EASA Annual Safety Conference
16 October 2013

Runway Icing Panel discussion:

Chemical effects of runway de-icers: Damage of carbon brakes and other aircraft parts

Presented by:

- Michael Arriaga – The Boeing Company
- Alun Williams – The Airbus Group
  - Co-Chairman of SAE G-12RDF Catalytic Oxidation of Carbon Brakes Working Group

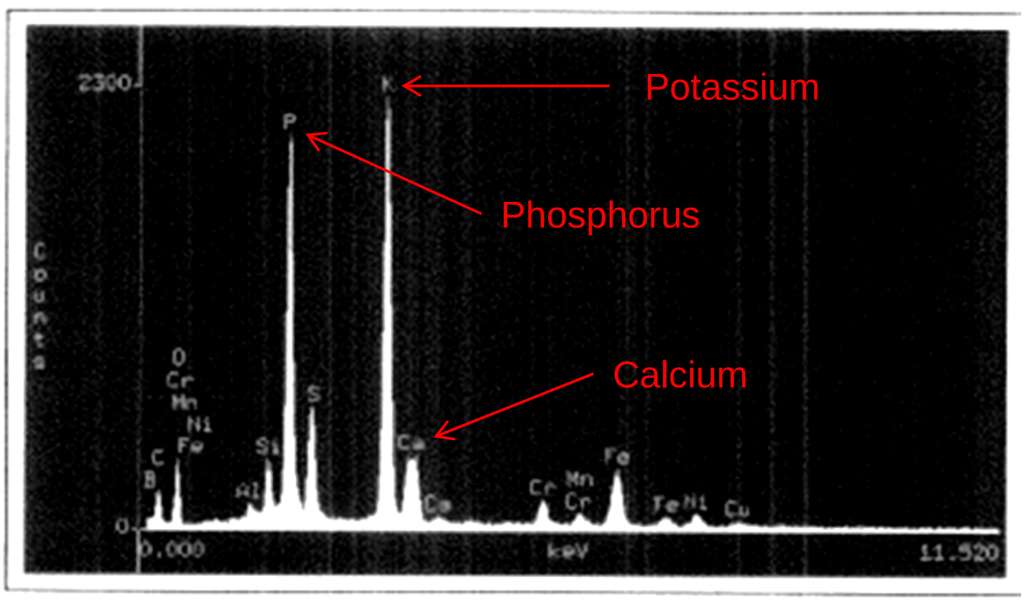
History of Catalytic Oxidation of Carbon Brakes

- Carbon brakes began widespread use on commercial aircraft mid-1980s
  - Less weight than steel brakes
    - Reduces fuel consumption and carbon dioxide (CO_2) emissions
  - Improved brake performance over steel brakes
  - High temperature stability
  - Better wear and longer life characteristics than steel brakes
  - Able to reuse worn carbon disks to make refurbished carbon disks

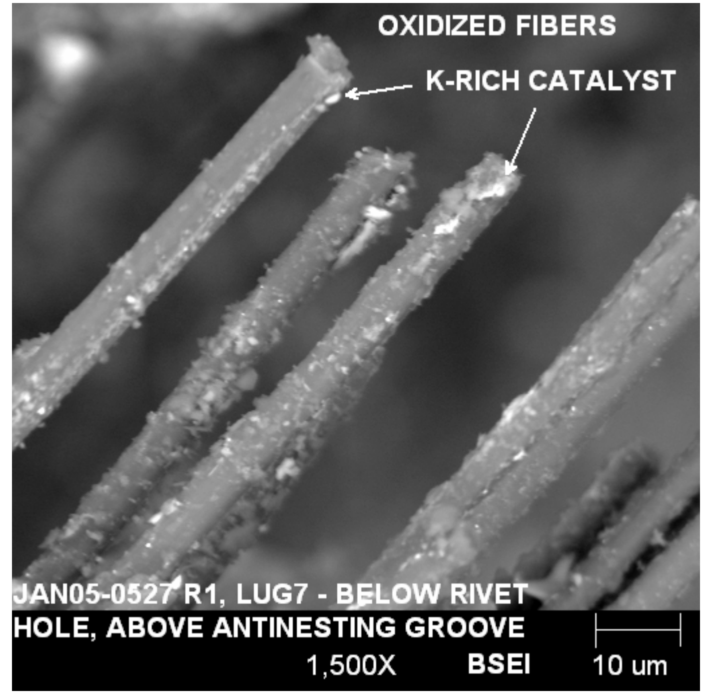
- Airlines began experiencing catalytic oxidation of carbon brakes early-1990s
  - Same time when airports began using alkali metal (mainly potassium, sodium, calcium) runway deicers

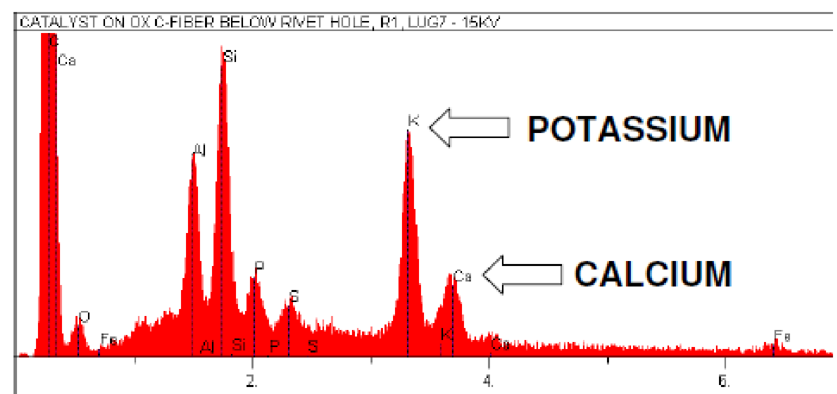
What is Catalytic Oxidation of Carbon?

- Oxidation occurs when a catalyst attaches to carbon and is subjected to high temperature for a duration of time; time at temperature
- Catalytic oxidation of the carbon results in mechanical and structural degradation of the carbon material



Provided by United Airlines





Provided by Embraer

Catalytic oxidation of aircraft carbon brakes is caused by contamination with alkali metal(s)

- Most current “environmentally friendly” runway de-icers contain, but are not limited to, either potassium, sodium, or calcium

The alkali metal(s) are a catalyst which lowers the temperature at which oxidation occurs

- The rate of carbon oxidation is a function of time the carbon is exposed to the alkali metal catalysis while at elevated temperature, ~500 deg C (~900 deg F)

Regulatory Assistance

EASA SIB No: 2008-19R2

EASA Safety Information Bulletin

SIB No.: 2008-19R2

Issued: 23 April 2013

Subject: Catalytic Oxidation of Aircraft Carbon Brakes due to Runway De-Icers

Ref. Publication:
- Aerospace Inc
(SAE G-12 Ru
of Carbon Bra
Effects on Air
- FAA Special A
- SAE AIR5567/
Oxidation.

