Alternative Jet Fuels - Aircraft Component Deterioration and Wear Assessment

&

Fuel Performance Testing

Federal Aviation Administration

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By: Mark Rumizen, Senior Technical Specialist, Aviation Fuels, Federal Aviation Administration

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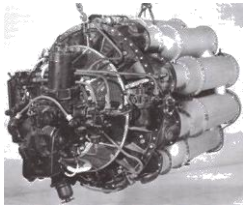
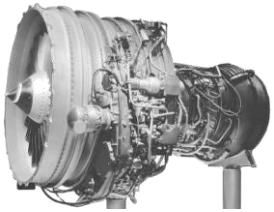
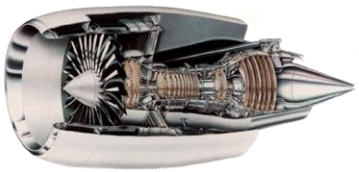
Renewable Jet Fuels Must Be Drop-In Fuels

New Engines

Existing Engines







Existing Fuel

1950's

1970's

1990's

2000's

New Fuel

Fuel Affects Many Engine Design Elements

Fuel Atomization
Freezing Pt., viscosity
Distillation, Thermal stability, Surface Tension

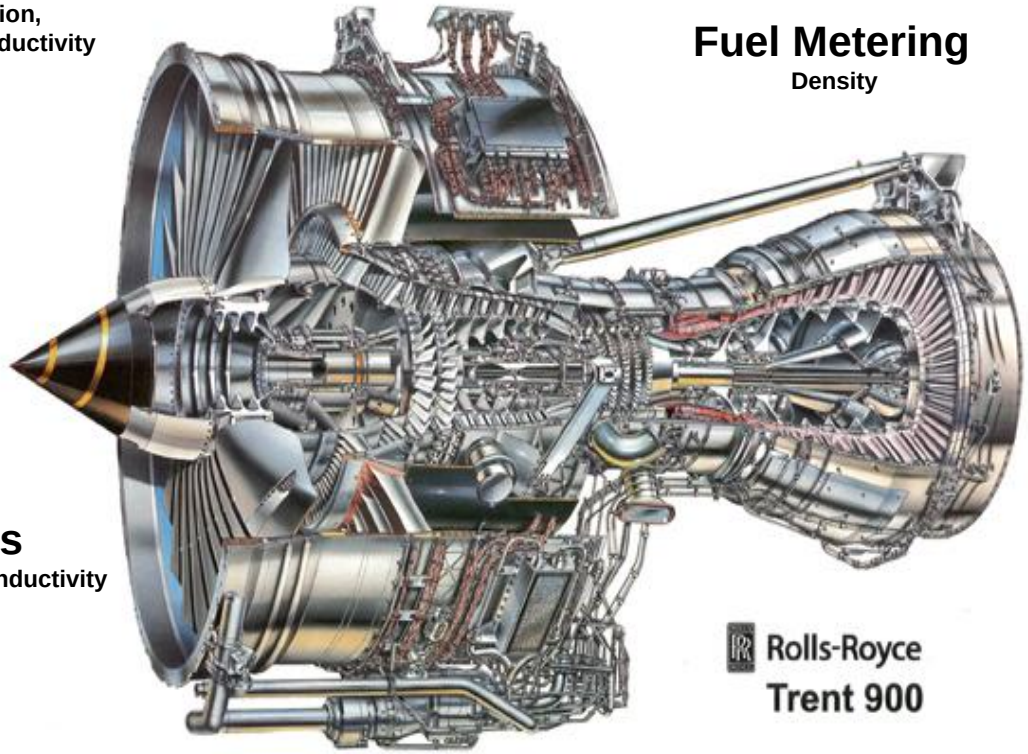
Fuel Pumping
Freezing Pt., viscosity
Distillation

Servo Mechanisms
Bulk Modulus

Handling Safety
Flash Pt., Auto-ignition,
Flame Speed, Elect Conductivity

Fuel Metering
Density

Deposition (coking)
Thermal stability, Gum,
Distillation



Durability
Thermal Stability
Lubricity
Acidity
Exist Gum

Hot-End Life
Thermal Stability, Acidity
Aromatics, Sulfur

Emissions
Aromatics, Sulfur
distillation

Heat Exchangers
Specific Heat, Thermal Conductivity

Cold Start & Alt re-light
Flash Pt., Heating Value
Distillation, viscosity

Material Compatibility
Aromatics, freezing pt.
Acidity, Copper Strip, Trace Elements

Future Technology
Specific Heat, Thermal Stab.
Aromatics, Sulfur/polar Materials

Legacy Hardware
Aromatics, lubricity

Aviation Fuel Qualification (ASTM D4054 Process)

