Insights into Jet Fuel Specifications

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Jet fuel experience

- Significant body of knowledge over 6 decades of jet engine propulsion
- Establish baselines or minimum requirements for properties of alternative fuels
- Lessons learned
- Unknowns - gaps in the specification process

‘Fit-for-purpose’ fuel

- In specifying requirements for Jet fuels, the main objective is to have a fuel ‘fit for purpose’
- Perform satisfactorily across the entire flight envelope
  - Wide range of temperatures and pressures
  - Extreme weather conditions

Factors affecting Jet Production

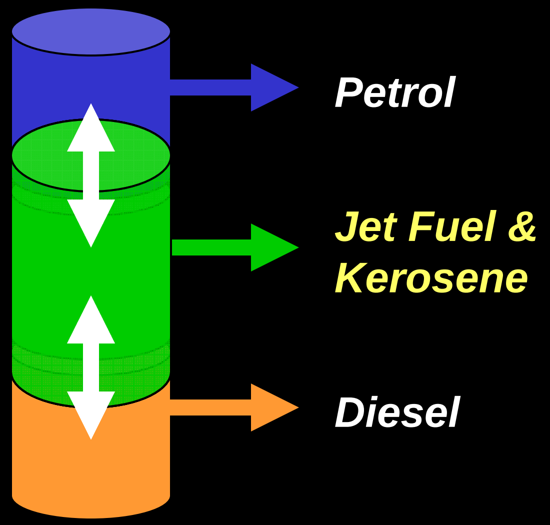
Jet is FRACTIONATED from Crude and then TREATED to remove impurities

Jet quality is determined by

a) Type of crude

b) Refinery processing

Jet availability and properties are influenced by the adjoining products: Gasoline and Diesel – High volume products



Functions of Specifications

- Safety is paramount in aviation
- Customer wants quality
- Defines minimum standard that is ‘fit for purpose’ – specified in terms of laboratory tests
- Defines “playing field” for refineries
- Provides mechanism to identify, measure and control properties

- ***Jet fuel - a commodity with limited scope for product differentiation***
  - ***Consistency in fuel quality supplied***
- ***Alternative fuels***
  - ***Many sources***
  - ***How tolerant are powerplants and airframes?***

Specifications

- American Society for Testing and Materials (ASTM)
- Aviation Fuel Committee, U.K – DEF STAN 91-91
- Russia, CIS and Parts of Eastern Europe – GOST Standard
- Other Countries issue own National Standards – nearly identical to ASTM or DEF STAN
- Differences exist on limits for certain parameters like freeze point, flash point, sulphur content and thermal stability
- Standardisation trend observed –some convergence

