

# Aerospace Industry Report 2007

## SAE G12 Working Group

### Aircraft Carbon Brake Oxidation

related to

### Runway/Pavement De-Icers (RDI)

# SAE International

## G-12F Aircraft Ground Deicing Fluids Subcommittee, Catalytic Oxidation Working Group

30 July 2007



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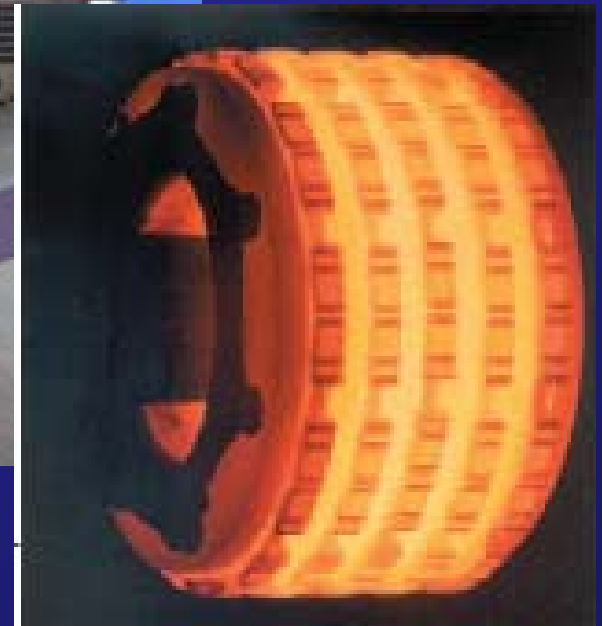
Rune Teigen

- Contents:
- Synopsis of reports of improvements to and for Carbon Brake Oxidation 2007, from:
  - Airlines
  - Regulatory Authorities & Airports
  - Brake Manufacturers
  - Airframe Manufacturers
  - RDI Manufacturers
  - Institutes & Specialists
  - G12F Working Group

## Mutual Inclusion

# AIRLINES

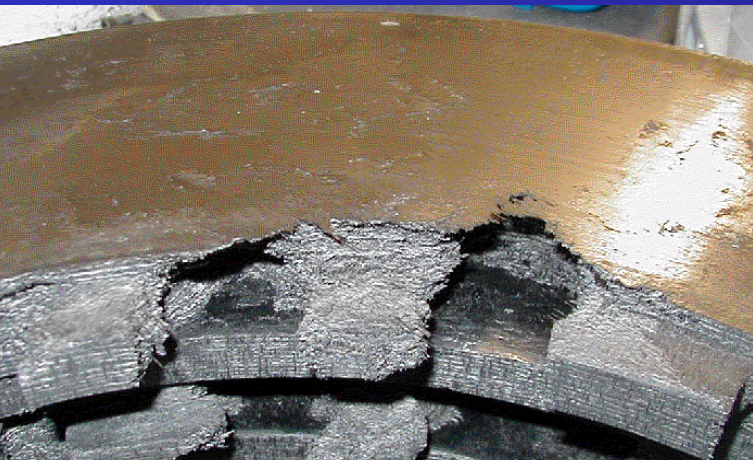
# Aircraft Brake Carbon Oxidation Report 2007



# Definition of Problem



US\$3Mil



## • Carbon Brake Degradation Cycle

What is actually happening!!!!

Aircraft lands:  
Brakes Heat 400 - 500°C:  
Carbon vaporises and leaves the brake disc:  
K permeates Brake Matrix and activates.

Aircraft takes off:  
U/C up,  
ice and slush melt:  
More RDI soaks into Brake Matrix where Carbon has vaporised



Aircraft taxis:  
RDI Spray from wheels:  
Soaks while standing

Aircraft taxis to take off:  
Brakes > 200°C:  
K Activation:  
Landing Gear carries ice and slush contamination.

Freezing also causes spalling of Carbon

# Constant Winter Cycle

## • Carbon Brake Degradation Cycle

- A carbon brake disc is obtained by using textile fibres and natural gas so that a heterogeneous carbon structure composed of solid carbon reinforced by fibres is obtained.
- The manufacturing process begins with long wicks of polyacrylonitrile fibres. After oxidation, untangling, woven into sheets then panels, these fibres are finally die-cut to form a black and rigid disc: the blank.
- Oxidation is the result of the effects of RDI exposure time, temperature and humidity: the carbon of the discs is slowly transformed into the gas carbon dioxide (CO<sub>2</sub>).



- Huge costs due to Departure Delays (\$20,000\*), Flight Cancellations (\$5,000\*), Brake Damage. **(\*2001 costs)**
- Yearly costs can be around US\$3 Mil.....
  - per airline! - for cost of inventory, spares & repair infrastructure!

Airframe Damage, additional Brake Material, Man-Hours on trouble-shooting etc.