Applicability: All large aeroplane
airports where run

Description: The use of low-we
and the concurren
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[...] Aircraft manuf
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This is information only. Recommendations are not mandatory.

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Service Difficulty Advisory

AV 2009-03
26 June 2009

Catalytic Oxidation of Aircraft Carbon Brakes due to Runway De-Icing (RDI) Fluids

This Service Difficulty Advisory (SDA) advises owners and operators of Transport Category Airplanes equipped with carbon brakes, utilizing airports where runway de-icing (RDI) fluids are used, that b rake failure or degradation may occur as a result of the switch to more environmental friendly organic salt RDI fluids (mainly potassium formate and acetate, but other alkalis as well

The RDI fluid remains on the underside of the aircraft and can collect as ice and slush on the landing gear, and coat the carbon brake rotors and stators . During landing gear retraction, the ice and slush on the gear (now in a horizontal position) melt on the brake units where it is further absorbed into the carbon rotors and stators.

The presence of the alkalis in the RDI creates a catalytic condition, which lowers the temperature of oxidation and softens the carbon. This condition causes the brake to flake and crumble over time, reducing the life and long-term efficiency of the brakes themselves.

As a result, there is a danger of possible brake failure during high-speed aborted take-off or dragged brake during normal take-off (and subsequent overheat, once airborne) or excessive vibration during any ground operation. It should be noted that the center of the brake unit cannot be easily inspected, and this is where its stator couplings are indexed to the torque tube, mechanically linked to the axle, thus transmitting the braking torque to the wheels.

The current Society of Automotive Engineers (SAE) Aerospace Material Specification (AMS) runway de-icer specifications were developed with the endorsement of the SAE G-12 aviation industry representatives, which included both domestic and foreign airlines, airframe manufacturers, and regulators. Modification of the SAE AMS specifications will occur once the affected parties formalize new testing protocol that has been formally endorsed by the SAE G-12, Aircraft Ground Deicing Committee.

Transport Canada recommends owners/operators of transport category airplanes equipped with carbon brakes that operate to/from airports where runway de-icing (RDI) fluids are used, to carry out a detailed visual inspection during each landing gear wheel removal, of the carbon brake rotors and stators for obvious damage, distortion, carbon chips, crushed, flaked, soft, fractured carbon or missing carbon elements. Carbon oxidation often develops on the inner diameter of the carbon stator drive lugs. Unless

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FAA
Aircraft Certification Service

SPECIAL AIRWORTHINESS INFORMATION BULLETIN

SUBJ: Landing gear: Catalytic Oxidation of Aircraft Carbon Brakes due to Runway De-icing (RDI) Fluids

SAIB: NM-08-27R1
Date: December 31, 2008

This is information only. Recommendations aren't mandatory.

Introduction

This Special Airworthiness Information Bulletin (SAIB) advises registered owners and operators of **Transport Category Airplanes equipped with carbon brakes and operated into and out of airports where runway de-icing (RDI) fluids are used that the use of carbon brakes in aircraft**
e environmental friendly organic salt RDI fluids
d, and that corrective actions may impose additional

space Material Specification) runway deicer
nt of the SAE G12 aviation industry
d foreign airlines, airframe manufacturers, and
al and equipment, the FAA will modify the SAE
alize new testing protocol that has been formally
nti-icing Committee.

3. Since the issuance of that SAIB, members of the
s working group have determined that the issue of
h carbon brakes and is not a direct result from the
runway deicers. Consequently, the working group
idation," as it appeared in a "Note" in SAIB NM-
different category of oxidation. The use of the term
ation in the "Note" may result in confusion for

necessary changes to SAIB NM-08-27:
some confusion with respect to the recommended
ent normally is not "scheduled," the timing of the
tion.
they appear in SAIB NM-08-27, need to be
stators" throughout the SAIB.

cessary, and have incorporated them into this
lated June 6, 2008, including these changes, is

manufacturers have informed airworthiness
ntaining organic salts (mainly potassium formate
by the wheels, mainly during aircraft take-off and
of the aircraft and can be collected as ice and slush
ray between wheels, which drives the RDI fluid
directly into the brakes and, particularly, coats the (carbon) brake rotors and stators, which are also