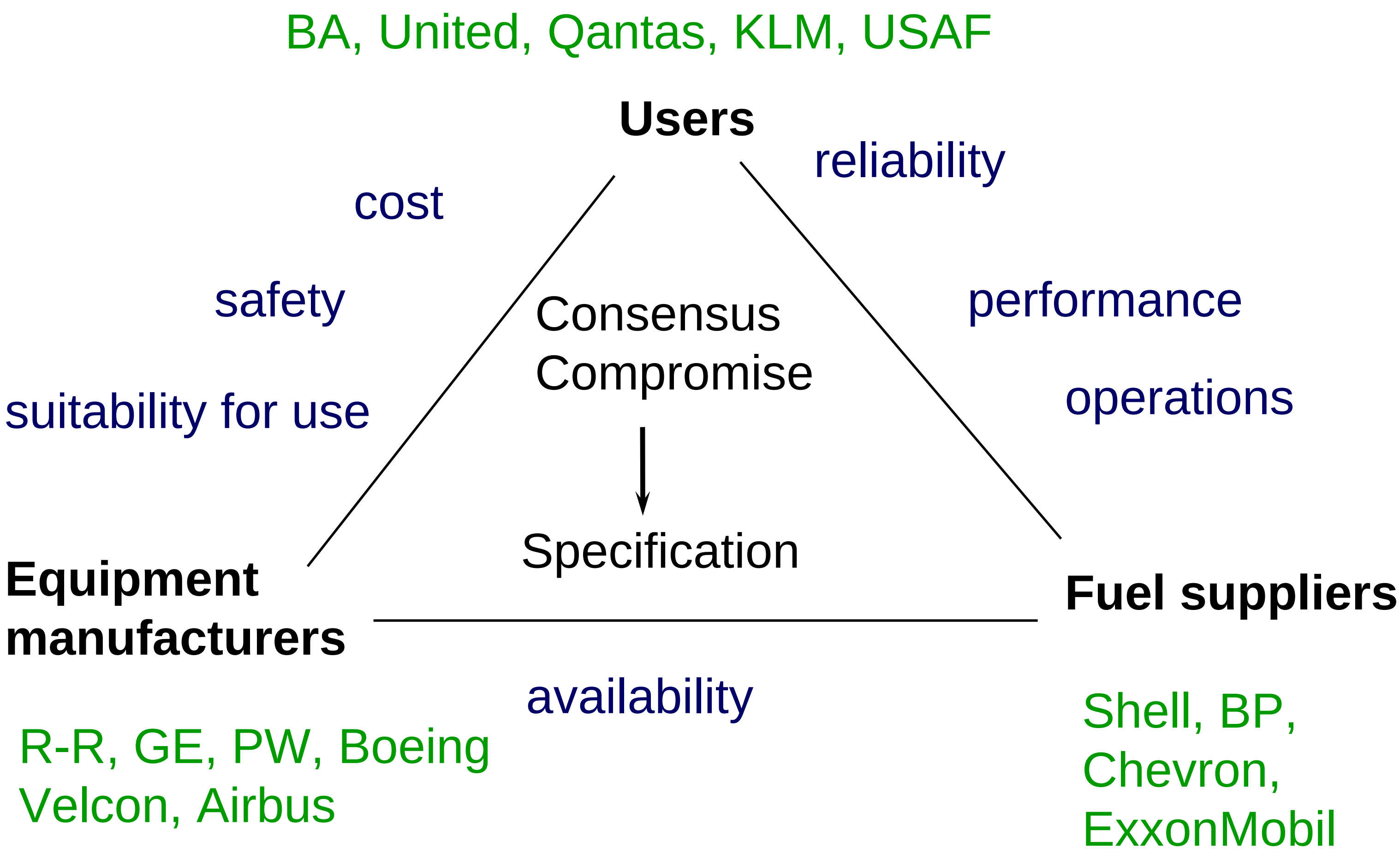
➢ ***ASTM vs DEF STAN?***

  ➢ ***Industry needs harmonisation!!!***

Key Fuel Parameters

- Energy content
- Pumpability (freezing point, viscosity,density)
- Thermal and Storage Stability
- Materials Compatibility
- Combustion & Emissions
- Fuel Handling
- Lubricity & Heat sink
- Additives
- Cost and availability

The Specification Process



Roles and Responsibilities

operate equipment according to manufacturer's requirements using certified fuels

Users

Equipment manufacturers

Fuel suppliers

produce equipment which operates on fuels meeting the specification

produce fuels which meet both the letter and spirit of the specification

Adequacy of Jet fuel specifications

- Suppliers were looking for a market to use the kerosene fraction
- Engine manufacturers successfully designed their engines around the basic kerosene product
- Performance based specifications led to
    - Physical and chemical properties developed to solve specific operating problems
    - Refinement of fuel dependent on experience gathered from aircraft operation in the field
    - Changes to specs were small to stay within the experience base

Operational parameters like engine efficiency: propulsion, fuel burn and emissions cannot be improved indefinitely without some fuel properties becoming limiting factors

➢ *Conventional Jet fuel at a crossroad wrt future generation engines – Opportunity for alternative fuels*

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Key parameters in Jet Specifications

Energy content

- Energy content or heating value of fuel determines engine thrust capability
- Impacts aircraft performance
  - Take-off thrust & aircraft range
- Specification min Jet A-1: 48MJ/kg
- Typical bio-diesel: 37.5 MJ/kg
- Some bio-fuels have better energy content

➢ ***Reduction in energy could significantly affect aircraft range***

Pumpability

- **Potential impact:** fuel starvation, spray pattern, combustion efficiency and low temperature starting
- Specifications properties concerned: Freeze point and viscosity
  - Freeze pt. max of -47 ºC for Jet A-1 and -40 ºC for Jet A
  - Low temp viscosity: max 8.0 cSt (mm2/sec) @ -20 ºC
- How will alternative fuels affect freeze point and viscosity?

