in service. A high or low temperature brake compared to other axle positions can also be a sign of contamination.