Carbon Brakes Installed on Main Landing Gear

Provided by UTC Aerospace Systems

Wheel and Tire Assemblies Installed on Main Landing Gear

Provided by UTC Aerospace Systems

Carbon Brake Contamination by Runway De-icers

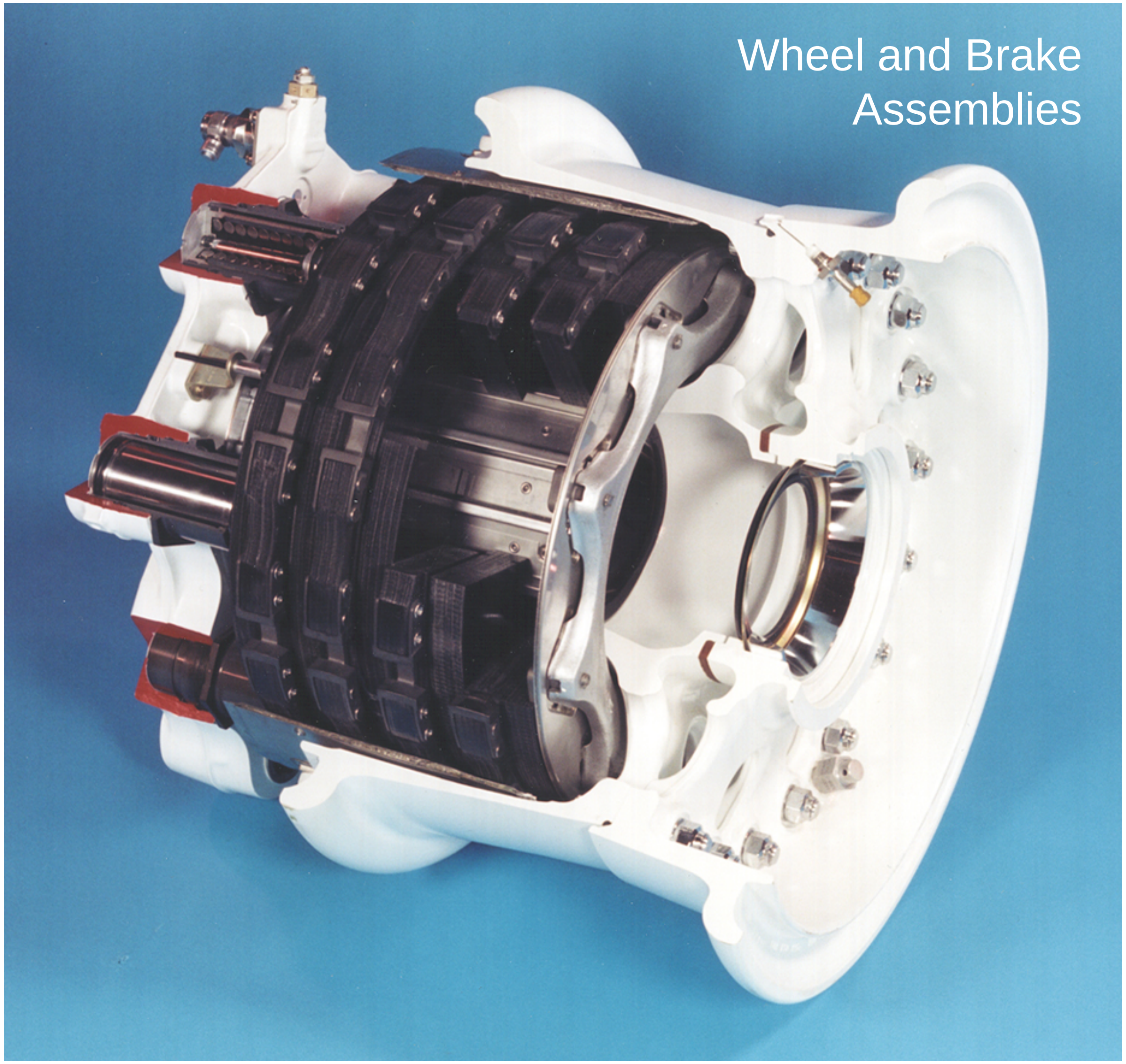
Provided by Transport Canada

During taxi and takeoff

Provided by John Kosak

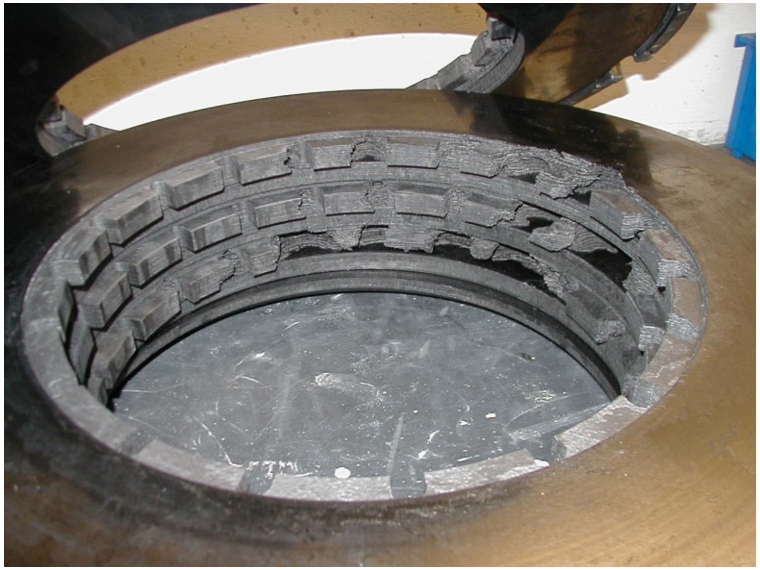
During Landing

Non-Detectable Damage to Carbon Disks

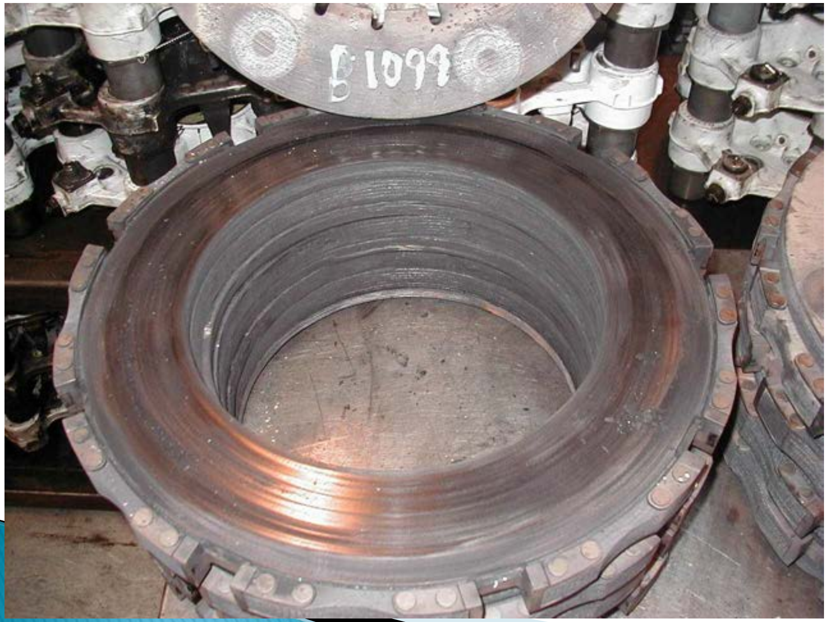


Provided by Honeywell

Non-Detectable Damage to Carbon Disks

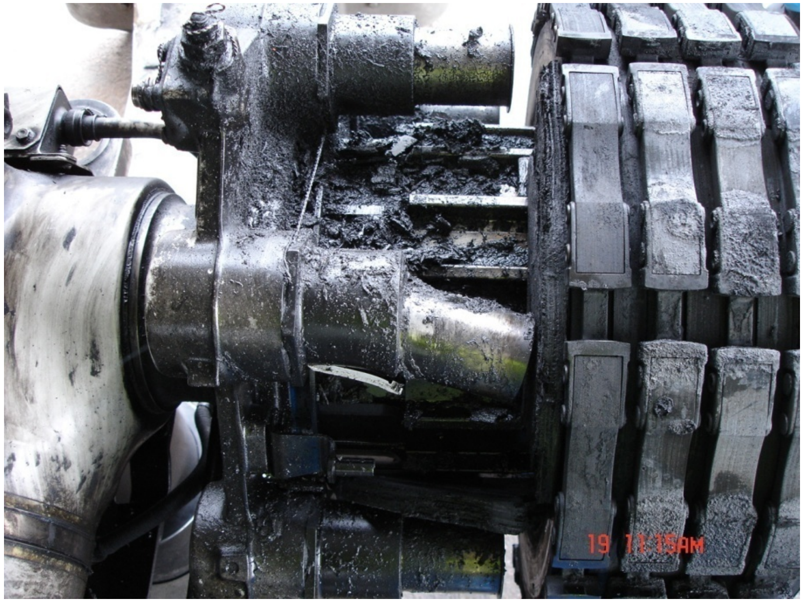


Provided by Honeywell



Carbon Stator Disk
Drive Lug Damage

Brake Fires Caused by Catalytic Oxidation of the Carbon



Provided by United Airlines

Provided by Honeywell

Airplane damage from Catalytic Oxidation of the Carbon

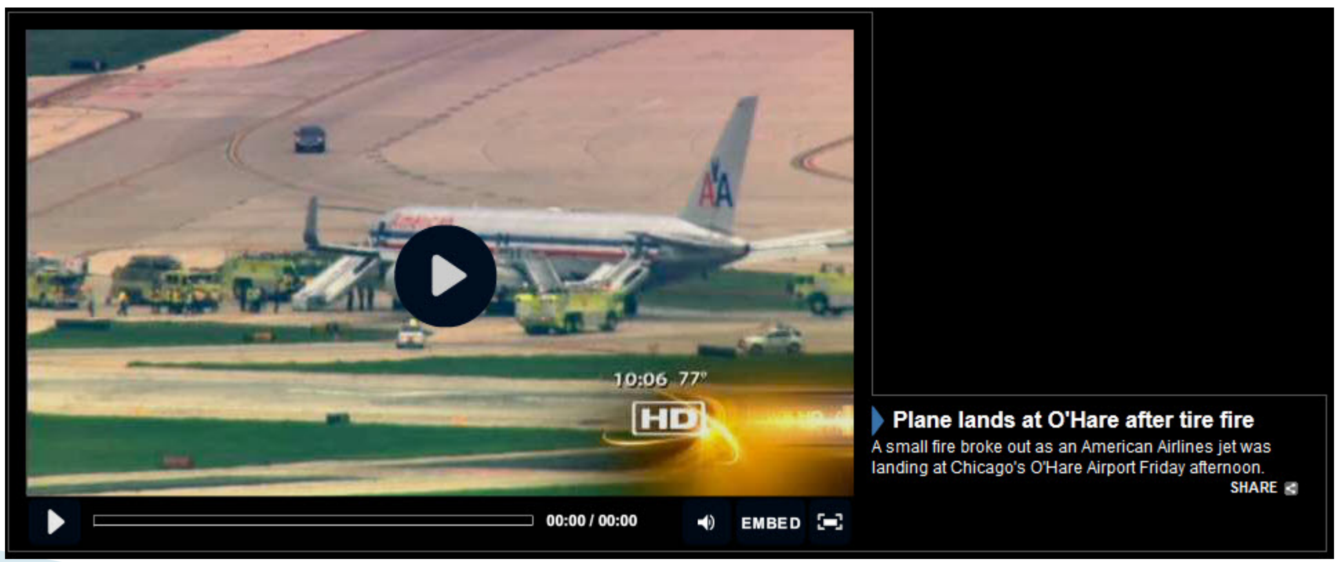
Provided by United Airlines

Events Due to Catalytically Oxidized Carbon Brakes

August 2010

NTSB Identification: **DCA10IA082**
Scheduled 14 CFR Part 121: Air Carrier
Incident occurred Wednesday, August 04, 2010 in Chicago, IL
Aircraft: , registration:
Injuries: 6 Minor,184 Uninjured.

August 2011



Cost of Carbon Brake damage from Catalytic Oxidation to Airlines

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Seating
Staying Connected
Dining
Lounges
Chauffeur-drive
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Emirates A380 Hub
Our Fleet
Emirates A380
Boeing 777-300ER
Boeing 777-200LR
Boeing 777-300
Boeing 777-200
Airbus A340-500
Airbus A340-300
Airbus A330-200

Boeing 777-300ER

From www.emirates.com

Home ▸ The Emirates Experience ▸ Our Fleet ▸ Boeing 777-300ER

