EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Water/Ice in Fuel research Activities

R.Deletain

Water/Ice in Fuel

B777 G-YMMM

Registered Owner and Operator	British Airways
Aircraft Type Boeing	777-236ER
Serial No	30314
Nationality	British
Registration	G-YMMM
Place of Accident	London Heathrow Airport
Date and Time	17 January 2008 at 1242 hrs

Water/Ice in Fuel

- Dual engine loss of power within 7s
- Probable Causal factors

  - Accreted ice from within the fuel system released, causing a restriction to the engine fuel flow at the face of the FOHE, on both of the engines.

Figure 52

Ice collected on the face of the FOHE

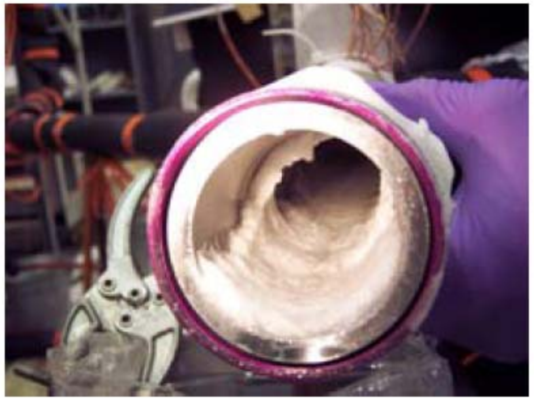


Figure 53

Ice in the flexible hose located at the rear of the strut

Water/Ice in Fuel

- 3 AAIB Safety Recommendations related to water/ice in fuel research
  - 2009-030 Review use of additives
  - 2009-031 Conduct research on ice formation
  - 2009-032 Conduct research on ice accumulation and release

> **Safety Recommendation 2009-030**
>
> It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency conduct a study into the feasibility of expanding the use of anti-ice additives in aviation turbine fuel on civil aircraft.

> **Safety Recommendation 2009-031**
>
> It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency jointly conduct research into ice formation in aviation turbine fuels.

> **Safety Recommendation 2009-032**
>
> It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency jointly conduct research into ice accumulation and subsequent release mechanisms within aircraft and engine fuel systems.

2009-030 Review use of additives

- "FUAD" (fuel anti-ice additives for civil aviation)
  - Literature review
  - Data collection on use of anti-ice additives
  - Major driver investigation :
    - airworthiness aspects: additives performance, engine / aircraft fuel system impact, material compatibility, maintenance impacts,...
    - distribution : transport, storage, quality control and refuelling procedures,..
    - deployment and economical factors: potential demand, changes to existing infrastructures, analyse cost-breakdown (production, delivery)

→ Feasibility analysis for commercial transport operations

2009-030 Review use of additives

- Call for Tender EASA.E.2.2011.NP.04 "FUAD" (fuel anti-ice additives for civil aviation) - sent on 28.10.2011
- 2 offers received
- Cranfield University selected
- Kick-Off: 01/02/2012
- Interim reports received 04/2012 – 07/2012
- Contact with aviation industry initiated – comments to be captured:
  - Fuel/refuelling companies
  - Airport facilities
  - Airlines.
- Final report delivery – likely to be delayed to end of 2012 / begining of 2013

2009-031 Conduct research on ice formation

- Call for Tender EASA.2010.OP.08 “WAFCOLT” (water in aviation fuel under cold temperature conditions) - sent in May2010
- Objective:
  - Identify and review the existing data/reports concerning the presence of water and ice in aviation jet fuel
  - Define tests and test procedures in order to:
    - Characterise the formation of ice crystals and the influence of key parameters including water concentration, fuel temperature range and cooling rate, presence of contaminants such as Fatty Acid Methyl Ester (FAME)
    - Characterise the type and related mechanical properties of ice crystals in fuel
  - Collect a set of aviation fuel Jet A-1 and A samples representative of the different manufacturing standards existing worldwide
  - Perform the retained set of tests and analyse the results to derive recommendations for preventive actions as to ice formation in jet fuel.