- Repair, Engineering, Evaluation, Transportation etc.
- Difficult communication – can be hard to find the right person at an airport.

# Mutually Inclusive Relationships

## History

- Since 2000, airports, worldwide, have increasingly switched to Alkali Formate or Acetate RDI's. Following this more aircraft have suffered oxidation and corrosion from these Runway De-icers.
- Alkali in Acetate or Formate forms is the main Runway De-Icer (RDI).  
(Potassium; Sodium; Calcium; Magnesium mainly for roads)
- **June 2006 - Airbus and Boeing joint chair of SAE G12 Fluids – Carbon Oxidation Working Group. Global Letter to Airports, Authorities, Manufacturers.**

## Letter to airports 2006

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### General Letter to Airports, Authorities, Operators and Suppliers

#### Use of Runway De-Icers - Potential Emissions/Exhaustion/Corrosion on Aircraft

Since 1997 a serious problem of catalytic oxidation has been occurring on aircraft using carbon brakes.

The requirement for the use of carbon brakes originated in various weight-saving initiatives by aircraft manufacturers during which steel brakes were replaced by carbon brakes and new aircraft were delivered with carbon brakes.

In 1997 because of a concerted initiative by airports, to improve or control their environmental pollution, a change in the use of runway de-icing fluids took place in favour of more environmentally mild products.

This resulted in the use of petroleum based products containing petroleum fractions and/or additives. These chemicals rapidly attack the carbon in the brake and subsequently create a catalytic oxidation which accelerates the life and long-term efficiency of the brake disc/drum. There is therefore a safety issue involved, namely that of a brake failure, during high-speed aborted take-off and the possibility of a brake wheel fire from hydraulic fluid released during the failure.

In 2000 Transport Canada Civil Aviation issued Airworthiness Advisory Circular AC 3000-015 which describes the situation regarding the severity of Petroleum Fractions reaction and advising that airports should not use it. At the time the circular was printed towards electrical corrosion and followed a Boeing Advisory from 2000. FAA also had issued a similar advisory at around the same time.

Since then it appears that Petroleum also attack carbon and Petroleum Additives also adds to the problem. Worst case for carbon is Petroleum, second worst is Aviation.

SAE G12F among other industry working groups have been working for some time to try and reduce these effects from runway de-icers used by airports, which not only reduce aircraft safety but also compromise engine performance, cost of ownership and of course, eventually passenger costs, in fact it is becoming apparent that perhaps hundreds of millions of dollars of industry and/or revenue have been lost over the last ten years on this particular issue. Airports, however, are also experiencing costs related to the use of these fluids, we understand.

During winter, snowplough activity leaves fairly large amounts of fluid and slush on runways because snowplough drivers lower the plough blade to within half an inch (15 mm) of the runway surface, leaving the rest left to be dealt with by the runway de-icing fluids, even though some airports use a brown wax to follow the plough and sweep the slush, there will still be heavy elements of spray from white salt and further precipitation just adds to the problem.

Unfortunately this causes a very wet, fluid (petroleum) impregnated runway surface. The fluid is carried over and under the aircraft landing and taking off, where it causes various types of corrosion.

On aircraft during take-off and landing roll, the spray is often taken onto the undercarriage, particularly the centre parts, where it builds into fairly solid ice because of the reduction of chemical action of the de-icer fluid.

When the aircraft takes off again, the undercarriage legs/wheels are pulled up into the undercarriage bay. At this point the ice on the undercarriage rolls and runs down onto the brake pads and contaminates the carbon disks. This fluid comprises water and petroleum-fraction and/or additives, perhaps both in aspects do not all use the same de-icing fluid.

In the more wet runway aircraft have the additional issues of Cathodic corrosion, aluminium corrosion, corrosion in landing gear joints, and electrical wire bundle degradation, also caused or accelerated by the same fluids, which, again, is a further unaccounted for expense.

In addition, there is the common cost associated with premature and severe OIE (operational corrosion inhibited) on the runway and ramp fluids applied by the airports. These runway fluids are now being found to adversely affect anti-icing fluid applied to aircraft and also to promote the formation of anti-icing fluid run-off in aerodynamically quiet areas of the aircraft.

As an immediate short-term goal, the co-chair party of the SAE G12F Catalytic Oxidation Working Group is now approaching all Airports, Airlines and Authorities, De-icing Fluid Manufacturers, and Carbon Brake Manufacturers, to discuss what can be done, to the mutual benefit of all, perhaps by using these fluids, which, as noted, are causing less corrosion in all 'wax', de-icing other fluids - all solutions are welcomed.