➢ ***QinetiQ study: Bio-diesel blend tests 3% FAME show real pumpability concerns at low temperatures***

Thermal stability

- Stable fuels under all operating conditions
- Thermally stressed fuels
  - high by-pass ratio engines
  - Increase airframe and engine heat loads
  - Reduction in fuel consumption
- Sulphur, nitrogen compounds, trace metals and acids in fuels become unstable at high temps.
  - Insoluble products such as gums, lacquers, particulates and coke deposits
  - detrimental to fuel systems: flow restrictions, injector fouling and filter blockage

➢ ***SwRI finding: FAME may affect Thermal stability test (JFTOT) at 1% level***

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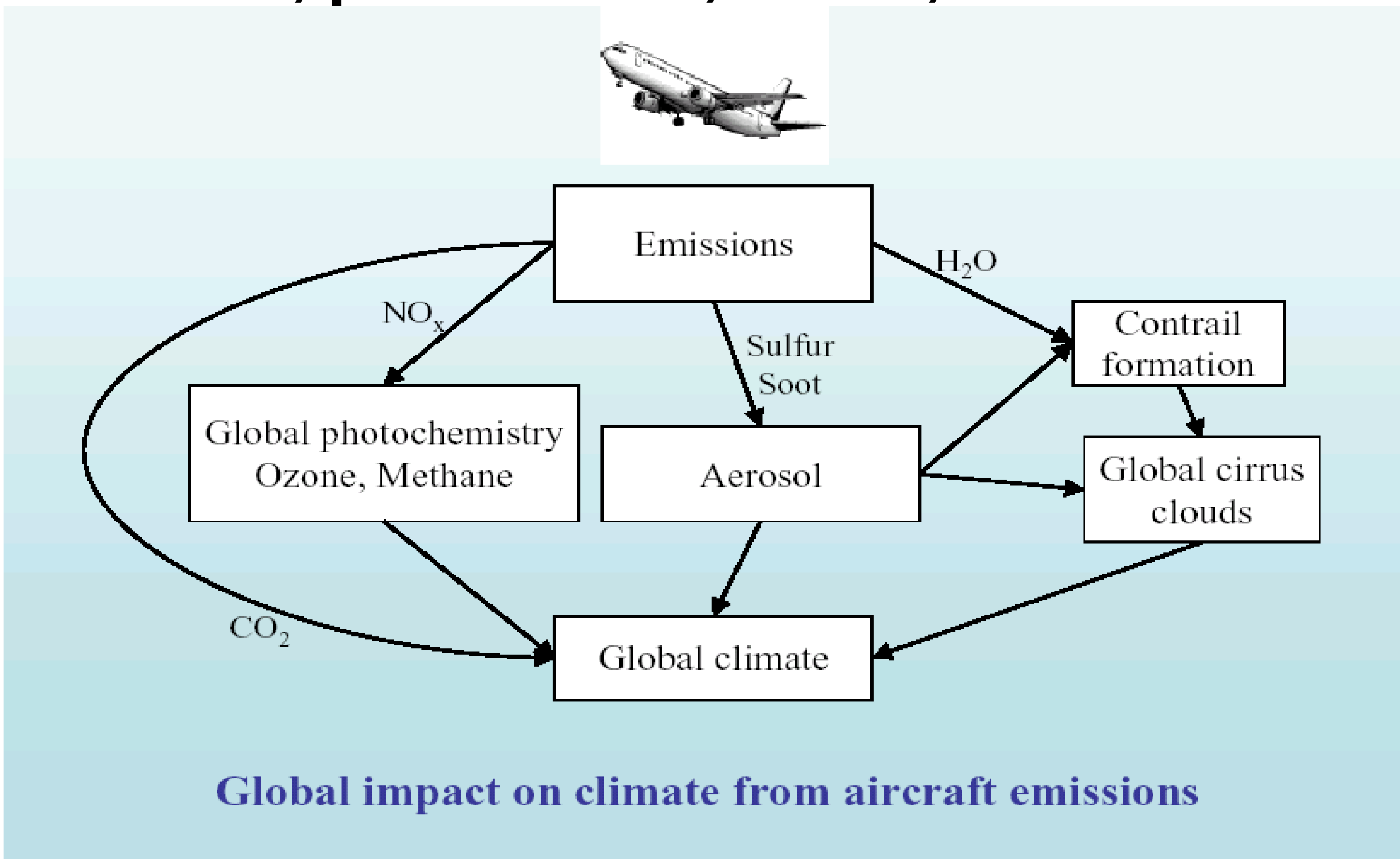
Combustion efficiency

- Gas turbine designs optimised for HC fuels
  - Distillation, smoke point and maximum aromatics limits are combustion control parameters in Jet specs.
- Depending on the sources of the new fuels
  - Synthetic Jet fuel - Improvement in some areas like no sulphur and lower particulate engine emissions vs Increased CO2 during manufacture
  - A hydrogen based fuel release more water vapour a GHG