The backbone of the Emirates fleet, we currently have more than 80 Boeing 777-300ERs, with many more on order.

2013 Carbon Brake Price/Cost:

- 1 new 777-300ER brake assembly = 100,952.03 $/USD
- 12 brake assemblies per airplane = $1,211,424.36
- Fleet of 80 airplanes = $96,913,948.80
  - 1 new replacement carbon heatsink = $59,702.47
  - 12 replacement carbon heatsinks = $716,429.64
  - 80 airplanes = $57,314,371.20 for replacement carbon heatsinks

As of October 2013, Worldwide fleet of 777-300ER airplanes = 499
$604,500,756 / €445,764,000 for new brake assemblies
$357,498,390 / €263,622,000 for replacement carbon heatsinks

SAE G-12RDF Runway De icing Fluids Committee, Catalytic Oxidation of Carbon Brakes Working Group

The Airbus Group
Alun Williams

The Boeing Company
Michael Arriaga

British Airways
Mark Paine

United Airlines
Dave Carnes

Delta Air Lines
Jack Cummins

Lufthansa Technik
Jens Ponath

UPS
Robert (Joe) Michal

KLM Royal Dutch Airlines
Rob Jansen

Bombardier
Jacques Desmarais

EASA
Ingo Goesling

FAA
George Legarreta
Robert Hettman

Transport Canada
Alice Krol

Portland International Airport
Susan Aha

Luftfartsverket
Fredrik Nilsson

Fraport AG
Christopher Strand

Pittsburgh International Airport
Kevin Gurchak

Meggitt Aircraft Braking Systems
Tom Webb

UTC Aerospace Systems
Steve McCrillis

Honeywell
Jim Shamo

Messier-Bugatti-Dowty
Nathalie Nicolaus

Battelle
Dr. Satya Chauhan

Clariant
Dr. Stephanie Hochreuther

ADDCON Nordic AS
Dr. Martin Westermaier

Cryotech
John Moles

Changes to Industry Accepted Runway De-icer Specifications to Try and Address Catalytic Oxidation of Carbon Brakes

Compound, Solid Runway and Taxiway Deicing/Anti-Icing.