2009-031 Conduct research on ice formation

- 4 offers received
- Airbus & Cranfield University selected
- Kick-Off: 17/01/2011
- Final report delivery date: March 2012

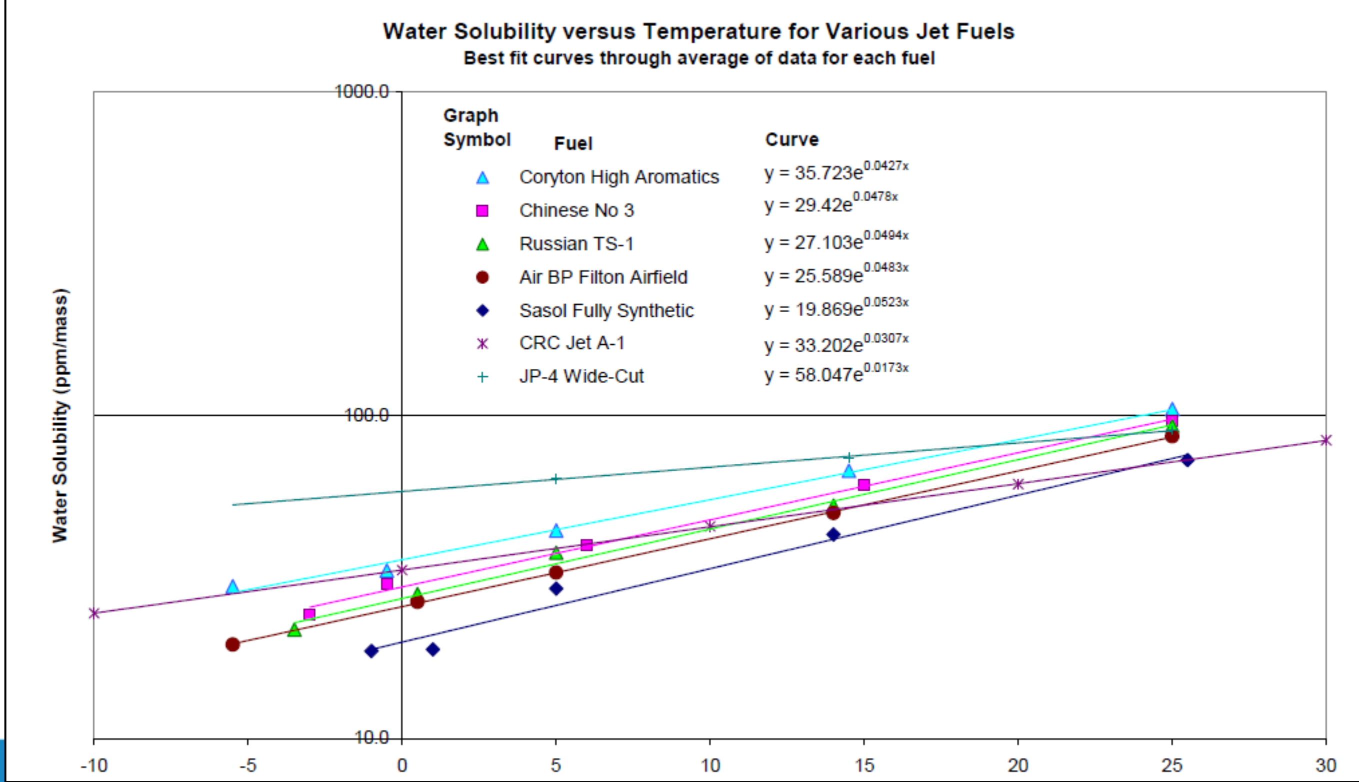
2009-031 Conduct research on ice formation

Fuel and Specification	Abbreviated Name	Provenance
Air BP Filton Airfield Jet A-1	Filton	Air BP UK Ltd
Chinese No 3	Chinese	PetroChina International (Hong Kong) Ltd
Coryton High Aromatics Jet A-1	Coryton	Coryton Advanced Fuels Ltd, UK
Russian TS-1 Aviation Kerosine	Russian	Blended by Coryton; tested/approved in Russia
Sasol Fully Synthetic Jet A-1	Sasol	Sasol, South Africa
JP-4 Wide-Cut Fuel	JP-4	Coryton Advanced Fuels Ltd, UK