Specification Properties

Fit-For-Purpose Properties

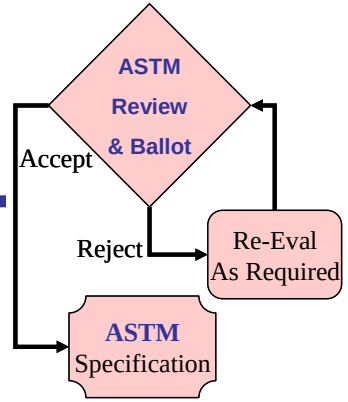
Component/Rig Testing

Engine/APU Testing

ASTM Research Report

EMBRAER
BOEING
Honeywell
Rolls-Royce
AIRBUS

FAA & OEM Review & Approval



ASTM Balloting Process

ASTM INTERNATIONAL
Standards Worldwide

ASTM D7566 Revision

D4054 Estimated Fuel Volumes

10 gals

80 gals

250 – 10,000 gals

450 – 225,000 gals

Specification Properties

Fit-For-Purpose Properties

Component/Rig Testing

Engine/APU Testing

D4054 Fit-For-Purpose Tests

FIT-FOR-PURPOSE PROPERTIES

CHEMISTRY

- Hydrocarbon chemistry (carbon number, type, distribution)
- Trace Materials/Metals

BULK PHYSICAL AND PERFORMANCE PROPERTIES

- Boiling Pt Distribution
- Vapor/Liquid Ratio
- Thermal Stability Breakpoint
- Lubricity
- Response to Lube Improver
- Viscosity vs Temp
- Specific Heat vs Temp
- Density vs Temp
- Surface Tension vs Temp
- Bulk Modulus vs Temp
- Thermal Conductivity vs Temp
- Water Solubility vs Temp
- Solubility of Air (oxygen/nitrogen)

FIT-FOR-PURPOSE PROPERTIES

ELECTRICAL PROPERTIES

- Dielectric Constant vs Density
- Electrical Conductivity and Response to Static Dissapator

GROUND HANDLING/SAFETY

- Effect on Clay Filtration
- Fitration (Coalescers & monitors)
- Storage Stability
  - Peroxides
  - Potential Gum
- Toxicity
- Flammability Limits
- Autoignition Temperature
- Hot Surface Ignition Temp

COMPATIBILITY

- Other Additives/Fuels
- Engine/Airframe Seals, Coatings, Metallics

D4054 Fit-For-Purpose Tests

TURBINE HOT SECTION
FRL 6.2

Oxidative/Corrosive Attack on Turbine Blade Metallurgy/Coatings (Burner Rig Test)

COMPONENT/RIG TESTING
FRL 6.3

Fuel System:
- **Fuel Control**
- **Fuel Pump**
- **Fuel Nozzle**

Combustor Rig Tests:
- **Cold Starting**
- **Lean Blowout**
- **Aerial Restarting**
- **Turbine Inlet-Temp Dist.**
- **Combustor Efficiency**
- **Flow Path Carboning/Plating**
- **Emissions**

APU Testing
- **Altitude Starting**

ENGINE TESTING
FRL 6.4

- **emissions**
- **durability**
- **ignition/relight**

Example Qualification Tests

Engine Endurance Tests

	Test Item	Thrust Class (LbF)	Cycles	Hours	Qty of Fuel (gals)	Pass/Fail Criteria
Engine 1	Synthetic Fuel	43K -50K	500	153	250K	Engine Performance, fuel sys comps visual insp, borescope of hot section
Engine 2	Additive	20K-30K	5000	600	630K	Engine Perf, fuel sys comps bench tests, borescope of hot section
Engine 3	Synthetic Fuel	7K	850	355	120K	Engine Perf, hot Section & fuel system hrdwr visual insps, fuel sys comps bench tests,

Example Qualification Tests

- **Materials Compatibility**
  - D4054 Short List of Test Materials
    - 37 non-metallics
    - 31 metals
  - Soak Test – 28 Days at High Temperature
    - Sealant, coating, composite, and adhesive materials must be cured before testing
    - Bladder, hose, foam, and wire insulation materials must be cut into test samples from sheets
  - Pass/Fail
    - Allowable variation defined for each material

Example Qualification Tests

- **Materials Compatibility (Continued)**
  - Typical Tests (non-metallics)
    - Lap Shear – Cohesion - Volume Swell – Tensile - Elongation
    - Tape Adhesion – Hardness - Peel Strength
    - Laminar Shear - Compression Set - Resistivity
  - Typical Tests (metals)
    - Surface Evaluation
    - Microstructural Evaluation

Research Goals

- **Reduce Testing Costs**
  - Fuel Volumes
  - Engine/Rig Requirements
  - Other Resources
- **Reduce Qualification Time**
  - Number of Tests
  - Equipment Availability

Alternative Fuels - Aircraft Component Deterioration and Wear Assessment

- **Examine the durability of aircraft engine components with the use of new candidate fuel formulations relative to wear, deterioration and deposit build-up.**
- **Develop new, or refine existing, laboratory and materials compatibility test methods and use them to evaluate the composition and impact of new candidate fuel formulations on both metallic and non-metallic materials.**

Alternative Fuels - Fuel Performance Testing

- **Develop new (or refine existing) laboratory, turbine engine rig, full-scale engine test, and aircraft flight test methods and use these to evaluate the performance properties of new candidate fuel formulations.**
- **Explore, develop and demonstrate analytical methods that use the composition of new fuel formulations to assess the combustion, handling, storage, and compatibility performance of these new fuels.**