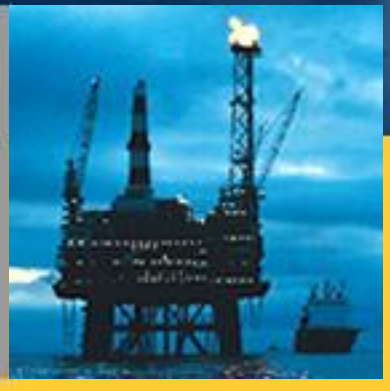
Joint Industry Project seeking OEM approval for up to 100 mg/kg FAME in aviation turbine fuel

Geoff Bishop,
EI Project Leader

Update for JIP Meeting, Norfolk, VA- June 2009



"Providing industry with cost effective value added scientific and technical knowledge on key current and future issues"

The Objective

" To gain OEM approvals for up to 100 mg/kg fatty acid methyl ester (FAME) in aviation turbine fuel"

Target approvals:

GE	Airbus
Pratt & Whitney	Boeing
Rolls Royce	Embraer
Honeywell	Bombardier
Snecma	Cessna

energy INSTITUTE

How it will work

Project Steering Group

Chairman	**Project Leader**	**Administrator**
Mike Farmery	Geoff Bishop	Martin Hunnybun

JIP Participants (funding)

Fuel suppliers: BP, Chevron, ExxonMobil, Shell, Total, Q8, ENI
Pipeliners: TRAPIL, CEPMA
Govt: DESC, UK MoD, UK DfT, French MoD
Organisations: CONCAWE, NBB, FAA

Participation by invitation of JIP Participants

Engine OEMs
Airframe OEMs

Airworthiness Authorities
Airline/IATA/ATA observers

energy INSTITUTE

Heightened interest in USA

- US govt. recently passed the Renewable Fuels Standard – 2.
- RSF2 will require refiners to incorporate 1 billion USG of biomass in diesel fuel by 2012. This means ca $^{2}/_{3}$ of the on-road diesel fuel in USA will be minimum B5.
- This volume can only be transported practically and economically if biodiesel is accepted into multi-product pipelines.
- Anticipating this potentiality, the National Biodiesel Board (NBB) and 5 major pipeline companies in the US (Buckeye, Colonial, Explorer, Magellan, Teppco) have formed a Pipeliner Biodiesel Steering Committee (PBSC) to identify the needed technical and regulatory approvals for transporting biodiesel blends on US pipelines.
- This Committee is keen to join the existing EI-JIP effort in order to get a head start and see the 100mg/kg approval as a key enabler to even consider transport of biodiesel in pipelines.

energy INSTITUTE

Funding/Budgeting

- Project cost GBP 1.42 million (USD 2.3 million)
- Project funding raised to date GBP 755k (USD 1.2 million) (GBP 400k industry; GBP 355k Government)
- Funding shortfall GBP 670k (USD 1.1 million)
- GBP 45k short of being able to fully fund engine endurance testing
- Options for making up shortfall: (US Department of Energy; FAA USD 250k; further funding from major oil companies ca. USD 400k; further funding from DESC; further approach to French Government)

energy INSTITUTE

JIP Status at June 2009

The Programme Document detailing the OEMs' requirements is divided into two stages:

1. **Specification and fit-for-purpose (laboratory) testing of FAME blends**
2. **Engine Risk Mitigation Programme, incorporating OEM rig and engine tests**

- **In common with industry practice, all testing is being conducted at 4x the required approval level (i.e. 400mg/kg) and will follow the ASTM D4054 Standard Practice for Additive Qualification and Approval. The stepwise programme begins with laboratory tests, to be followed by rig and engine tests.**
- **Agreed that the tests will be conducted on a FAME cocktail (RME/POME/SME/TME). Additional "worst case" FAME (yellow grease/tallow) will also be investigated in lab tests**

energy INSTITUTE

Stage 1 - Lab Testing Summary

- The initial specification and fit-for-purpose testing required by the OEMs has been conducted on the FAME cocktail and on the four component FAMEs (Note: these are the same materials that were used in the laboratory test development programme)
- Tested in both Merox and hydrotreated base fuels
- Majority of testing complete but some repeat testing required
- So far, no indications of significant effects on fuel performance properties
- No incompatibility with approved additives seen.
- Extensive materials compatibility testing not yet commenced; awaiting OEMs' clarification on rationalised shortlist of materials to be tested, taking into account the chemistry of FAME vs. previously tested and approved additives
- "Worst-case" FAME testing just commenced at SwRI

energy INSTITUTE

Lab Testing – Specification testing results

- Blends of the four individual FAMES – RME, SME, POME, TME/UCOME – at 400mg/kg plus blends of the cocktail (100mg/kg of each FAME) in two base fuels (Merox and hydrotreated) have been subjected to full jet fuel specification testing.
- In summary:
  - General properties – distillation, density, flash point, smoke point, Cu strip corrosion, acidity, existent gum – no significant effect
  - Thermal stability – no significant differences in JFTOT results either at 260°C or at breakpoint temperature
  - Lubricity – no significant effect
  - Water separation properties – no significant effect
  - Electrical conductivity – no significant effect