Study of Ice Crystal Structure in Fuel

Study of Water Droplet/Ice Formation

Figure 1 Water Solubility Curves Using Averaged Water Content Data



2009-031 Conduct research on ice formation

- Visualisation of ice formation upon temperature cycling
  - Russian and Sasol tends to nucleate slightly smaller water droplets;
  - Droplet formation ranging from 18°C-10°C
  - Floating droplets below 5°C
  - Below -2°C large scale nucleation process starts

Plate 13 Coryton High Aromatics Jet A-1, on warming to -38°C, showing spherical droplets, a few of which appear to be 'cracked'

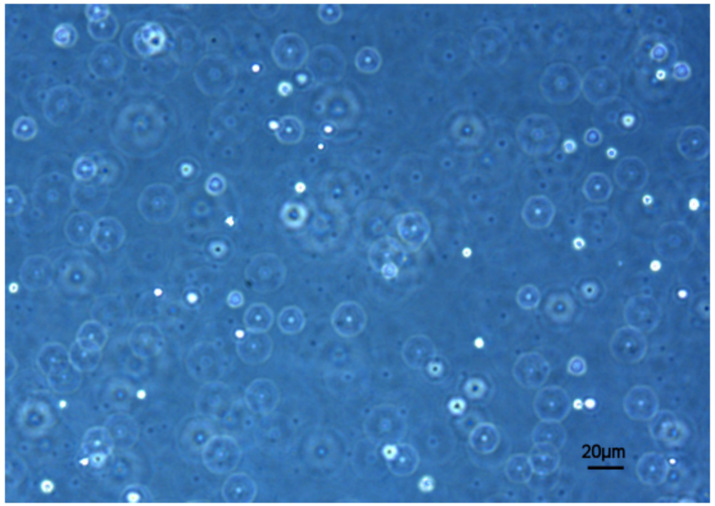
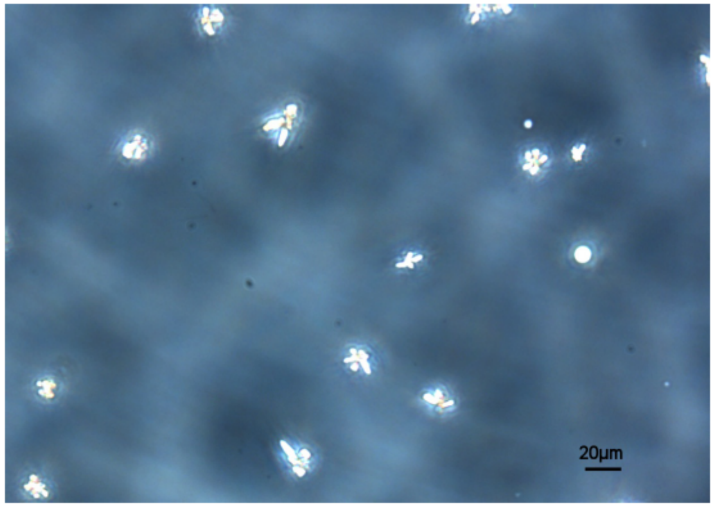


Plate 14 Air BP Filton Airfield Jet A-1, on warming -10°C, showing original crystal formations, but most microdroplets have redissolved