Product Code: AMS1431
Revision Number: D
Date Published: 2012-06-08

Issuing Committee:
G-12rdf Runway De Icing Fluids

Scope
This specification covers a deicing and anti-icing compound in the form of a solid. Unless otherwise stated, all specifications referenced herein are latest (current) revision. These compounds have been used typically at airports on aircraft maneuvering areas, such as aprons, runways, and taxiways, for the prevention and removal of frozen deposits of snow, frost, and ice, but usage is not limited to such applications.

Fluid, Generic, Deicing/Anti-Icing Runways and Taxiways.

Product Code: AMS1435
Revision Number: C
Date Published: 2012-06-07

Issuing Committee:
G-12rdf Runway De Icing Fluids

Scope
This specification covers deicing and anti-icing materials in the form of a fluid.

This deicing/anti-icing fluid has been used typically on runways, taxiways, and other aircraft maneuvering areas for the prevention and removal of frozen deposits of frost and ice. Fluids must not be used to deice/anti-ice aircraft.

AIR5567 issued May 2009 and amended to AMS1431 and AMS1435 in 2010

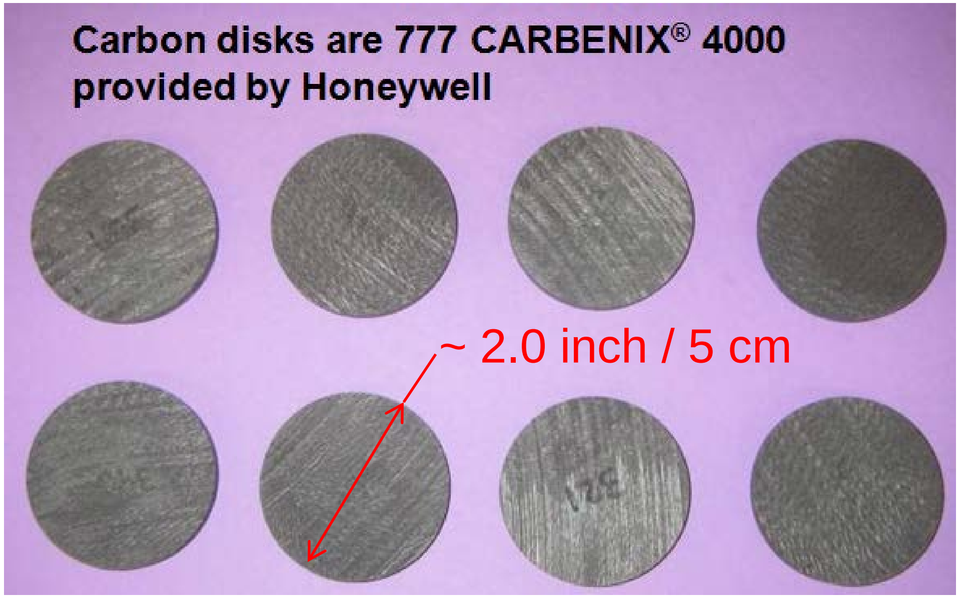
Test Method for Catalytic Carbon Brake Disk Oxidation.

Product Code: AIR5567
Date Published: 2009-05-13 - *A newer version of this standard is available.*

Issuing Committee:
A-5a Wheels, Brakes And Skid Controls Committee

Scope
The scope of the test method is to provide stakeholders including fluid manufacturers, brake manufacturers, aircraft constructors, aircraft operators and airworthiness authorities with a relative assessment of the effect of deicing chemicals on carbon oxidation. This simple test is only designed to assess the relative effects of runway deicing chemicals by measuring mass change of contaminated and bare carbon samples tested under the same conditions. It is not possible to set a general acceptance threshold oxidation limit based on this test method because carbon brake stack oxidation is a function of heat sink design and the operating envirnoment.

What Does AIR5567 Do?



Carbon Disks soaked in diluted 25% w/w runway de-icer

After drying, disks are weighted

Placed in furnace at 1022 F / 55 C for 24 hours

Provided by Anti-icing Materials International Laboratory

What Does AIR5567 Do? (continued)

Disks are cooled then weighed

Calculate mean normalized carbon weight loss (%) due to catalytic oxidation

4.2 Reporting of Results as part of AMS1431 and AMS1435

When performing AIR5567 as part of AMS1431 and AMS1435 a simplified report format can be adopted. The 'mean normalized weight loss deicer contaminated coupons' (Section 3.5 k) may be utilized as "mean normalized carbon weight loss (%)" and reported as the measure of performance.

Date
Test Location

Deicer name	
Deicer supplier	
Mean normalized carbon weight loss (%)	