Aviation impact on the environment : CO2, NOx, particulates, cirrus, contrails



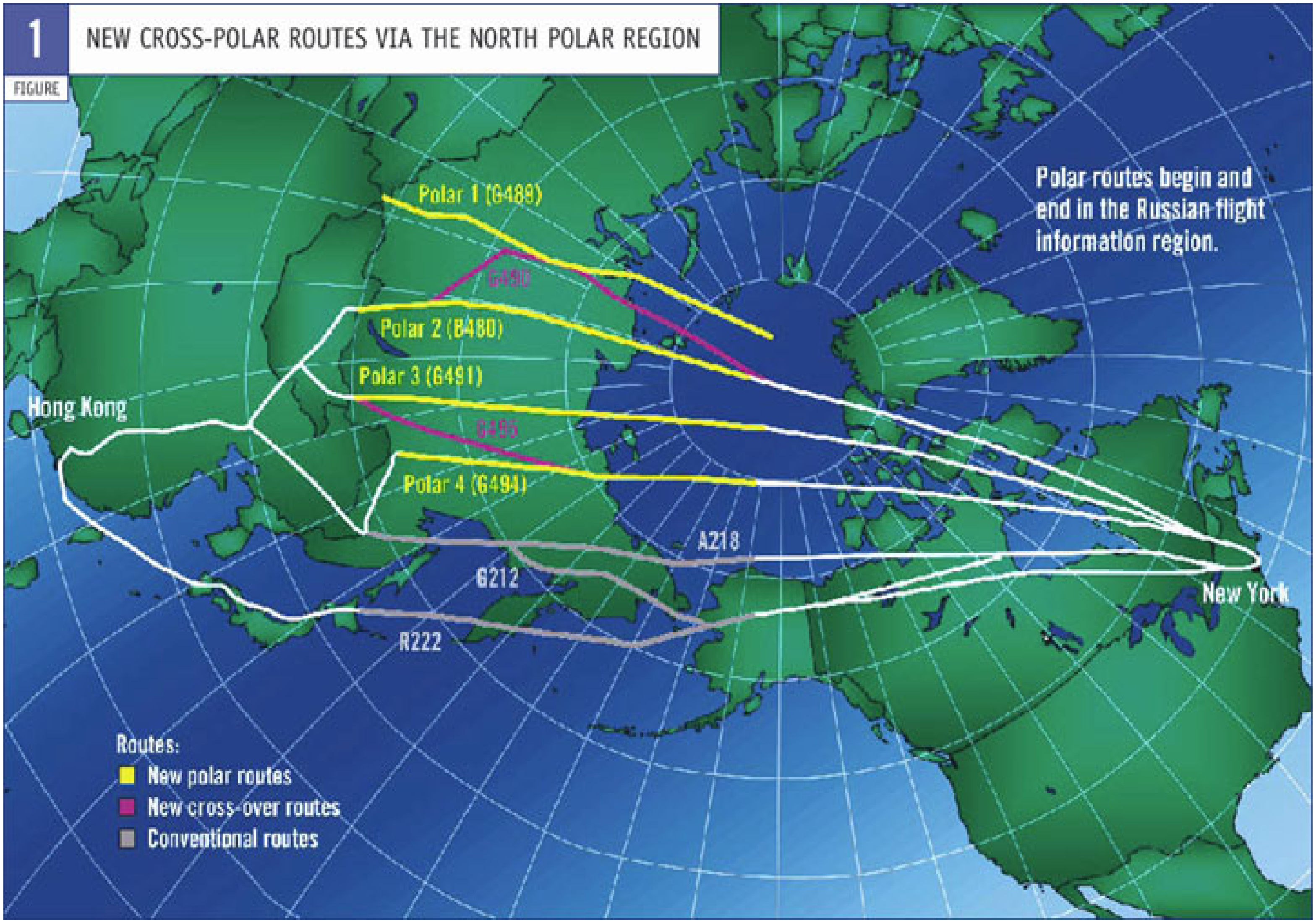
Source: SAV

Water contamination

- All fuels contain some amount of dissolved water - cannot be removed by sumping and filtration
- When fuel temp gets below freeze point of water, the latter comes out of solution and solidifies
- Impact: Cause restriction in fuel feed system
- BA Boeing 777 flight 38 incident 17 Jan 08 on final approach to LHR
  - Interim measures taken by Boeing, FAA, EASA to reduce risk of ice formation, ex. Limiting flying hrs under certain temp conditions

➢ ***FAA and EASA reviewing current certification requirements to ensure that aircraft and engine fuel systems are tolerant to the potential build up and sudden release of ice in the fuel feed system***.