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Study of Ice Accretion

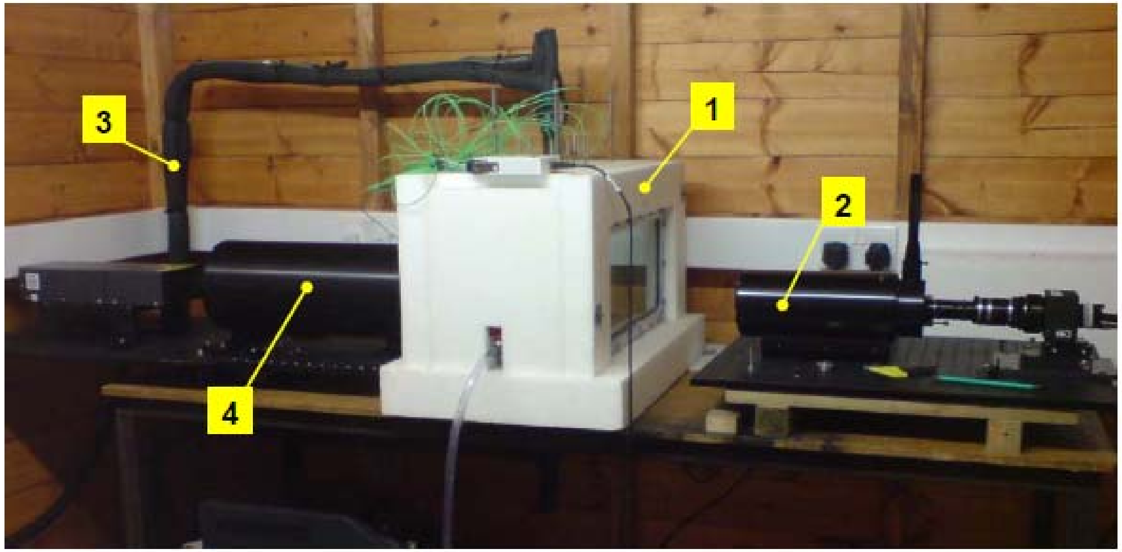
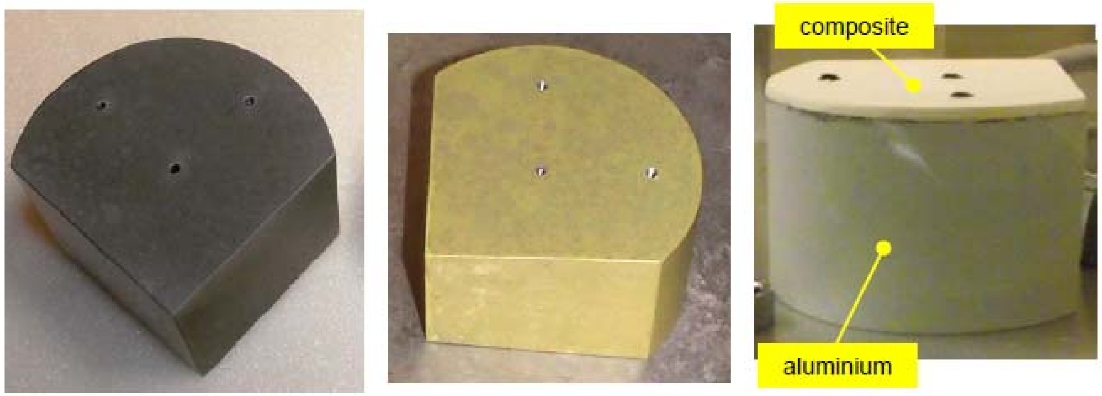


Figure 2 The simulated fuel tank experimental rig [8]. Key: 1 – simulated fuel tank; 2 – camera with long rang microscope lens; 3 – coolant supply tubing (with insulation); 4 – laser and diffuser.



(a) SB1 (Bare) (b) SB2 (Painted) (c) SB3 (Composite)

Figure 12 Specimen blocks. (a) Bare aluminium block; (b) Painted aluminium block and (c) Composite strips bonded on the top and one of the flat vertical faces of the baseline aluminium block.

