ACI Briefing Note
May 2015

Pavement De-icing Products (PDP) and Carbon Brake Catalytic Oxidation (CBCO)

To help ensure safe winter operations, many airports and tenants must use chemicals to prevent or remove ice on aircraft movement areas. Airport operators must comply with both aviation and environmental regulation. There is some evidence that the de-icers with the least environmental impact also contribute to the premature structural deterioration of carbon-based aircraft brakes. The issue thus spans airport winter operations and environmental management, aircraft brake design and maintenance, airline economics and operations, and operational safety. This ACI Briefing Note provides airport operators with an overview of the main issues and highlights the need for detailed internal discussions.

Pavement De-icing Products (PDP)

To help ensure safe operations, many airports must address the hazards associated with snow and ice accumulating on airport pavements (runways, taxiways, aprons, etc.) during winter months. Snowploughs, blowers and sweepers can physically remove most of the snow, but conditions induced by temperature fluctuation above and below freezing, and wet precipitation can result in slush or ice formation.

At some point, most, if not all, airports experiencing winter conditions will need to use chemicals to prevent ice formation (anti-icing) or remove ice (de-icing) on pavements. Collectively, the chemicals are referred to here as Pavement De-icing Products **(PDP)**, not to be confused with Aircraft De-icing Fluids **(ADF)**, which are discussed below.

Until the 1980's, most PDP were "Generation 1" products based on urea or glycol, including mixtures of both.

"Generation 2" PDP were developed to address the environmental impacts of Generation 1 PDP and to provide improved melting performance. From the mid-1980's sodium **(Na)** and potassium **(K)** acetates were introduced and in the mid-1990's Na-, and K- formates. These are also known as "alkali" or "alkali metal" PDP.

"Generation 3" PDP were developed since 2000 following issues with the corrosion on certain aircraft parts; many are hybrids of alkali and glycol (or polyol) products. The chemical compositions of these new products are often not fully disclosed by PDP manufacturers. (Note: GEN3 is one specific brand of a Generation 3 PDP.)

Figure 1: Photo: Daniel Asplund

International performance standards for PDP are developed by the SAE International, G12 Committee. The standard **AMS1431** concerns solid products usually used for de-icing and **AMS1435** concerns fluids (or liquids) usually used for anti-icing. In some jurisdictions, only AMS compliant PDP may be used.

Environmental Impacts of PDP

Generation 1 urea and glycol products can have significant environmental impact, causing the depletion of dissolved oxygen and chemical contamination in downstream water bodies and groundwater. In addition, urea can readily form ammonia which is toxic to fish and glycol products have historically contained additives which could be further harmful to the environment.

Oxygen Demand potential **(OD)** can be measured by various standardized methods such as Biochemical Oxygen Demand **(BOD)** and Chemical Oxygen Demand **(COD)**. Other measures related to OD include Total Organic Carbon (TOC) and Theoretical Oxygen Demand (ThOD), which can be more useful depending on circumstances. Ultimately, many analytical parameters are indicators of potential OD within the environment or a watercourse.

Most environmental authorities enforce regulations or issue environmental permits based on the BOD or COD limits on stormwater discharges from airports and other industrial sites. Stormwater discharges may be regulated at the point of pipe discharge or directly within a watercourse crossing the airport boundary, but can also include the seepage to groundwater aquifers below the airport. Each airport has its own unique environmental challenges and regulatory requirements.

In terms of OD, PDP rank from highest to lowest as follows:

- Generation 1 urea and glycol
- Generation 3 hybrid PDP
- Generation 2 acetate PDP
- Generation 2 formate PDP .

Some airport operators who moved to acetate PDP, subsequently switched to formate PDP due to an increased need to reduce the total OD contained within discharged stormwater.

Aircraft De-icing Fluids (ADF)

Glycol is the base chemical of choice for **ADF**. While much of the ADF glycol can be collected and recycled or treated, a significant proportion adheres to aircraft (by design) and is subsequently dispersed on the airport. Without intervention, an airport's stormwater discharge will include run-off from virtually all areas, so the total OD of the discharge will be a combination of the unrecovered ADF and the total PDP used.

Airports that approach or exceed their permit limitations can attempt to implement some or all of the following actions:

- Reduce glycol ADF usage;
- Increase glycol ADF recovery rate, perhaps by improving collection, storage and treatment facilities;
- Increase use of non-chemical procedures such as hot sand;
- Collect run-off water for treatment or recycling to reduce the OD of the run-off; and,
- Use PDP with the lowest OD possible and optimize its use.

Carbon Brakes and Catalytic Oxidation

An aircraft brake consists of a series of stator and rotor annular discs enclosed within each wheel on the main landing gear as shown in Figure 2. During operation, multiple pistons press on the end plate disc to compress the stators and rotors together and generate a braking effect to slow and stop the aircraft.