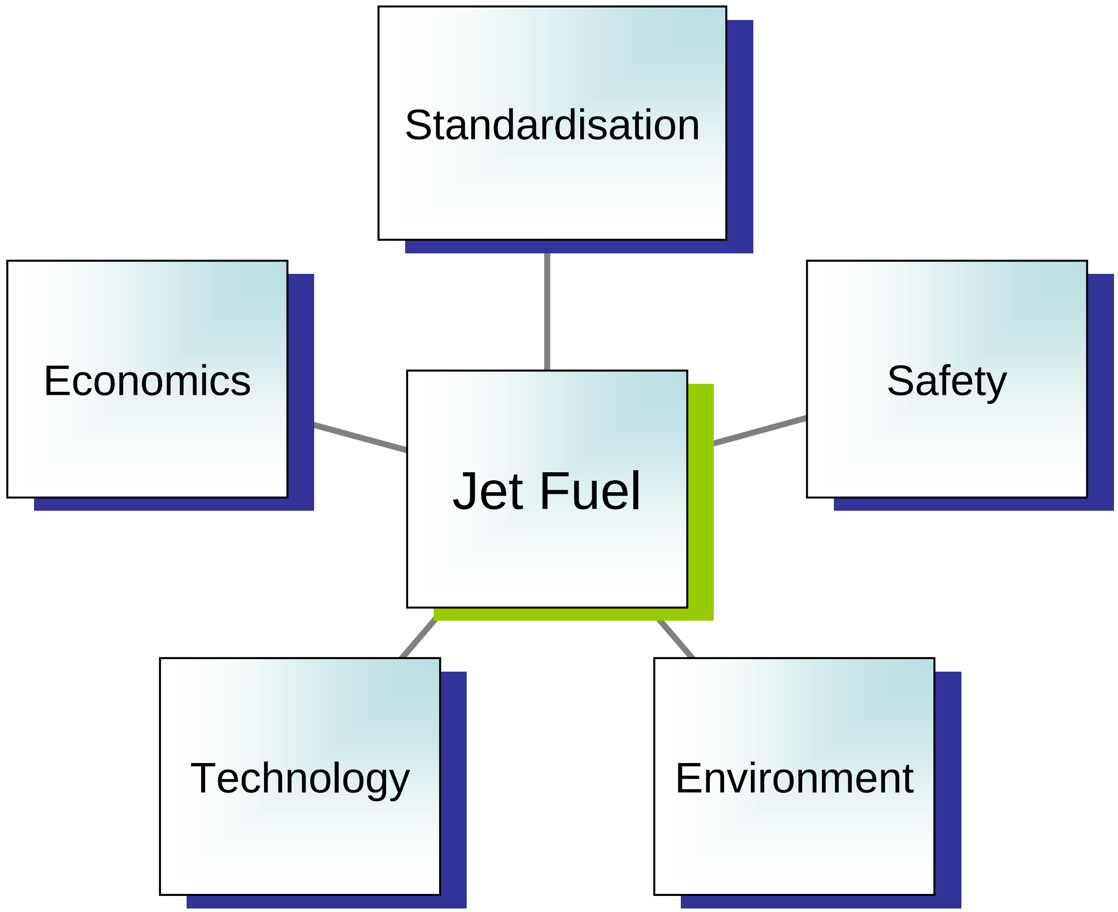
Polar Routes



Non-specified properties

- Elastomer and fuel system compatibility – fuel reacts and causes swelling of elastomers
- Micro-biological growth – serious contamination leading to engine filter blockages
- Lubricity – property essential for fuel pumps
- Di-electric constant –electrical property to indicate polarization propensity
- Bulk modulus – measure of compressibility
- Thermal conductivity – Fuel as heat sink

Factors affecting Jet fuel specifications



Fuel flammability- Safety

NTSB MOST WANTED Transportation Safety Improvements:

Eliminate Flammable Fuel/Air Vapors in Fuel Tanks on Transport Category Aircraft

Amber indicating slow progress

Fuel Tank Explosions – The Evidence

- In history of operating large turbojet aircraft, altogether 17 events of fuel tank explosion or rapid overpressure occurred
- Several cases like sabotage, uncontained engine failure, engine separation, open tank maintenance, refueling with dry running pumps and lightning
- Root causes of most of this events are known and suitable corrections have been implemented
- For 3 cases there is still no official or complete conclusion on the root cause/s:
- May 1991, B737 at Manila airport
- July 1996, B747 after start from New York JFK (TWA 800)
- March 2001, B737 at Bangkok airport