Airbus and Boeing believe that, because the issue is wide and varied and the common denominator in every country's problem appears to be the use of one type of material having an effect on many materials that an industry working group has the best way to begin to promote the discussion. We are therefore requesting a response from all parties with regard to an appropriate time and venue for this meeting and more commitment in helping to fund solutions to the issue. With regard to a venue, my expectation will be to provide the use of it facilities would also be appreciated.

*Michael Arrigo* *Alan Williams*  
Michael Arrigo Alan Williams

## Letter to manufacturers 2006

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General Letter to Airports, Authorities, Operators and Suppliers

Use of Runway De-Icers - Potential Emissions/Exhaustion/Corrosion on Aircraft

Dear Challenge:

It has come to the attention of the manufacturer that carbon brake manufacturers and airports during several manufacturing spans in for landing and parking the appropriate in their respective products in carbon from others addressing the issue in the SAE G12F Forum.

The carbon brake manufacturers are trying to develop anti-oxidation coating systems to protect their carbon brake against various reactions due to the exposure to petroleum based and petroleum based fuels that are contained in most currently used runway de-icing materials, while the runway de-icing manufacturers are trying to develop de-icing fluid with less environmentally mild environmental regulations.

By now you should have received the Letter to Airports touching the issue of catalytic oxidation of carbon brake resulting from exposure to runway de-icing containing petroleum based and petroleum based fuels that are contained in most currently used runway de-icing materials which have less contribution or, in general, to modify all runway de-icing materials to the lowest possible oxidation and galvanic corrosion protection possible.

We are writing to you to request that the carbon brake manufacturers address the de-icing material manufacturers work together to discuss and understand the impact of catalytic oxidation of carbon brake and what can be done to address the problem between the

two parties in order to reduce, or better yet, to eliminate catalytic oxidation of carbon brakes.

We, the Co-Chairmen of the SAE G12F Catalytic Oxidation Working Group, possibly with the help of the SAE A-SA, Whistle Blower and Solid Corrosion Subcommittees, would be happy to facilitate this proposed cooperation, perhaps through a series of teleconferences and email exchanges of information, as a start.

Runway de-icing material manufacturer Cryotech has already indicated a willingness to join this activity, and we sincerely hope that all other parties involved will be willing to participate as well. Certainly any work such as this will benefit the changes expected in the AMS1818 and AMS1815 Specifications, and will benefit the industry as a whole.

*Michael Arrigo* *Ed Dwyer* *Alan Williams*  
Michael Arrigo Ed Dwyer Alan Williams