Since the mid-1980's,steel disc brakes have been replaced with brakes with discs made from carbon fibres. The operational advantages of carbon brakes are lower weight, longer life and improved aircraft stopping performance; these represent substantial fuel and cost savings for aircraft operators. Virtually all commercial passenger aircraft made since the mid-1980's have been delivered with carbon brakes. Some aircraft operators have been retrofitting their steel brake equipped aircraft to carbon brakes if that option exists.

Figure 2: Photo: SAE G12 presentation June 2012

Since the 1990's some aircraft operators and carbon brake manufacturers have reported the accelerated deterioration and loss of structural integrity of many carbon brakes' discs. If undetected, the braking performance can be affected and the carbon discs can soften allowing the pistons to penetrate the end plate destroying the brake, as shown in Figure 3.

The brake disc deterioration has been identified as being due to oxidation of the carbon material occurring at high temperature, which is believed to be accelerated by the presence of alkali metals acting as a catalyst. This accelerated effect is known as Carbon Brake Catalytic Oxidation **(CBCO)**. It appears that during taxi, take-off and landing solutions of alkali PDP can splash on the brake and be absorbed into the porous structure of the carbon discs.

Once present the alkali metals chemically assist the oxidation of the brakes when at the elevated temperatures experienced during and after regular operation.

The consequences of untreated CBCO for aircraft operation could include reduced brake performance and increased brake operational temperatures. If the pistons damage the end plate, there could be brake disintegration, damage to hydraulic hoses, and brake fires. To date, there have been several instances of brake overheating but no runway excursions due to CBCO.

Figure 3: Photo: SAE G12 presentation June 2012

Brake Maintenance

CBCO is not easily detectable by visual inspection of in-situ aircraft undercarriage, even when the wheel is removed. Sometimes CBCO is only found when the brake is dismantled, especially if the deterioration started at the inner diameters of the annular discs. Information is unavailable whether brake wear rates or brake operation temperatures can indicate CBCO.

CBCO can result in premature removal of a brake and can result in a flight delay or cancellation if a spare brake is not available. Carbon discs with CBCO cannot be reused. As many aircraft operators use brake maintenance contractors, some may not be fully aware of the extent of CBCO nor the total cost of maintenance, and aircraft operators may not raise the issue of CBCO with individual airport operators.

Anti-Oxidant Coating (AO)

Brake manufacturers apply an anti-oxidation **(AO)** coating to the non-friction surfaces of the carbon brake discs to prevent the infiltration of dissolved PDP and continue work to the AO formulations to prevent CBCO. As an example, one aircraft manufacturer has reported that since 2009, when a new AO formula was incorporated on certain aircraft models, there have been no events of CBCO.

Due to individual carbon brake design requirements for airplane performance that are significantly different from airplane-to-airplane and airframe manufacturer-to-airframe manufacturer, a common AO cannot be applied to all carbon brakes.

AIR5567 Testing of PDPs

In 2009, SAE International published a test procedure to assess the potential effect PDPs have on CBCO. **AIR5567** testing involves taking a carbon sample of a specific size, shape, carbon composition, and treatment with a specific AO coating. This carbon "coupon" is dipped in a solution of the PDP being tested, dried and weighed to determine the amount of PDP absorbed, then heated to a specific temperature for a specific period. After cooling, the coupon is re-weighed to determine the percentage of carbon that has been lost to oxidation. The AIR5567 test result for each PDP is quoted as a percentage of carbon weight loss.

AIR5567 was developed on the basis that it would provide information to airport operators and airlines on a PDP, and not as a pass/fail test. PDP manufacturers usually only provide the AIR5567 percentage of carbon weight loss rating of their products as part of the bid package information and upon request. Data often provided to airport operators is commercially confidential.

In terms of AIR5567 percentage carbon weight loss, PDP rank from lowest to highest as follows:

- Generation 1 urea and glycol PDP (including glycol-based ADF)
- Generation 3 hybrid PDP
- Generation 2 acetate PDP
- Generation 2 formate PDP

It should be noted, that some data results from AIR5567 have shown substantial deviations for the same PDP being tested. The test itself is therefore not thought to be reliable throughout the industry.

As of June 2014, the SAE A5A Aircraft Brake System Committee is considering the conversion of the AIR5567 recommendations, to become an Aerospace Standard **AS6289.**

Conflicting Needs

Some airlines have raised the issue of the extent of CBCO, resulting in increasing maintenance costs and the potential safety risk, bringing their concerns to aircraft and brake manufacturers, IATA, regulators and certain airports. Some airlines and manufacturers would like to see the cessation of the use of Generation 2 PDP with high percentage carbon weight loss ratings.

At the request of two airframe manufacturers, SAE A5A is also considering that AS6289 include a pass/fail limit at a 10% weight loss. Should this AS6289 replace the current AIR5567 within the AMS1431 and AMS1435, acetate and formate PDP as well as substantial proportion of hybrid PDP would no longer pass the AMS requirements. They would effectively become banned.