Fuel Tank Explosion

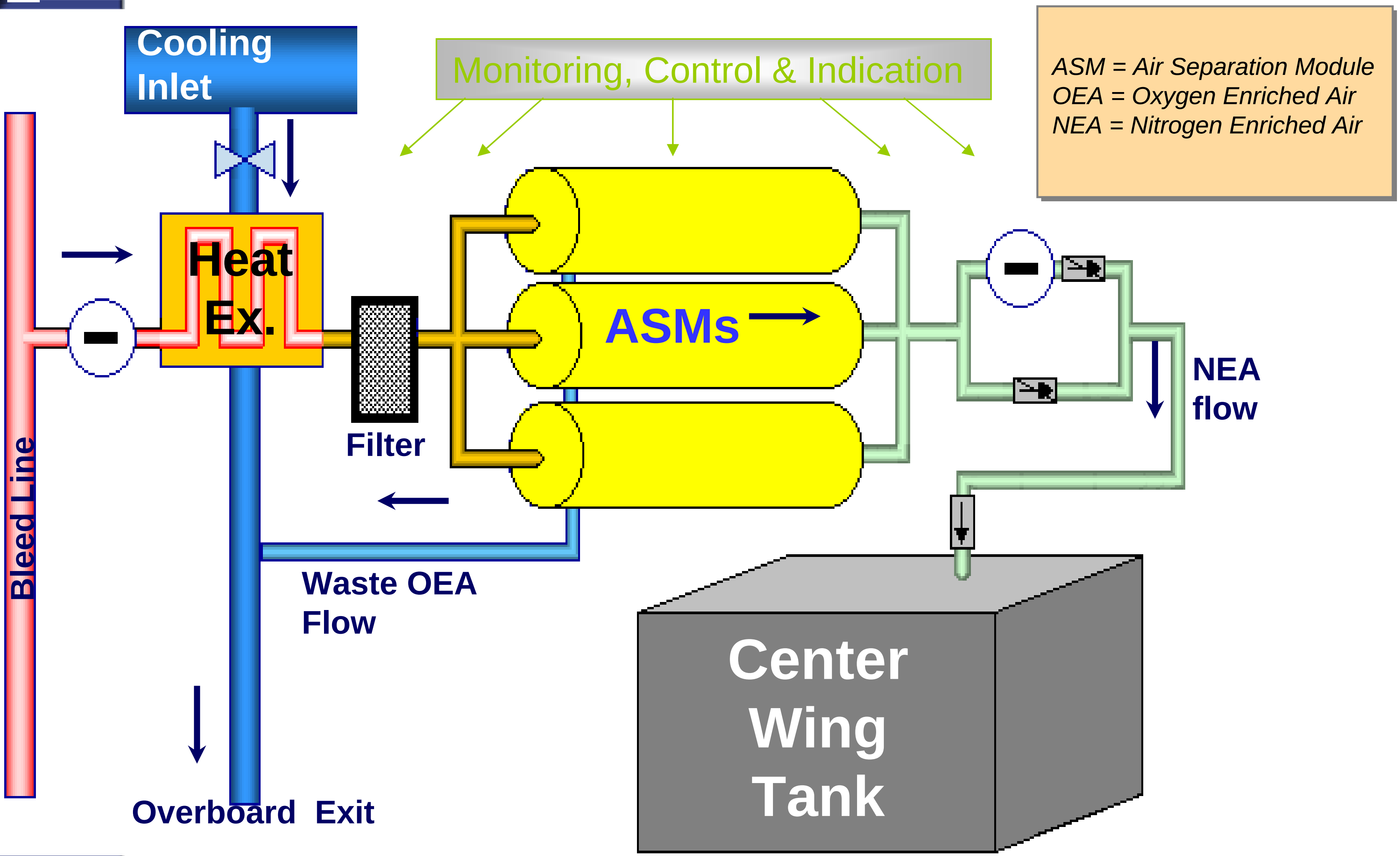
Aircraft Fuelling

A Boeing 747-259B received substantial fire damage to the right wing during refueling Dec. 1, 1998, at Miami International Airport, Florida, U.S. (Photograph by Timothy Swick)

Fuel Tank Safety and Flash Point

- During certain portions of the missions, the vapor space (ullage) of aircraft fuel tanks achieve flammable composition
- Fuel tanks also have numerous electrical penetrations that can produce ignition sources
- Flash point related to volatility – an essential property that affects combustibility of fuel
  - Affects viscosity, engine starting, altitude relight, fuel system temperature etc.
- FAA ARAC Committee evaluated the feasibility of raising minimum Flash point and concluded:
  - Combination of changes to fuel properties
  - Increase in manufacturing costs and decrease the availability of modified Jet fuel