energy INSTITUTE

Lab Testing – Low temperature properties

- Freezing point – no significant differences seen with either the manual freezing point method (D2386) or any of the automatic methods
- Low temperature viscosity – simple viscosity measurements (ASTM D445) at -20, -40, -54°C, and at 5°C above the freezing point showed no significant differences.
- Further studies by Rheotek using the JETVISC automatic method again showed no effects of FAME at 400mg/kg on KV at the above temperatures, nor on the temperature at which 12cSt was reached. Tests at higher FAME concentrations did show significant effects:

  At 10,000mg/kg (1%m) KV was increased by 1.5%, 1.8% and 2.2% at -20, -40 and -45°C respectively.
  At 30,000mg/kg (3%m), KV was increased by 5%, 6% and 22% at -20, -40 and -45°C respectively
- Low temperature hazing at -50°C for 21hrs – no sediment in samples; no differences in clarity after warming up.

energy INSTITUTE

Lab Testing – Other properties

- Water solubility – apart from one spurious result for TME in one of the base fuels only, the presence of FAMEs at 400mg/kg had no significant effect on water solubility properties in either base fuel.
- Surface tension – no significant effect
- Testing of fuel after aging for 12 weeks @ 43°C – results for acidity, existent gum, particulate matter and peroxide content were all low and below spec maximums. Similarly for JFTOT. However, no results on the aged bases fuels are available for comparison due to an omission by the testing lab. All tests are being repeated.
- Compatibility with Approved Additives – Testing according to the protocols in ASTM D4054 showed no incompatibility problems between the FAMEs and approved additives – FSII, CI/LI, MDA, SDA
- Dielectric constant/permittivity – tests completed by Airbus; results show little variation but awaiting interpretation.

energy INSTITUTE

Lab Testing – Materials Compatibility

- Still awaiting OEM finalisation of the list of materials to be tested; when complete will request quotes for testing from SwRI and UDRI.
- Testing expected to be complete by the end of Q3 2009

Reporting

- **Results of testing reported in the EI JIP Report, a living document which will be updated as and when further results are available. Report v1.2 currently residing on the JIP microsite:**

  http://www.energyinst.org.uk/new/users/login2.cfm?return=microsite&id=57&CFID=60718&CFTOKEN=6a71c684e39538d7-4516EA55-E0C4-ED84-0AB36C24424E8B11

  (note: access to this site is restricted to JIP participants and others authorised by the JIP)

Stage 2 – OEM Rig and Engine Tests

- NOTE: Normally, Stage 2 testing would not commence until the OEMs have had chance to review all the Stage 1 test results and agreed to proceed. However, owing to the urgency, rig and engine tests are being organised without waiting for completion of the lab testing.
- Engine altitude relight/cold start – completed 19th March 2009 (Rolls-Royce): results show no cause for concern
- Aircraft Fuel System Thermal Stability Simulator (AFTS) test – will commence this week (Rolls-Royce) – to be completed July 2009
- Fuel nozzle spray pattern impact – Q3 2009 (Honeywell)
- Fuel filter cold flow test – Q3 2009 (Honeywell)
- 5000 cycle engine test in a CFM 56-5B – commencing July 2009 for 16 – 20 weeks (GE/CFMI)

energy INSTITUTE

Stage 2 – OEM Rig and Engine Tests (cont.)

- **APU altitude relight/cold start – (whether this test is deemed necessary will depend on the results of the engine altitude relight and nozzle spray pattern tests)**
- **Hot-end materials/corrosion testing – OEMs agree that this testing is not necessary, based on the chemical composition of FAME.**
- **Emissions and combustor exit traverse test – to be determined if necessary.**

energy INSTITUTE

Programme Timeplan

- The intention is to complete all the testing required to achieve OEM approvals for 100mg/kg FAME by the end of 2009. Review of results by OEMs and granting of approval expected within 3 months of test programme finish.

- How the approvals will be implemented, e.g. by inclusion in the fuel specification, is yet to be decided.

FAME Test Method Development

- Analytical test methods for detecting FAME in jet fuel down to 5mg/kg are being developed under a separate EI project.
- Laboratory methods:
  - GC-MS method published as IP PM-DY/09
  - HPLC-ELSD method being balloted as IP PM-DV
  - SPE-GC method being balloted as IP PM-EC
- Rapid Screening Method based on SPE-FTIR (for measuring 30 – 100ppm) published as IP PM-DT/09
  - Now available as the FIJI apparatus from Stanhope-Seta
- Above methods are about to enter round-robin testing to develop precision data
- Full details of all these methods will be discussed during relevant section meetings during this ASTM meeting

energy INSTITUTE