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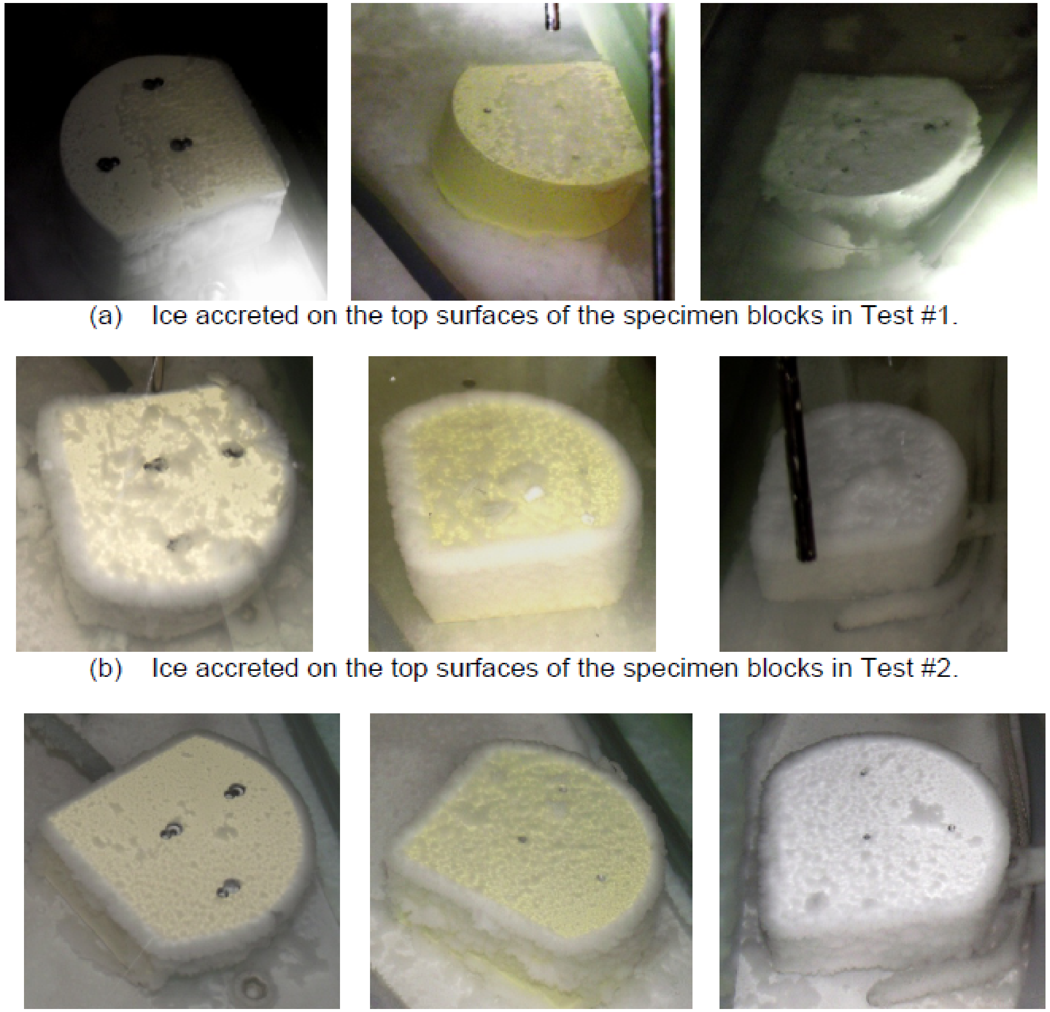
Fuel	Cooling Plate Temperature	
	-35°C	-55°C
Jet A-1 Merox treated	#1	-
Coryton High Aromatics Jet A-1	#2	#3
SASOL Fully Synthetic Jet A-1	#4	-



(a) Ice accreted on the top surfaces of the specimen blocks in Test #1.

(b) Ice accreted on the top surfaces of the specimen blocks in Test #2.

(c) Ice accreted on the top surfaces of the specimen blocks in Test #4.