- **So, why not move back to Steel brakes?**

**Carbon = Higher Braking Efficiency  
= Weight = Fuel Performance**

**Steel = Less efficient = Heavier brakes for  
same braking. Larger actuators, increased  
design 'space' profiles.**

**Also possibly Larger Brakes thus Larger Wheels**

REGULATORY  
AUTHORITIES,  
AIRPORTS;  
ENVIRONMENTAL

# **Why Alkali Formates & Acetates?**

**Chemical Oxygen Demand      COD**

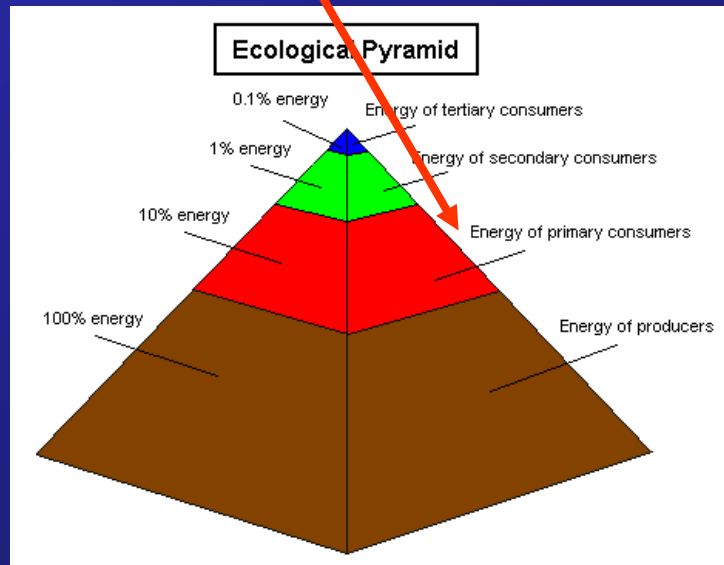
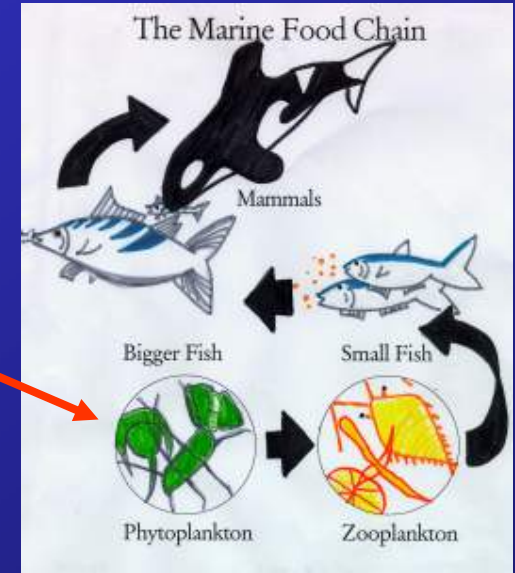
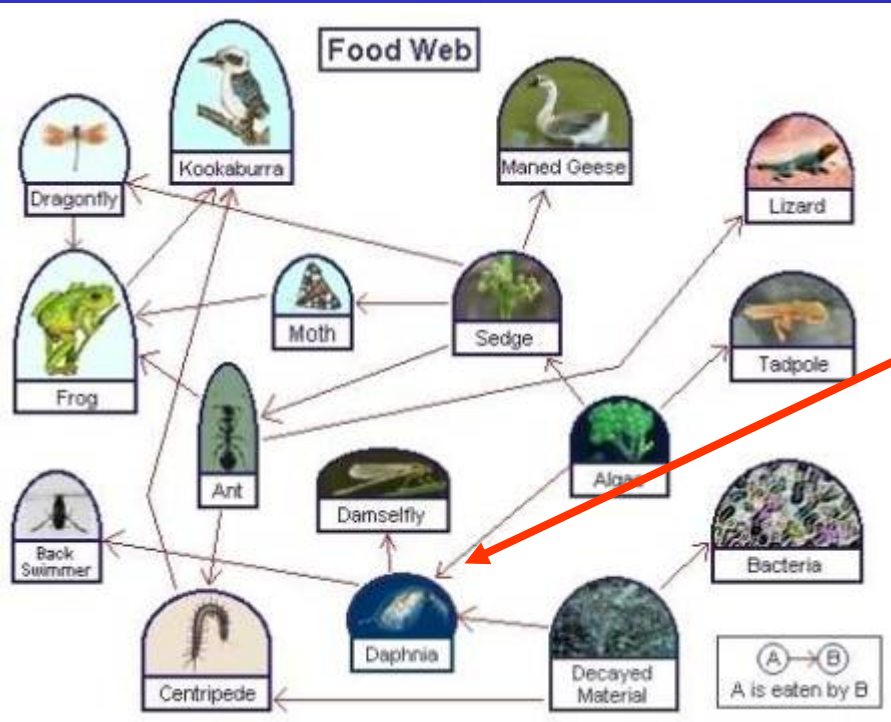
**Biochemical Oxygen Demand    BOD**

**Runway Friction**

**Better Temp Range than Urea/Glycol**

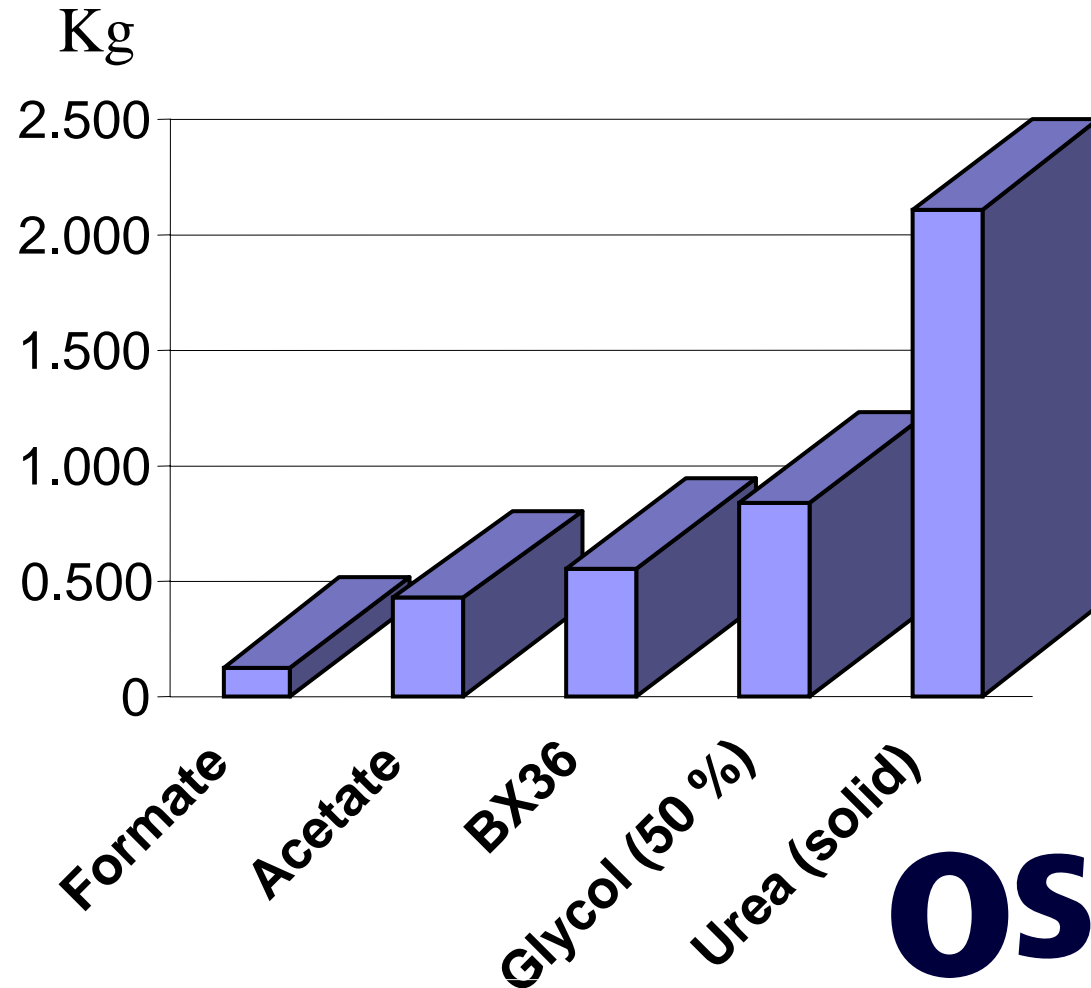
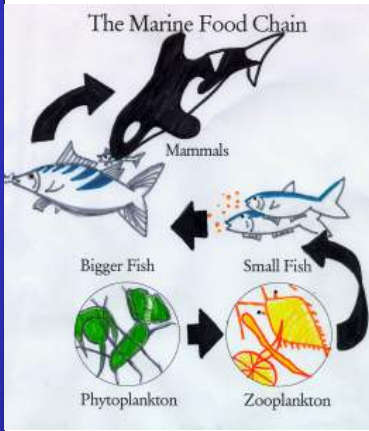
# Aircraft Brake Carbon Oxidation Report 2007