Use one table for each deicer tested

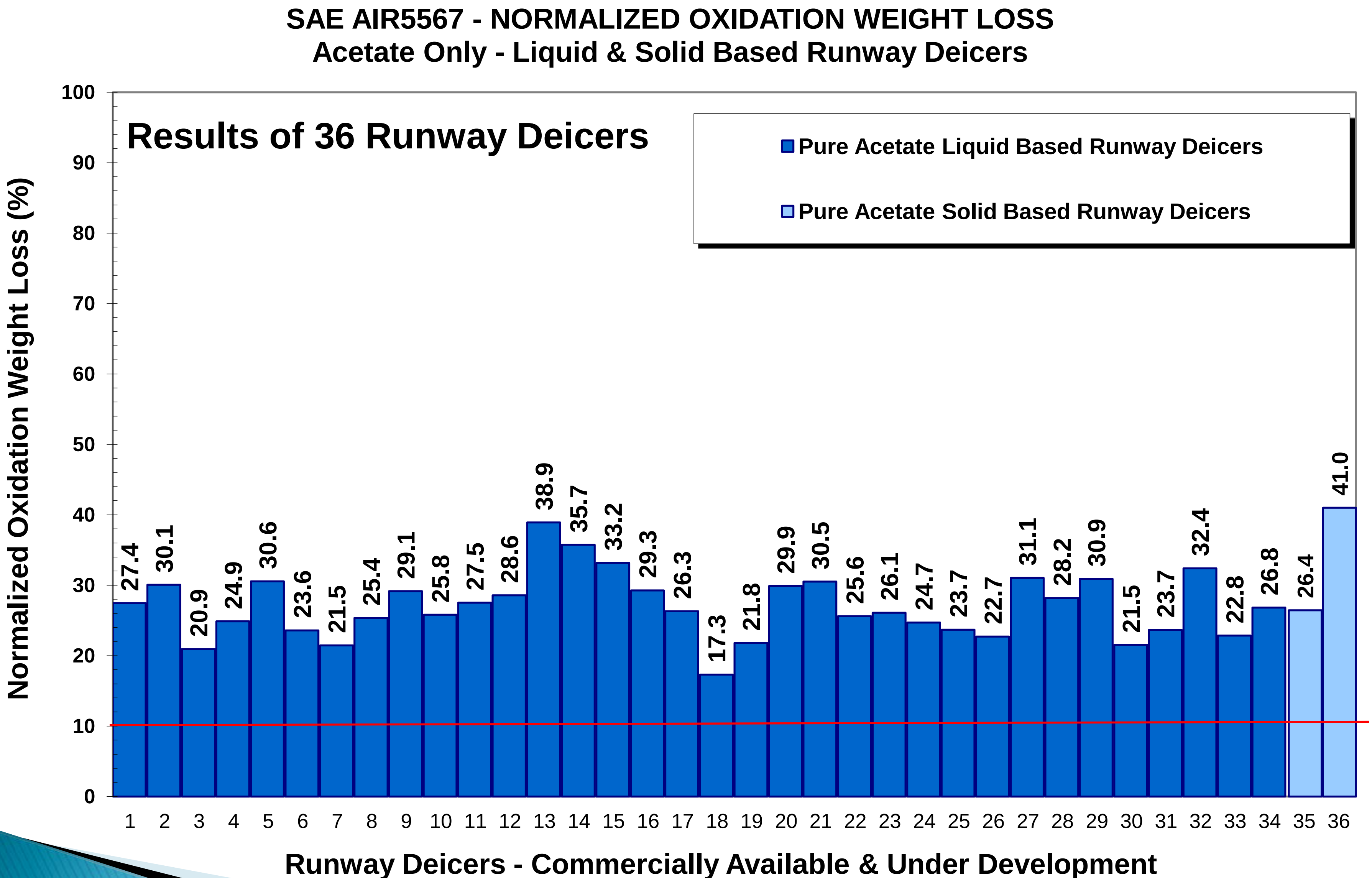
The lower the % weight loss the lower the risk of the carbon-carbon heat sink being damaged through catalytic oxidation.

Catalytic Oxidation of Unprotected Carbon

- The rate of oxidation increases as temperature increases
- Table shows time to reach 5% carbon mass weight loss for alkali metal contaminated carbon sample in still air
- Carbon brake manufacturers (Honeywell, Meggit, Messier-Bugatti-Dowty, UTC Aerospace Systems) have all agreed that a 10% carbon mass weight loss equals 50% loss of structural strength of the carbon disk

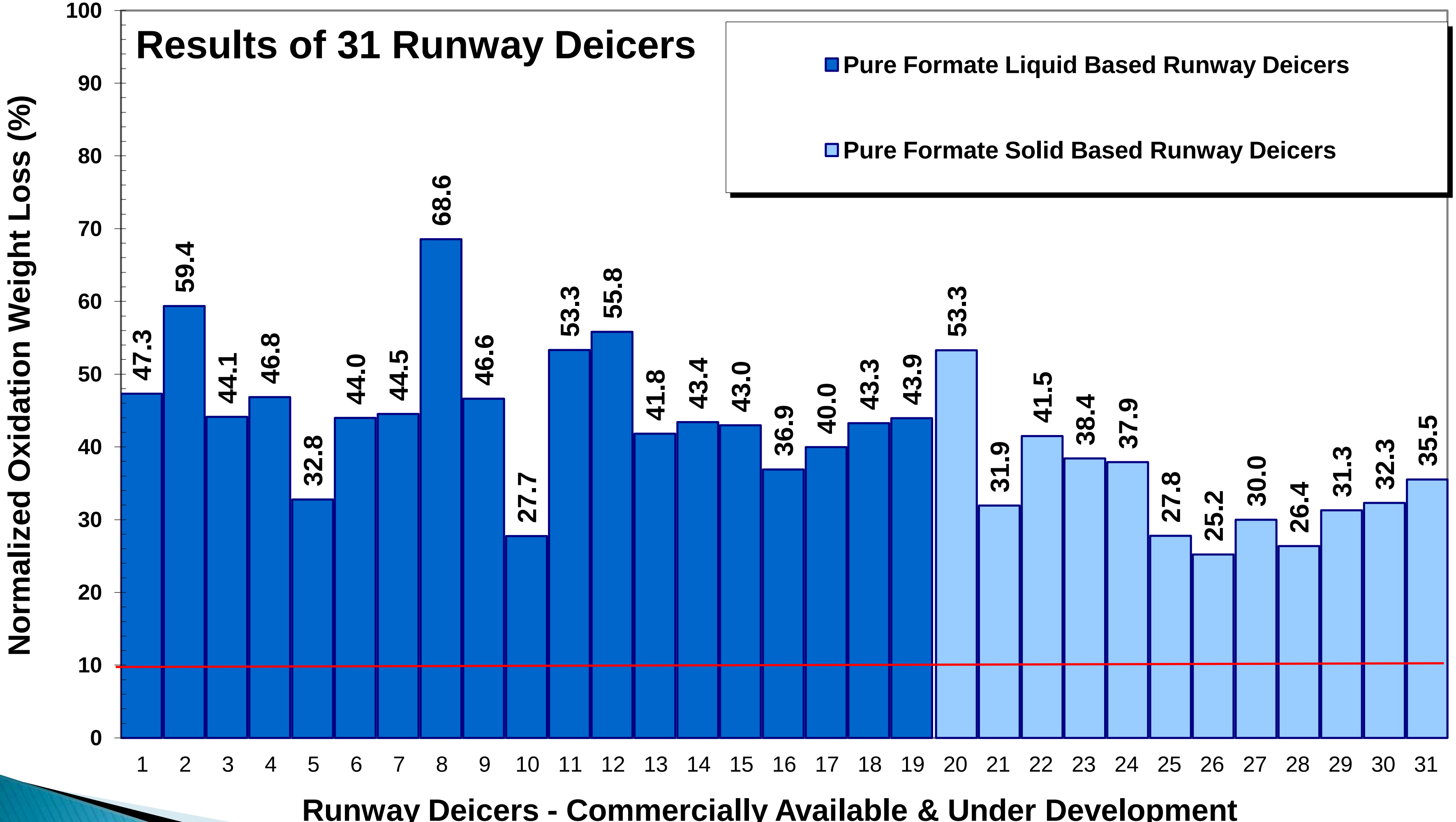
Temperature	Time to reach 5% weight loss
25ºC (77ºF)	Very long time
400ºC (752ºF)	33 days
500ºC (932ºF)	15 hours
600ºC (1,112ºF)	45 minutes
700ºC (1292ºF)	4 minutes

Table shows approximate times based on laboratory experience. Field experience is similar.