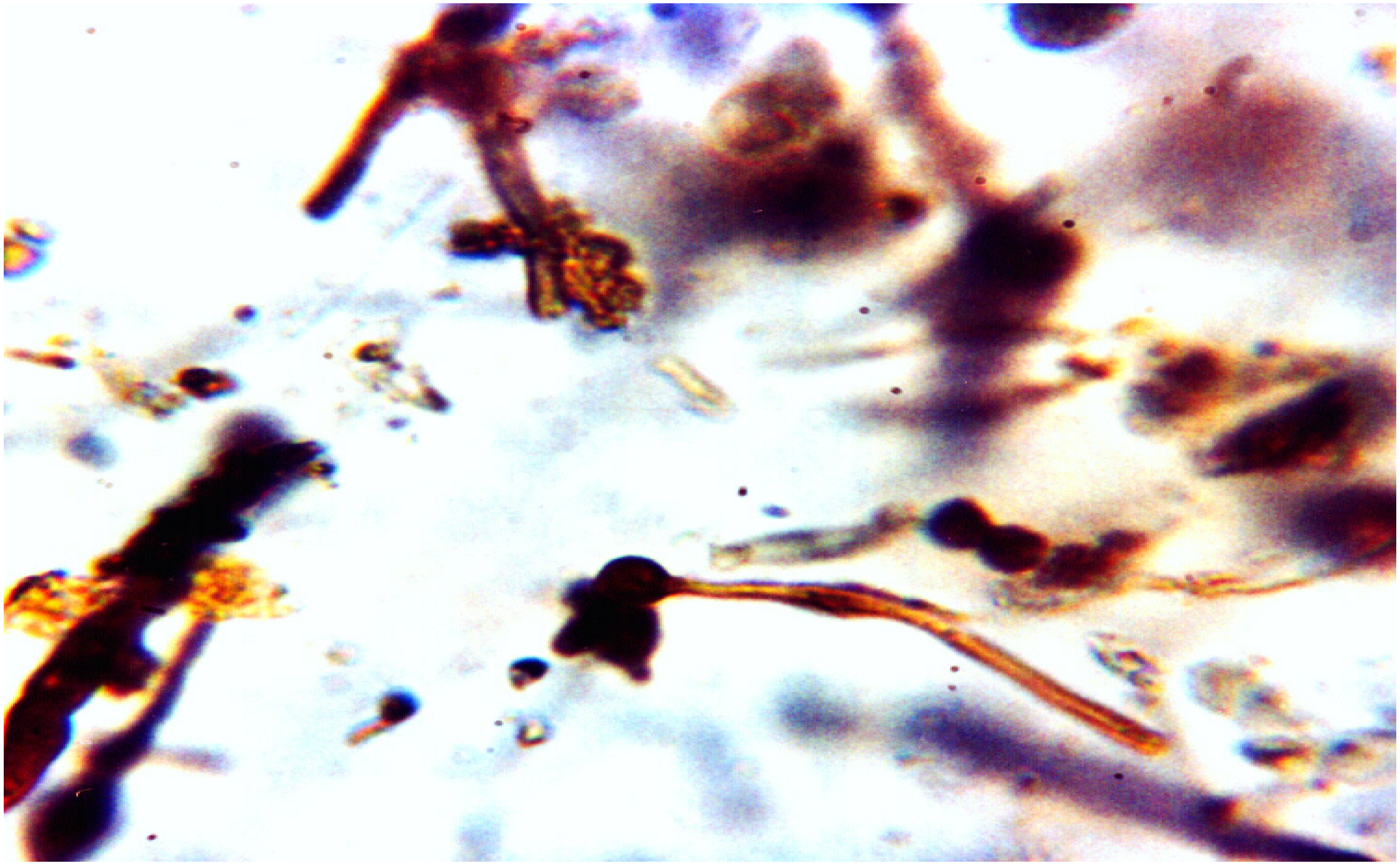
Flammability Reduction System (FRS)



