Alkali metal runway deicers clearly damage carbon brakes resulting in catalytic oxidation of the carbon.

Effects of Alkali Metal Runway Deicers on Carbon Brakes

Alkali metal (i.e., organic salt) runway deicers have caused catalytic oxidation of carbon brakes, resulting in mechanical damage to the brakes, and have the potential to degrade airplane stopping performance. Mitigating actions can reduce the severity of catalytic oxidation of carbon brakes but cannot eliminate the occurrence of catalytic oxidation of carbon brakes as long as cold weather airports continue to use alkali metal runway deicers.

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Two types of oxidation can occur on carbon brakes: thermal oxidation and catalytic oxidation. Thermal oxidation occurs as the temperature of the carbon material is increased and an oxidizer, such as oxygen, is present. Catalytic oxidation of carbon occurs when a catalyst, such as an alkali metal(s), is present. When a catalyst is present, the temperature at which thermal oxidation occurs is lowered. Airplanes equipped with carbon brakes are susceptible to catalytic oxidation caused by exposure to alkali metal runway deicers. These deicers are in common use at cold weather airports around the world mainly due to environmental legislation. Although airplane deicers applied to the wings and fuselage do contain very small amounts of alkali metals, airplane deicers are glycol-based and do not contribute to catalytic oxidation of carbon brakes. SAE Aerospace Recommended Practice (ARP) 5149 (*Training Program Guidelines for Deicing/Anti-Icing of Aircraft on Ground*) and ARP 4737 (*Aircraft Deicing/Anti-icing Methods*) provide guidance to airplane deicing crews not to spray the landing gear or wheels and brakes with airplane deicer fluid.

This article explains the history of catalytic oxidation of carbon brakes, the catalytic oxidation process caused by alkali metal runway deicers, the effects of runway deicers on carbon brakes, and how airlines and airports can minimize these effects.

THE HISTORY OF CATALYTIC OXIDATION OF CARBON BRAKES

Widespread use of carbon brakes on commercial airplanes began in the mid-1980s. Carbon brakes offer a significant weight savings compared to steel brakes, which translates into a lighter airplane and directly contributes to decreased fuel consumption and reductions in engine emissions.

Carbon brakes also offer other advantages over steel brakes, including improved brake performance, high temperature stability, better wear characteristics and longer life, and the ability to reuse worn carbon disks to make refurbished carbon disks that would otherwise end up being disposed of in a landfill. (For more information about the advantages of carbon brakes, see *AERO* third-quarter 2009.)

By the early 1990s, airlines began experiencing catalytic oxidation of carbon brakes at about the same time that airports began using alkali metal runway deicers. These alkali metal deicing formulations — containing primarily, but not limited to, potassium, sodium, and calcium — were introduced because of environmental concerns over the use of urea- and glycol-based runway deicers. When airports were using urea- and glycol-based runway deicers, there were no reports of catalytic oxidation of the carbon brakes. Environmentally friendly alkali metal runway deicers were introduced because they reduce the biological and chemical oxygen demand (removal of oxygen from the water) on water systems around airports, limiting the environmental impact to aquatic and plant life.

Airlines reported that carbon brakes were showing indications of oxidation (soft carbon) and structural deterioration of the carbon disks (i.e., chips, cracks, or complete disk failure). Chemical analysis of the contamination on the carbon brake disks by the brake manufacturers found high levels of the alkali metals potassium, sodium, and calcium (see fig. 1). Further investigation determined the source of these alkali metals was from airports' use of environmentally friendly runway deicers, since these alkali metals by themselves are not used during the manufacture of the carbon brakes or the airplane.

CATALYTIC OXIDATION OF CARBON

Catalytic oxidation of airplane carbon brakes is caused by contamination with a catalyst, in this case alkali metal(s). The rate of catalytic oxidation is a function of the time the carbon is exposed to the alkali metal catalysis while at an elevated temperature, which can be the normal operating temperature of the carbon brake. Over time, the catalytic oxidation of the carbon results in mechanical and structural degradation of the carbon disk material. Unfortunately, due to the many variables involved during normal takeoff and landing — weather conditions, airplane weight during takeoff and landing, airplane landing speed, thrust reverser usage, flap setting, autobrake setting, altitude of airport, outside air temperature, wind speed and direction at landing, after-landing instructions by air traffic control to vacate the runway, taxi distances, the worn condition (mass of the carbon heat-sink) of the carbon brakes, the amount and concentration of runway deicer on the runway and taxiway — it is not possible to predict the rate at which the carbon disks will catalytically oxidize.