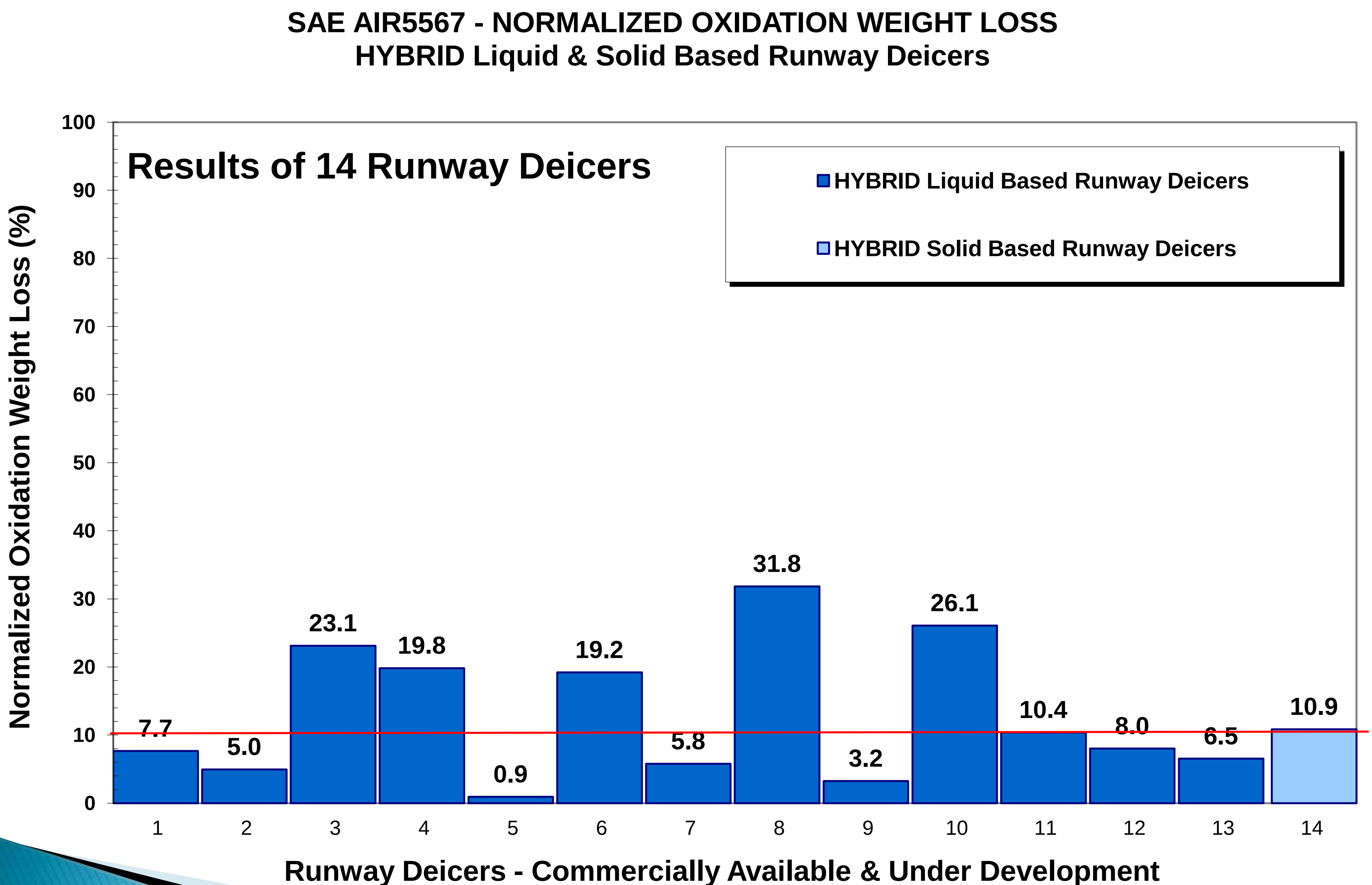


Test results provided by Anti-icing Materials International Laboratory, May 2013

SAE AIR5567 - NORMALIZED OXIDATION WEIGHT LOSS
Formate Only - Liquid & Solid Based Runway Deicers



Test results provided by Anti-icing Materials International Laboratory, May 2013



Test results provided by Anti-icing Materials International Laboratory, May 2013

Communications Sent to Affected Organizations on Catalytic Oxidation of Carbon Brakes Caused by Runway De-icers that Contain Alkali Metals

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An SAE International Group

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September 27, 2011

Ms. Katherine B. Preston
Director, Environmental Affairs
Airports Council International - North America
1775 K Street NW, Suite 500
Washington, DC 20006

Mr. Christopher J. Oswald
Vice President, Safety and Technical Operations
Airports Council International – North America
1775 K Street NW, Suite 500
Washington, DC 20006

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

Dear Ms. Preston and Mr. Oswald,

The intent of this letter is to advise Airport and Airline representatives of a recent revision to AMS1431 and AMS1435, the two SAE Aerospace Material Specifications that require testing of deicing and anti-icing solid and fluid runway and taxiway de-icers. Both specifications are referenced in FAA AC 150/5200-30A as approved airside chemical specifications, (http://ntl.bts.gov/lib/000/400/434/5200-30a.pdf).