**COD**  
**BOD**



## Environmental impact caused by runway deicers

**COD**  
in kg of  $O_2$   
per m<sup>3</sup> or ton  
of RDF

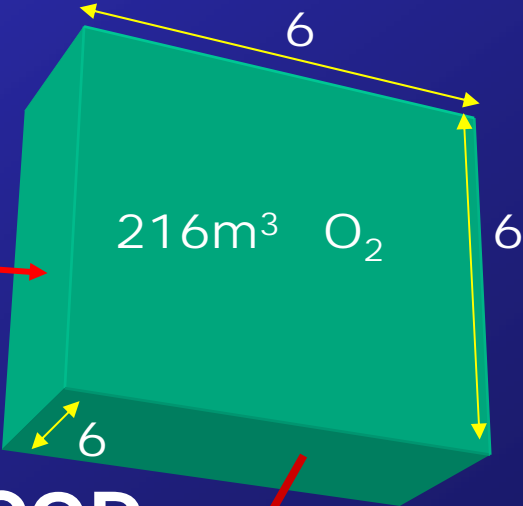


## De-icer comparison: Environmental impact: COD

### – Chemical oxygen demand (COD)

- per kg de-icer & for a real situation (10 ha, at  $-3^{\circ}\text{C}$ ):

	COD [g(O <sub>2</sub> ) / kg dry deicer]	COD in kg (for 10 ha surface)
Kfo	190	285
KOAc	653	1134
Urea	2133	5365



- **Kfo and KOAc have a much lower COD:**
  - ⇒ less contamination of rivers through organic carbon
  - ⇒ less oxygen depletion

Oxygen in water = 10g/m<sup>3</sup>  
285 kg = 285,000g O<sup>2</sup> / 10 = 28,500 m<sup>3</sup>  
Cube of O<sup>2</sup>/water approx 30 m sides

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## De-icer comparison:

### Environmental impact: nitrate generation

- **Nitrate equivalent:**

- **Generation of nitrates in wastewater**
  - per kg deicer
  - for a concrete case (10 ha, at  $-3^{\circ}\text{C}$ ):

Deicer	$\text{NO}_3$ [g( $\text{NO}_3$ ) / kg deicer]	$\text{NO}_3$ in kg (ex: 10 ha surface)
Kfo	0	0
KOAc	0	0
Urea	2067	5199

- **Urea leads to formation of ammonia, which is further oxidized to nitrate.**
- **1 kg urea consumes as much oxygen as available in  $340 \text{ m}^3$  water saturated with air.**  
**( $2,100 \text{ m}^3$  if  $\text{O}^2 = 10\text{g}/\text{m}^3$ )**

# Environmental

- From the previous slides it can be seen that the environmental case is very compelling.
- European airports environmental requirements are written in such a way that would make other known deicing fluids than formates unusable.
- However, they could accept any deicer with a low CO rate, as long as the environmental impact is fairly equal or better than, for example, formates.
- US position probably more uncertain.
- **These materials are effective and apparently here to stay. More research is required for Oxidation Inhibitors.**

Modify Fluids if possible or improve  
Collection systems?