DAMAGE TO CARBON BRAKES CAUSED BY ALKALI METAL RUNWAY DEICERS

Carbon brakes become contaminated by runway deicers during taxi, takeoff, and landing when runway deicers splash onto the carbon brakes (see fig. 2).

Once the carbon brakes are exposed to the alkali metal runway deicers, the alkali metal cannot be removed from the carbon disks. Subsequent exposure to these alkali metals on successive takeoff and landing cycles, combined with the braking action of the airplane, leads to the mechanical and structural degradation of the carbon disks.

Catalytic oxidation of the carbon does result in decreased service life (premature removal) of a carbon brake (see fig. 3). In rare instances, severely catalytically oxidized carbon brakes have caused a brake fire when a piston (or pistons) penetrates a severely catalytically oxidized carbon pressure plate (first rotor disk) and contacts the adjacent rotor disk, which is rotating at the same speed as the wheel. The rotational force of the rotor disc fractures the piston assembly, allowing hydraulic fluid to contact the carbon heat-sink, which is at an elevated temperature as a result of the kinetic energy absorbed by the brake during the landing stop (see fig. 4).

Figure 1: Scanning electron microscope analysis of carbon brake disk contamination

Laboratory analysis showed that carbon brakes were contaminated by sodium, potassium, and calcium, which caused the carbon to oxidize.