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December 20, 2011

Mr. Raymond Elgy
Chair, Group of Aerodrome Safety Regulators
Head of Licensing & Training Standards
UK Civil Aviation Authority
Aviation House
Gatwick Airport South
West Sussex RH6 0YR
United Kingdom

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

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September 27, 2011

Mr. Paul McGraw
Director, Airport Development
Air Transport Association
1301 Pennsylvania Avenue, NW Suite 1100
Washington, DC 20004-1707

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

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September 27, 2011

Mr. James Freeman
Director of Regulatory Affairs
American Association of Airports Executives
601 Madison Street
Suite 400
Alexandria, VA 22314

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

Communications Sent to Affected Organizations on Catalytic Oxidation of Carbon Brakes Caused by Runway De-icers that Contain Alkali Metals (continued)

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December 20, 2011

Mr. Benoît Mars
Environmental Officer
ACE/ENV - Subdivision ESDD
Service technique de l'Aviation civile
9 av. du Dr Maurice Grynfogel
BP 53735 - 31037 Toulouse Cedex 1
France

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

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December 20, 2011

Mr. Philipp Ahrens
Safety Manager
Airports Council International Europe
6 Square de Meeûs
1000 Brussels
Belgium

Subject: Notice of Changes to SAE Runway De-Icer Specifications AMS1431 and AMS1435

IATA

30, 2012

World
3ox 302
Rue du Square Victoria
ntreal, Quebec H4Z 1G8
ada

Attention: Mr. David Gamper, Director Safety, Technical and Administration

Subject: Catalytic Oxidation of Carbon Brakes due to Exposure to Alkali Metal Runway and Taxiway De-icers

Dear David,

Airframe manufacturers, such as Airbus and Boeing, began using carbon brakes on their airplanes in the late 1980s. Alkali metal (mainly sodium and potassium) de-icers were introduced in the mid-1990s (likely to replace urea and glycol-based runway de-icers due to environmental reasons) thereafter airline operators of carbon brake equipped airplanes began experiencing structural damage (soft carbon, fractured carbon disks) to their carbon brakes. The source of the damage to the carbon brakes was traced to the alkali metal de-icers. It has since been found that no material compatibility testing was done to determine the effects the alkali metal de-icers would have on airplanes, airport infrastructure (ground support equipment, runway and taxiway lights, or runway and taxiway surfaces) before the alkali metal de-icers were introduced for use.

Continuous Improvement on Carbon Anti-Oxidation Protection Systems by Brake Manufacturers

UTC Aerospace Systems

NEWSBRAKE July 2013

A NEWSLETTER FROM WHEELS & BRAKES

IN THIS ISSUE:

Industry-Leading Innovation Continues at Wheels & Brakes with our HTx® Carbon Disk Oxidation Protection System

UTC Aerospace Systems Wheels & Brakes has begun delivering 777-200LR/300ER and ERJ-145 carbon disks with a new oxidation protection system, referred to as HTx®. The HTx® oxidation protection system, developed over a ten-year period, represents a technological breakthrough in the field of carbon disk coatings. Significantly improved thermal and catalytic oxidation protection has been validated both in the laboratory and during a three-year in-service evaluation conducted on hundreds of carbon heat sinks.

Qualification of the HTx® protection system on 747-8 carbon disks is underway with first deliveries anticipated fourth quarter 2013. The HTx® system will be qualified and introduced on other carbon brake programs in the future.

For more information, please contact kyle.cable@utas.utc.com.

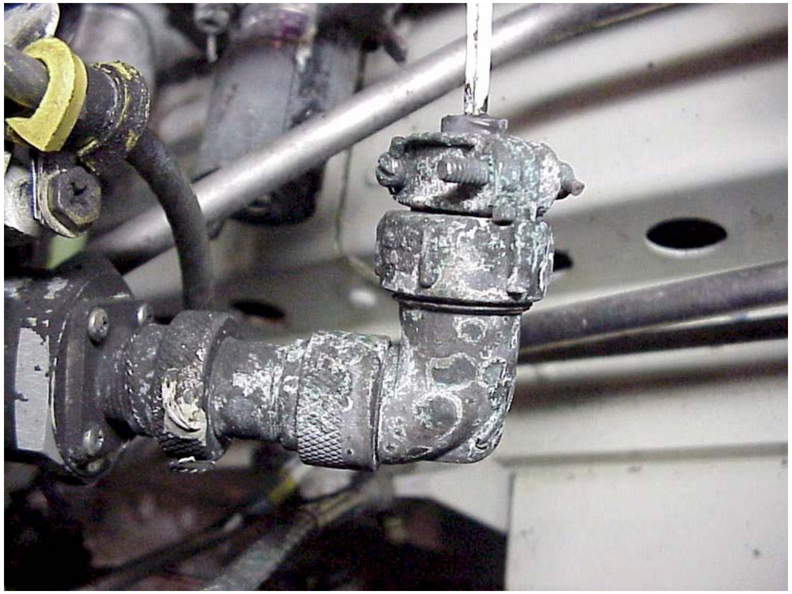
Other Types of Airplane Damage Caused by Alkali Metal Runway De-icers

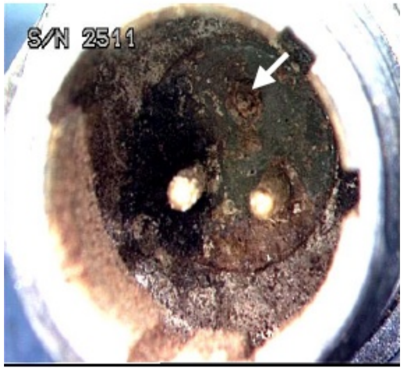
Cadmium Corrosion

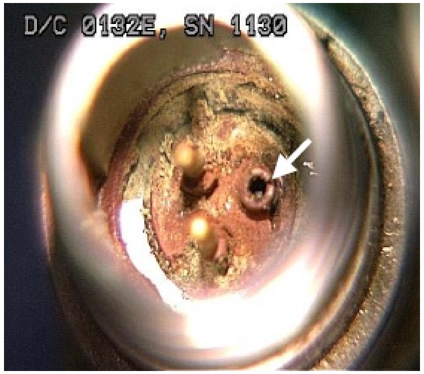
Provided by United Airlines

Other Types of Airplane Damage Caused by Alkali Metal Runway De-icers

Electrical







Provided by United Airlines

Best Path Forward

- Airframe Manufacturers continue to work with Carbon Brake Manufacturers to improve anti-oxidation coatings for carbon brakes

- Airlines continue to improve brake inspection techniques to find and remove catalytically oxidized carbon brakes from the airplane

- Airports:
    - Apply runway de-icers per manufactures recommended application rates
    - Use Total Organic Carbon meters to measure effluent instead of Biochemical Oxygen Demand (BOD5) or Chemical Oxygen Demand (COD)
    - If unable to use TOC measurement, build containment systems to capture and treat effluent

- Aviation Regulatory Agencies (EASA, FAA, Transport Canada, etc.) engage Environmental Regulatory Agencies to discuss changes to environmental legislation to maintain and improve aviation safety