# Runway Efficiency

- Alkali Formates and Acetates also appear to provide the best Runway efficiency – Friction coefficients etc.
- Lower temperatures.

Cooperate

## De-icer Cost-Effectiveness

- Copenhagen Airport Report:
  - Anti-Icing versus De-Icing
    - Anti-Icing is more cost-effective because it uses less RDF for the same effect.

Cooperate

# Airport & Personnel Damage

- European Airports Report:
  - Corrosion damage to vehicles and equipment such as runway lights.  
(ACRP Synthesis ongoing on this.)
  - Staff protection problems – skin burns.  
(Scandinavian countries have controlled both these issues by upgrading vehicles and by provision of Health Care/Health and Safety Regs.  
Some other countries don't have these. Extra Cost.)

More to do

# Brake Manufacturers

# Brake Manufacturer Reports

- Synopsis of five Mfr. Reports
- ABSC
- Dunlop
- Goodrich
- Honeywell
- Messier-Bugatti

## Brake Manufacturer Reports

- **Honeywell - BPX- 44: Oxidation Reduction**
- **Messier-Bugatti - Anoxy 66: Ox Reduction & production of Generic AO Coating - SAE**
- **ABSC – 2 Coat system P7 : Good reduction**
- **Goodrich – Good AO System/Reduction**
- **Dunlop – AO DMS 745/692: D-Ox™: D-Ox 100™**



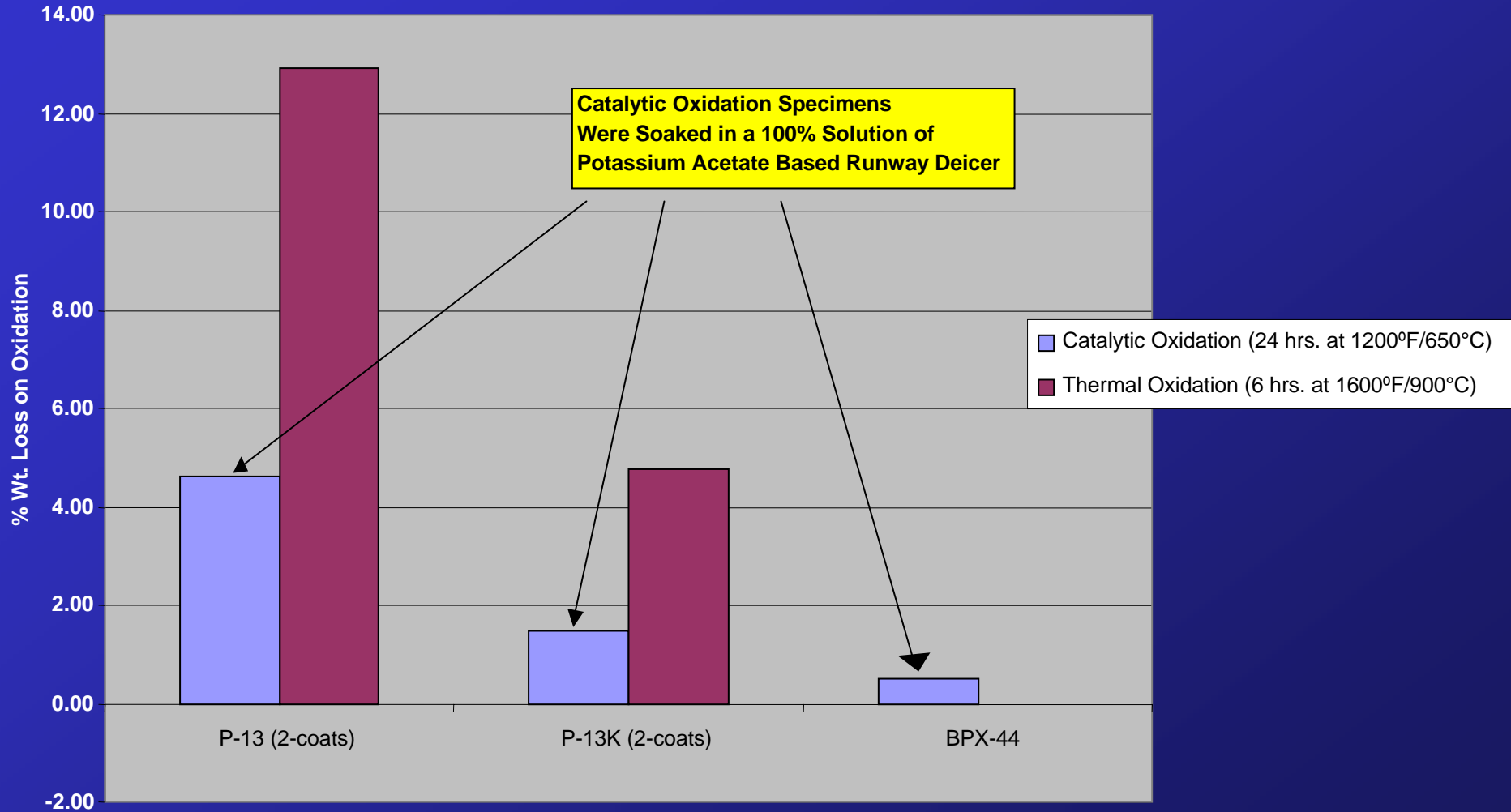
- **Brake & Fluid Mfr Joint efforts**
- **Honeywell/Cryotech**
- **M-B/Clariant/BASF**