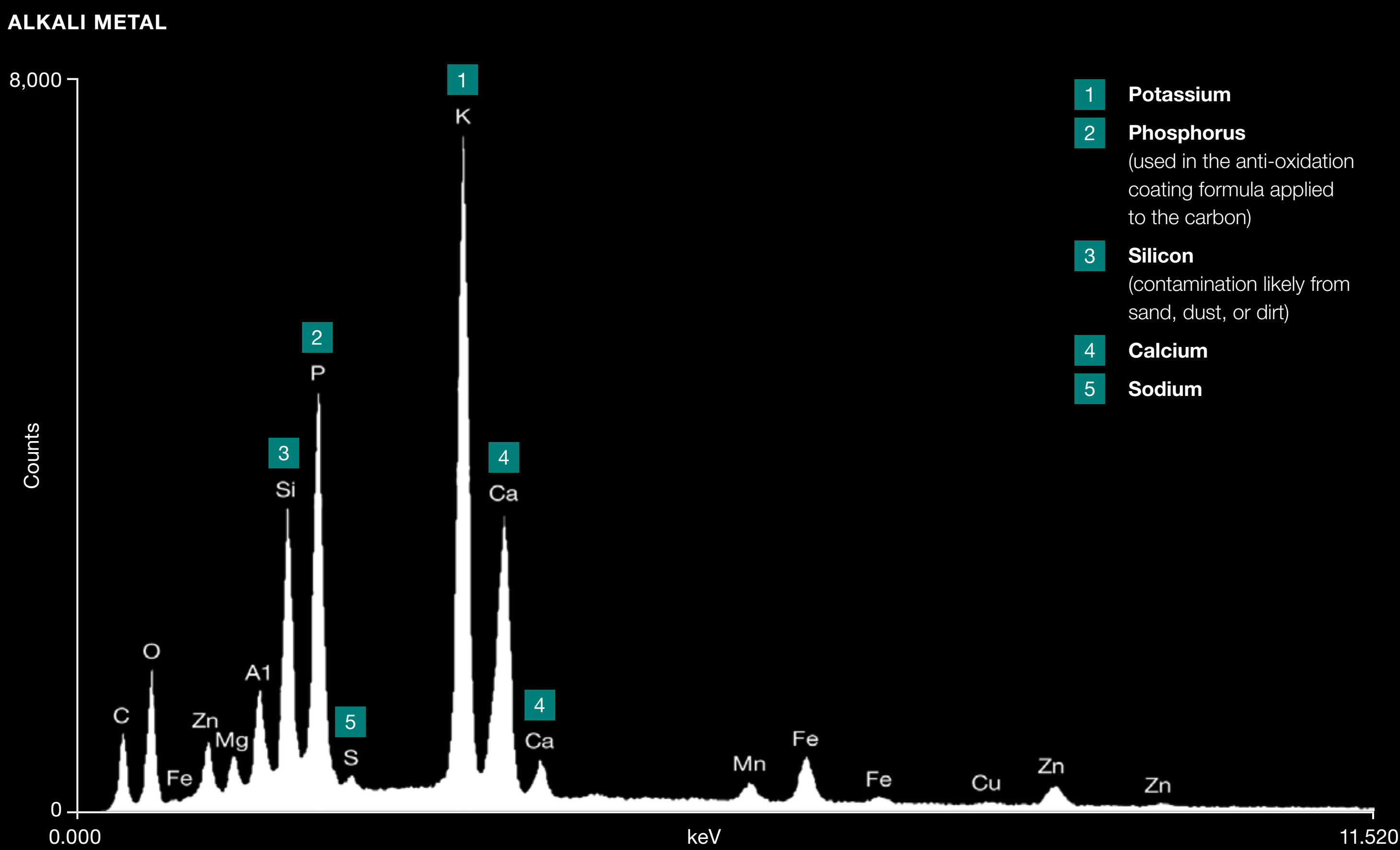


Figure 2: Carbon brake contamination by runway deicers

When deicers are present on taxiways and runways, alkali metal runway deicers splash onto the carbon brakes.

Figure 3: Carbon stator-disk-drive lug damage

The damaged stator-disk-drive lugs on this carbon heat-sink are an example of the type of damage alkali metal runway deicers can cause to carbon brakes. The top photo shows a new carbon heat-sink. The middle photo reveals significant damage with most of the stator-disk-drive lugs missing. The bottom image shows a complete loss of all stator-disk-drive lugs.

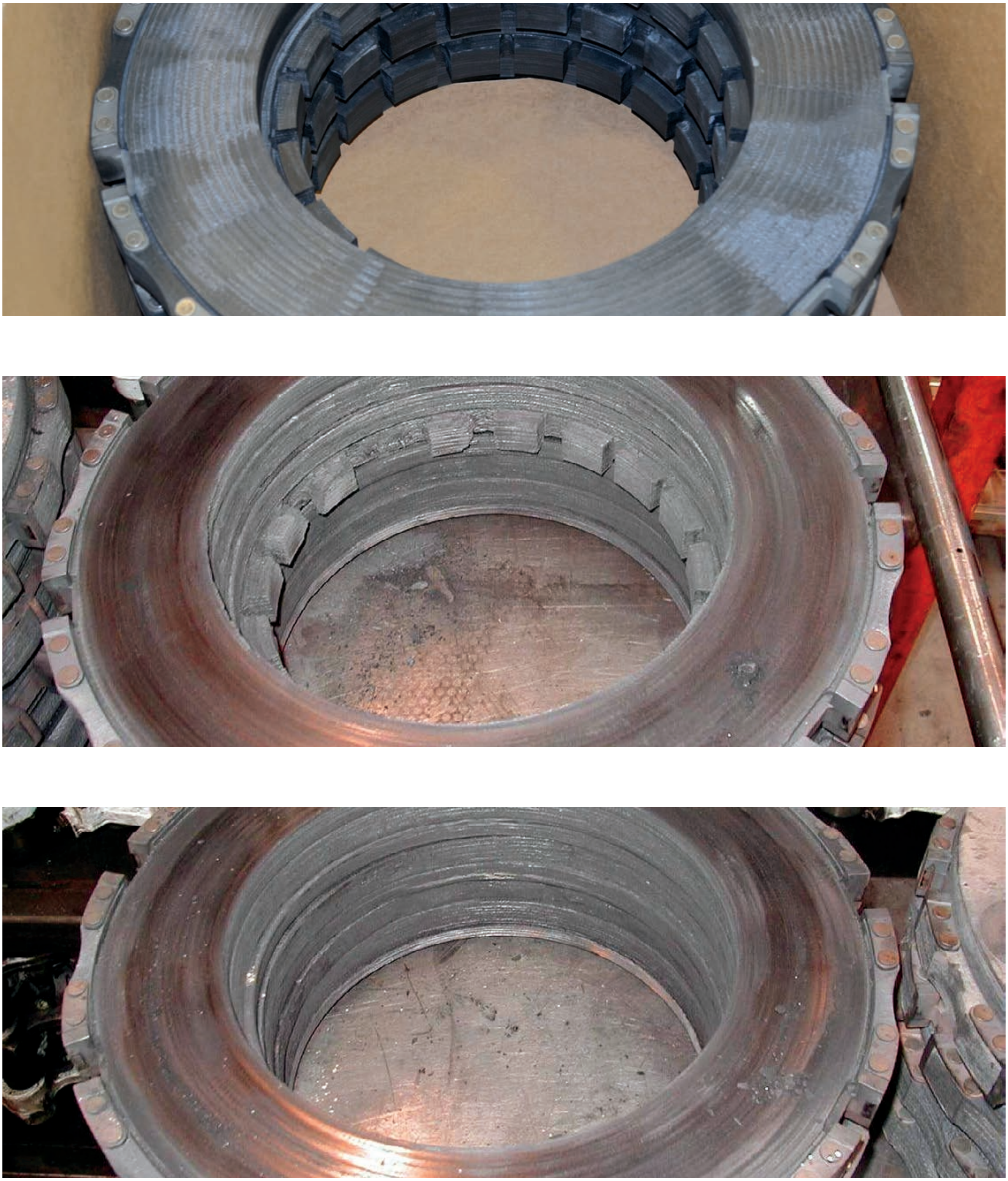
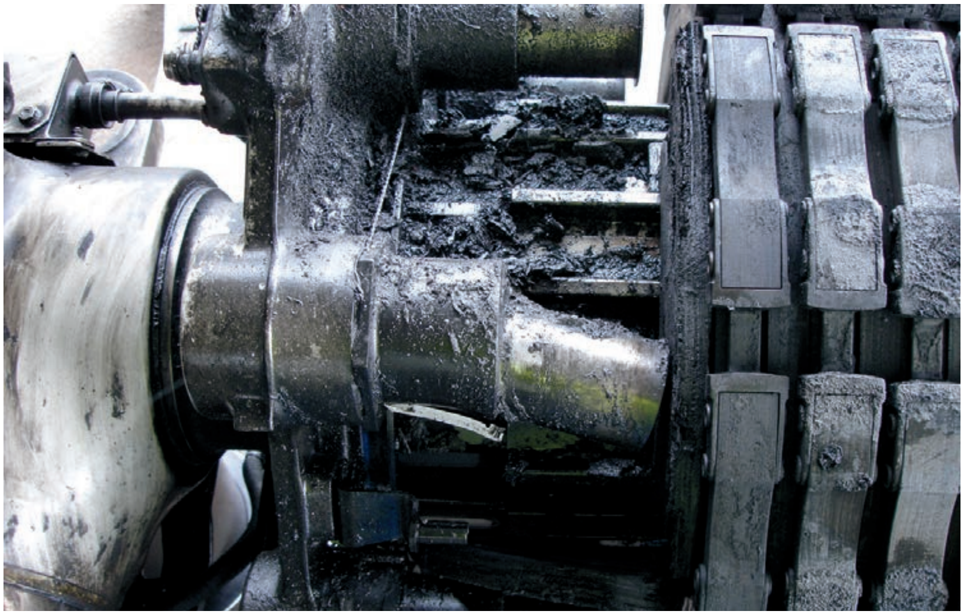