Figure 18 **Ice accreted on top surfaces of the specimen blocks. (a) Test #1, (b) Test #2 and (c) Test #4. Left: SB3 (composite); Middle: SB2 (painted); Right: SB1 (bare).**

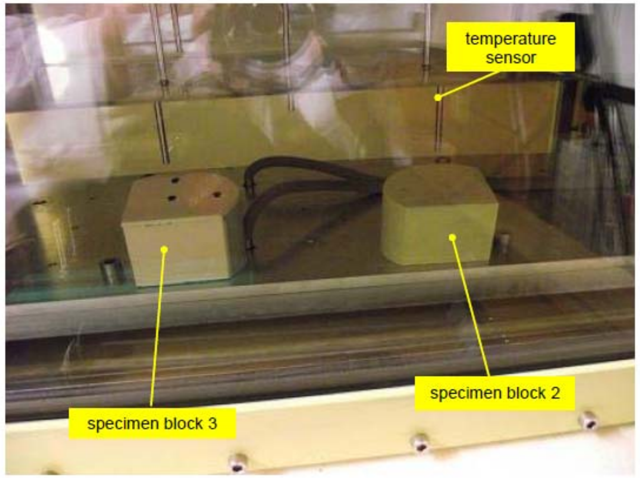


Figure 14 **Simulated fuel tank with specimen blocks sitting on the 'top' cooling plate lowered to the tank bottom.**

Table 2 **Temperatures at various locations in the simulated fuel tank in tests #1 to #4.**

Locations	Tests #1, #2 and #4		Test #3	
	Temperature, °C	Degree of subcooling relative to [a], °C	Temperature, °C	Degree of subcooling relative to [a], °C
Tank bottom	-24.2	-19.1	-47.1	-3.6
3 cm above the cooling plate, [a]	-5.1	0.0	-43.5	0.0
Top surface of SB1 (bare)	-17.3	-12.2	-46.2	-2.7
Top surface of SB2 (painted)	-13.7	-8.6	-45.0	-1.5
Top surface of SB3 (composite)	-10.0	-4.9	-43.7	-0.2
Room temperature	17.7	22.8	14.8	58.2

2009-031 Conduct research on ice formation

Study of Ice Accretion

- Bare aluminum : highest ice accretion rate, lowest for composite
- Fuel with higher aromatics = increased ice accretion
- Found ice very weak mechanically

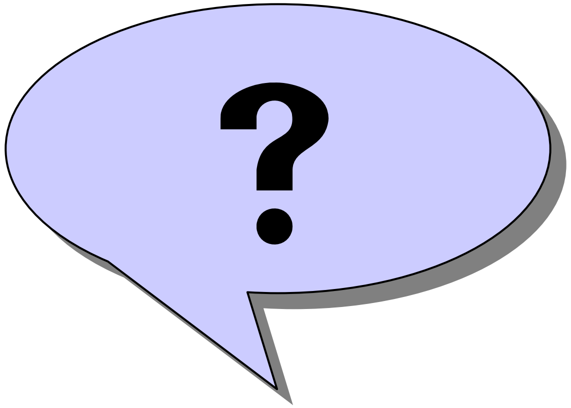
- Summary
  - Complex and wide range of possible activities in this research field. Small portion explored.
  - Quite an interesting range of fuels tested (Chinese, Russian,…).
  - Measurement of ice mechanical properties was a challenge.
  - Report available since Mar 2012.
  - To be commented and accepted by EASA
  - Final dissimination by end of 2012.
  - Seminar organisation 4Q2012 – 1Q2013 (TBC)

2009-032 Conduct research on ice accumulation and release

- Call for Tender EASA.2012.OP.14 "ICAR" (ice accretion and release in fuel systems) – 10/09/2012
- Investigate accumulation and shedding of ice in a representative turbine engine aircraft fuel system through tests.
- Scope:
  - Use of a fuel supply system test rig representative of large turbine engine aircraft (geometry,configuration of fuel pipes, fuel pumps, valves, filters and fuel/oil heat exchangers).
  - Operating conditions: shall reproduce the different flight conditions in cold atmosphere
  - Fuel flow and ice content: different scenarios for fuel supply to the engines and the injection of different types of ice crystals (e.g. soft and hard) or water shall be evaluated

2009-032 Conduct research on ice accumulation and release

- Deadline 29/10/2012
- Opening Session 08/11/2012
- Completion of tender Evaluation November 2012
- Signature of contract Decembre 2012
- Duration 12 months



Thank You For Your Attention