In April 2015 evidence of the variability and unreliability of AIR5567 test results was presented to A5A. The SAE G12 established a plan to work with the A5A to investigate the causes of the variability. A5A have indicated that the draft AS6289 might be reworded so that the 10% weight loss would become a "limit of compatibility with carbon brakes". PDP with weight loss greater than 10% would be deemed "incompatible" with carbon brakes.

Many airports have such restrictive environmental permits or their operations have reached a level that they can only use Generation 2 PDP with the lowest available OD. Traffic growth and increased ADF use can exacerbate the problem. In some cases, environmental authorities have specified the use of certain categories of PDP. Urea is effectively banned in some regions.

If certain Generation 2 PDP were to become classified as "failing" an AIR5567 (or AS6289) test or "incompatible" with carbon brakes, some airports would be faced with the choice of closing movement areas during icy conditions or using higher OD PDP. In order to operate within environmental limits with a higher OD load would require that stormwater draining from runways, taxiways and ramps be collected and processed to reduce the OD level before it could be discharged to the environment. This could require costly major new earthwork, drainage, storage networks and water treatment infrastructure to collect and treat the water run-off prior to discharge. In some cases, for airports directly adjacent to water bodies or those with large snow accumulations that melt in the spring, treatment of all water runoff might not be physically possible. In many cases, water seeping into the ground can be monitored and regulated, but cannot be readily collected and treated.

In certain regions operational and environmental regulations require companies to apply Best Available Techniques **(BAT)** when designing and operating their businesses. Airports apply BAT through use of physical removal of snow and use of improved weather forecasting technology to minimise the amounts of chemicals deployed. BAT principles also require that products with the lowest possible environmental impact be used and substitution of chemicals with higher OD loads is not permitted. Utilising a PDP with higher OD than already in use would directly contravene this environmental goal and violate current environmental legislation.

Utilising a PDP not complying to the AMS1431 and 1435 (incorporating the AS 6289, if approved) would result in a violation of best practice utilisation of the industry recognised SAE standards and leave airport operators and accountable managers open to significant liability issues.

Safety Risk Assessmeent (SRA)

Between 2012 and 2015, IATA and ACI formed a working group that included airports and airlines, aircraft and brake manufacturers and safety regulators, to examine this problem.

The group conducted an analysis of the safety issues for aircraft and environmental impacts using ICAO Safety Risk Assessment (**SRA**) principles. This SRA identified the following major consequences for the identified hazards that need to be avoided:

- Runway excursion
- Aircraft brake overheating resulting in brake fire and requiring emergency evacuation
- Brake disintegration and FOD damage to own or other aircraft
- Mass mortality of aquatic life or contamination of water
- Loss of airport environmental permit or other punitive action
- Airport winter closure

The analysis indicated that under the currently existing controls there was no issue rated as Intolerable and raising a red flag.

Figure 4: Photo: Fraport

The major recommendations from the SRA include the following "new controls" and mitigation actions:

- Continuous improvement and application of best available technology in carbon and anti-oxidant coatings for carbon brakes
- Tracking aircraft exposure to PDP and taking appropriate action
- Consultation between airports, airlines and water quality regulation authorities on use of non-alkali PDP
- Minimizing the use of alkali PDP
- Reducing the use of aircraft brakes during operation (airmanship)
- Plan adequate stocks of PDP for each winter season
- Development of environmentally and airplane friendly PDP

(Quoted with permission from IATA.)

ACI Recommendations

In line with the above new mitigation actions, ACI makes the following recommendations for actions by its members affected by winter operations.

- Airport operators should include current information on the presence and type of PDP applied to pavements (runways, taxiways, ramps) in their Runway Condition Reports, NOTAM's, SNOWTAM's or Seasonal Snow Plans (or Snow and Ice Control Plans (SICP)). In conjunction, airlines would need to collect PDP exposure data of each aircraft and correlate the exposure with the condition of the aircraft's brake.
- Airport operators should minimize the use of PDP's, especially alkali PDP's, using approved operational efficiency improvements and alternative techniques and materials, where equivalent safety requirements are met and there is a business case.
- Airport operators should work with their airline partners to minimize taxiing distances and the need for taxiing aircraft to brake. Airport operators should provide rapid exit taxiways (designed in accordance with ICAO Annex 14) wherever there is a business case, based on reducing runway occupancy. In conjunction, airlines would work with pilots regarding training on taxiing procedures to reduce braking.
- Airport operators should work with ACI to organize a trial meeting at one airport with local water quality authority, including ACI/the airport, IATA/the principal airline, OEM/brake manufacturer.

ACI and certain airports continue to work within the SAE to raise awareness of airport perspectives on this issue and discourage the adoption of the proposed AS6289.