Figure 4: Catalytically oxidized carbon pressure plate disk failure resulting in a brake fire after landing



REGULATORY AND INDUSTRY RESPONSE TO CATALYTIC OXIDATION OF CARBON BRAKES

As the extent of catalytic oxidation of carbon brakes has become widely known, the following bulletins and reports have been published.

- Transportation Research Board of the National Academies, Airport Cooperative Research Program Synthesis 6 (*Impact of Airport Pavement Deicing Products on Aircraft and Airfield Infrastructure)*, 2008.
- U.S. Federal Aviation Administration (FAA) Special Airworthiness Information Bulletin NM-08-27R1, December 31, 2008.
- European Aviation Safety Agency (EASA) Safety Information Bulletin 2008-19R2, April 23, 2013.
    - Both FAA and EASA bulletins recommend that when an airline removes a wheel and tire assembly from the landing gear axle, a detailed inspection of the periphery of the carbon heat-sink be performed per the aircraft maintenance manual (AMM) for indications of catalytic oxidation of the carbon disks.
- SAE G-12RDF Catalytic Oxidation of Carbon Brakes Working Group's yearly, *Aerospace Industry Report*.
- SAE A-5A Wheels, Brakes and Skid Control Committee developed and published AIR5567 (*Test Method for Catalytic Carbon Brake Disk Oxidation*), May 2009.
- SAE A-5A Wheels, Brakes and Skid Control Committee developed and published AIR5490 (*Carbon Brake Contamination*), May 2012.
- Aerospace Material Specification (AMS) 1431 *(Compound, Solid Runway and Taxiway Deicing/Anti-Icing)* Revision C published September 2010 to add AIR5567.
- AMS1435 Fluid *(Generic, Deicing/ Anti-Icing Runways and Taxiways)* Revision B published September 2010 to add AIR5567.

WHAT AIRLINE OPERATORS CAN DO

To help operators of airplanes equipped with carbon brakes comply with FAA Special Airworthiness Information Bulletin NM-08-27R1 and EASA Safety Information Bulletin 2008-19R2, Boeing added information to the Main Gear Wheel Brakes – Inspection/Check section of the AMM to help airline maintenance personnel identify catalytically oxidized carbon brakes when the wheel and tire assembly are removed from the main landing gear axle. These inspections and checks include examining the carbon pressure plate disk for piston impressions or chipped or cracked carbon disks, verifying that the stator disk alignment grooves have not migrated, and, if the rotor disks have rotor clips, assuring the attachment fasteners are not loose.