Communication opening and improving  
In the Industry. **Much Progress**



# Aircraft Brake Carbon Oxidation Report 2007

## Typical Performance of Various Anti-oxidant Systems CARBENIX® 2400 Brake Material



# Brake Manufacturer Reports

- **Better definition on Time, Geographical and Fleet Location – clarifies where the worst problems are in Global terms. Improved Management.**
- **Brake Mfrs providing suggestions to Airframers on Design improvements. (Review for future designs).**
- **Brake Mfr visits to Airports**

**Inclusive – Not closed**

# Oxidation Testing



- Aggressive temperature testing to simulate application

# Aircraft Brake Carbon Oxidation Report 2007



No Picture

T-22151 El Brake RTO.mpg

# FLUID MANUFACTURERS

# Fluid Manufacturer Reports

- Cryotech reports that the new BX36 was trialled at 2 airports over winter 2006/7 with good results and lower BOD/COD levels than Urea or Glycol (still not down to Kac or Kfor).
- Battelle 'Ice-Clear' indicates a lowered BOD/COD and improved oxidation protection.
- Finnish Betaine (trimethyl glycine) RDFs. Produced from Sugar Beet molasses (est. \$12-15 per gal) AMS 1435 qualified – non-corrosive – favourable asphalt & bitumen test. More viscous, performance/environmental issues not known. Melting times could be slower – maybe better for ant-icing.
- Various reports of alternatives based on Glycerine from Biodiesel
  - No aerospace information yet.

# Willing Cooperation

# AIRCRAFT MANUFACTURERS

# **Airbus/Boeing Joint Report**

## International

- Airbus/Boeing cooperation at SAE:
  - Working with all parties & peer groups.
  - Coordinating solutions.
  - Facilitating communication.

## 'Home'

- Maintenance and Engineering effort to support customers.
- Supplier communication.
- System review.
- Future design lessons.

## Cooperation

## Comment:

- While there is Carbon there will always be Thermal Oxidation – but brake life expectancy is known.
- Alkali RDFs accelerate the rate of thermal oxidation in brakes to an unacceptable and costly level.

## Pragmatic Approach

# Institutes & Specialists

# Specialist Reports

- Southern Illinois University
  - Doctor Peter Filip
- BASF
  - Doctor Xavier Sava
- Molecular Knowledge Systems
  - Dr K. Joback

## Specialist Reports

- Research advice on protection systems and possible/probable avenues of research
- Impact of deicers on Oxidation Protective System:
  - Investigation of the mechanism
  - Inclusion of inhibitors in the anti-oxidation coating formulation.
  - Investigation into Environmentally Friendly Oxidation Inhibitors – what is available?

Molecular Knowledge Sys - Offer of research information already performed on Environmentally Friendly Oxidation Inhibitors.

- Also ACRP Project A11-03 RDF Damage to US EPA (Airport Cooperative Research Programme) - (Environmental Protection Agency)

## Proposals for further action

Review for:

- Inhibition of Catalytic Oxidation of Carbon:
  - Addition of corrosion inhibitors to the deicer for capture of potassium cations:
  - Potent. inhibitors: aluminum-salts, phosphates, silicate (at 500 and 5000 ppm)
    - ⇒ Issues:
      - activity in catalytic amount (carbon corrosion # metal corrosion)
      - performance & ecological impact
    - Inclusion of these corrosion inhibitors into the carbon matrix structure
      - ⇒ Efficiency comparison
- Impact of deicers on Oxidation Protective System:
  - Investigation of the mechanism
  - inclusion of inhibitors in the anti-oxidation coating formulation

# G12 Working Group

- Way Forward?
- Problem largely caused by the removal of Oxidation Inhibitors (OI) under the Environmental mandate.
- Improved Anti-Oxidation (AO) coatings being produced by brake manufacturers.
- SAE A5 Carbon Oxidation Test for addition to Specs SAE AMS 1431 & 1435.
  - Target: end 2007.