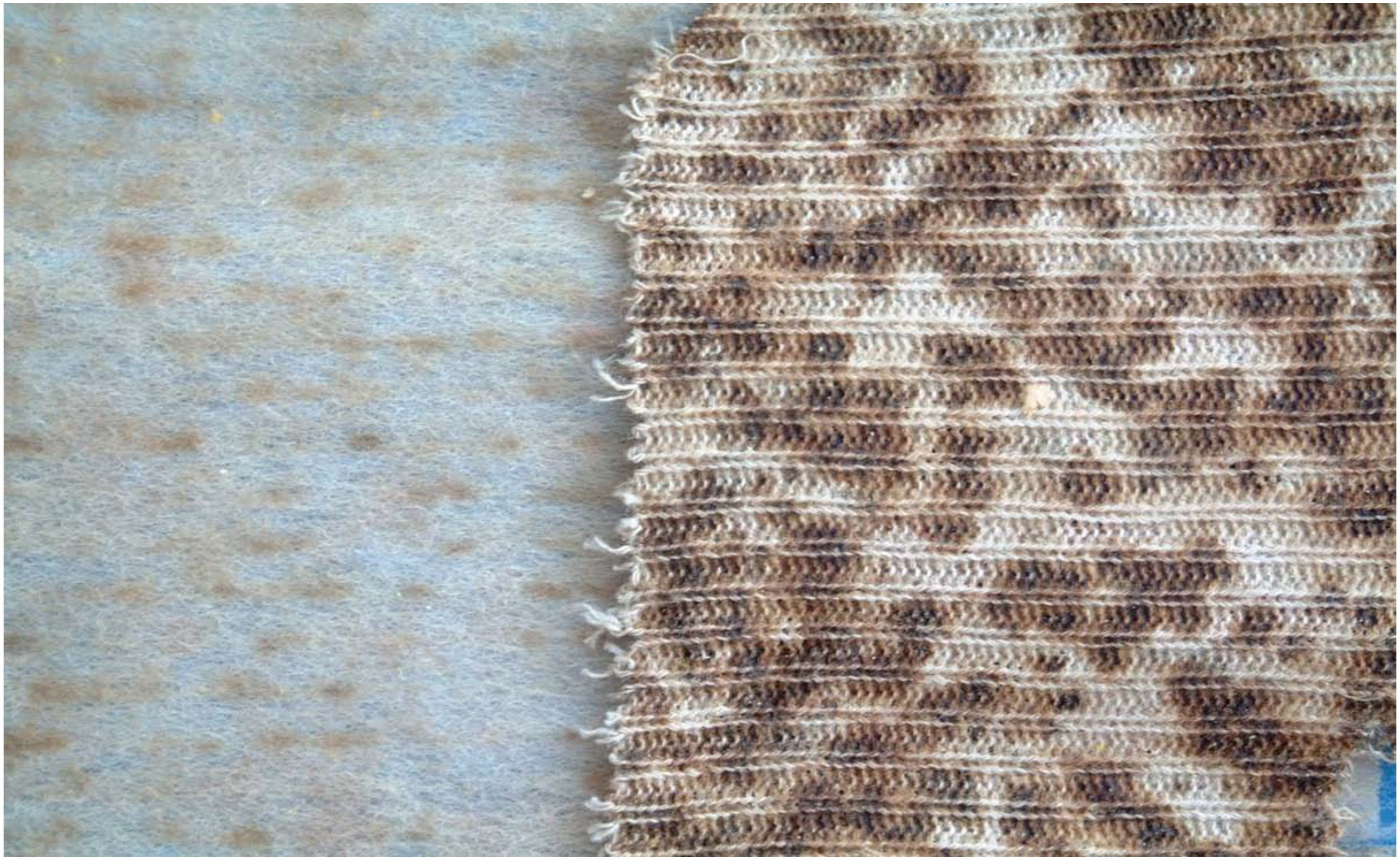
Microbial Growth

- Microbial Growth is produced by various forms of micro-organisms that live and multiply in water which is in jet fuel
- These micro-organisms form slime that can be red, brown, green, or black
- The organisms feed on hydrocarbons in the fuel but require water to multiply
- This buildup can:
  - Interfere with fuel flow and quantity indications
  - Start electrolytic corrosive action

Filter Deposits



Fungal Growth on Coalescer Sock



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Boeing 737 Sump

Issues/Risks

Technical Risks

- **Thermal stability – fuel system component coking**
- **Storage stability – microbiological growth**
- **Cold flow properties**
- **Combustion properties**
- **Material compatibility – fuel system and hot section**
- **Trace contamination (metals, micronutrients)**
- **Low Density – reduced aircraft range**

Quality Risks

- **Inconsistent product (diverse sources)**
- **Lack of robust control**
- **Fragmented industry**

Extensive Certification Process

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Closing remarks

- Unique opportunity to design/develop a fuel that is adapted to the requirements of Industry
- Jet fuel specs provides a good baseline
- New protocol for assessment/certification of alternative fuels
  - Robust, cost effective with shortest possible route
- Unique challenges to rapid adoption
  - Industry needs a harmonized approach
  - Must work with standard setting agencies
  - End-users need to be more involved
  - Regulatory oversight: ICAO, FAA and EASA
- Framework: ASTM Guideline for the Qualification and Approval of New Turbine Fuels and Fuel Additives

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Thank you!

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