In addition, Boeing has released service letters regarding the corrosion caused by alkali metal runway deicers on various airplane parts located mainly in the wheel well where exposure to runway deicers can occur, including carbon brakes (767-SL-32-106, *Effects of Alkali Metal [Organic Salt] Runway Deicer on Carbon Brakes*), hydraulic tubes (737-SL-29-092, *Recommended Action to Resolve Corrosion of Hydraulic Tubes in the Wheel Wells Caused by Exposure to Potassium-Containing Runway Deicing Fluids*), cadmium-plated components (737-SL-27-184, *Flight Controls in Main Wheel Well — Changes to the Finish of Cadmium Plated Components*), and electrical connectors (737-SL-20-053, *Electrical Connector Corrosion in Unpressurized Areas*).

Because exterior airplane cleaners can also contain small amounts of alkali metal, airlines are encouraged to use wheel covers when washing their airplanes.

DEVELOPING A LASTING SOLUTION

Eliminating or reducing the effects of catalytic oxidation on carbon brakes, and other airplane components, requires an industry-wide effort. For example, airlines, airports, and interested parties can work together to discuss the selection of an AMS1431 and/or AMS1435 runway deicer that has the lowest AIR5567 mean normalized carbon weight loss percentage. The lower the carbon

Proper flight operations (e.g., touchdown speeds, landing points, using available runway) will help reduce the amount of kinetic energy absorbed by carbon brakes during landing, lowering the brake temperatures and reducing the rate of oxidation.

weight loss percentage, the less catalytic oxidation of the carbon that will occur.

Additionally, to help alleviate the problem:

- Carbon-brake manufacturers should continue to develop new and improved anti-oxidation coatings for application to the carbon disks.
- Airframe manufacturers should continue to work with brake manufacturers, airlines, airports, and regulatory agencies to raise awareness of catalytic oxidation of carbon brakes caused by alkali metal deicers.
- Airlines can improve brake inspection techniques to find and remove catalytically oxidized carbon brakes from airplanes before they result in a flight delay or cancellation and damage to the airplane, such as when carbon disks fracture and depart the brake. Carbon disk pieces departing from the brake results in foreign object debris, which could affect other airplanes moving through the runway, taxiway, or ramp areas.
- Airlines that service the same cold weather airport that are experiencing catalytically oxidized carbon brakes can collectively approach the airport's airfield maintenance department and discuss the type of runway deicer the airport is using that can be contributing to catalytic oxidation of carbon brakes. The optimum deicer for use at cold weather airports is the deicer with the lowest mean normalized carbon weight loss percentage per AIR5567 testing.
- Airlines should be cognizant of the type of runway deicer being used by the airport so that they can take appropriate maintenance and planning actions.
- Airlines can also contact airline trade organizations, such as Airlines for America (formerly Air Transport Association) and the International Air Transport Association, to request their assistance.
- Additionally, proper flight operations (e.g., touchdown speeds, landing points, using available runway) will help reduce the amount of kinetic energy absorbed by carbon brakes during landing, lowering the brake temperatures and reducing the rate of oxidation.
- Airports should utilize mechanical snow removal methods, such as broom trucks and snowplows, as much as possible to reduce the amount of runway deicer used. Airports should apply runway deicers per the runway deicer manufacturers' recommended application rates. Over-application results in higher levels of alkali metal exposure to carbon brakes.
- Airports can also use the best available technology to measure effluent levels to comply with environmental legislation. Total organic carbon (TOC) measurement, in place of biological oxygen demand (BOD5) and chemical oxygen demand (COD) measurement, is a reliable, inexpensive, and real-time method that can be correlated to COD. If airports are unable to use TOC measurement in place of BOD5 and COD, a containment system can be built to capture and treat effluent before it is discharged to a public water treatment system or water bodies around the airport.
- Aviation regulatory agencies such as the FAA, EASA, and Transport Canada can engage environmental regulatory agencies to discuss changes to environmental legislation to maintain and improve aviation safety.

SUMMARY

Alkali metal runway deicers are clearly associated with damage to carbon brakes resulting in catalytic oxidation of the carbon. Airlines can work with airports to use runway deicers that are less harmful to carbon brakes, and aviation and environmental regulatory agencies can engage in discussion to change environmental legislation to maintain and improve aviation safety. A