# Reduce Fluid Effects

- Next Steps
  - Research for Environmentally friendly OIs, which can be included in RDF and will not raise COD/BOD levels.
  - Discussion with all authorities how to use these.
  - Assist with environmental and regulatory dialogue towards a:
    - Technical, economic, balanced, reasonable outcome.

## Inclusive – Exploration

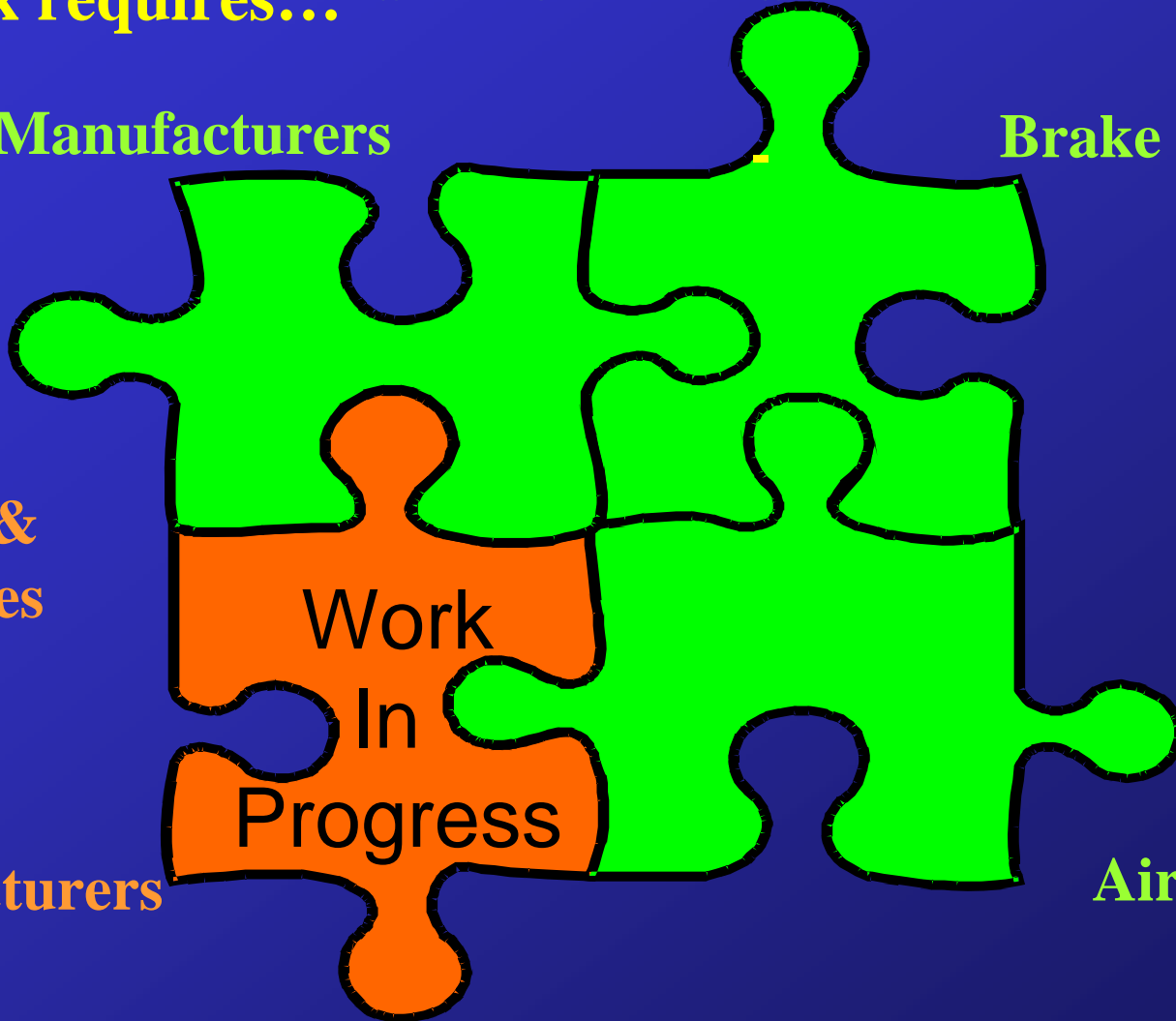
## Conclusion

# Aircraft Brake Carbon Oxidation Report 2007

**Final Fix requires... SAE G 12F & SAE A-5A**

**Aircraft Manufacturers**

**Brake Manufacturers**



**Work  
In  
Progress**

**Airports &  
Authorities**

**Fluid  
Manufacturers**

**Aviation Authorities**

**Airlines**