Fit-For-Purpose Properties

Air Force Research Laboratory
Aerospace Systems Directorate

Overall Alternative Fuel Approval Process

Specification Properties

Fit-For-Purpose Properties

Component/Rig Testing – operability, durability

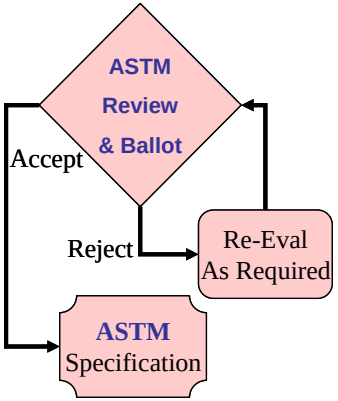
Engine/APU Testing

R&D (AFRL)

Cert. (AFCO)

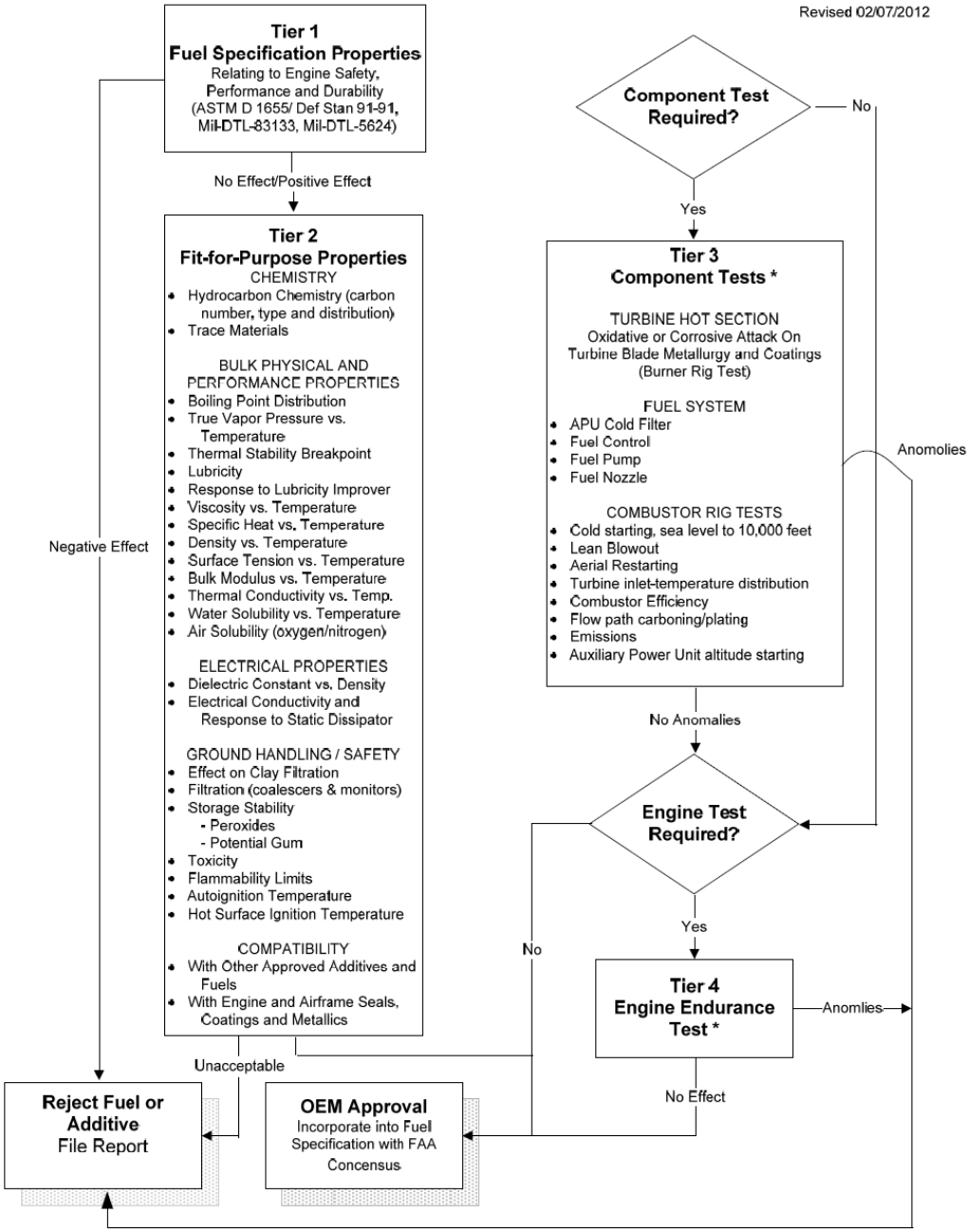
ASTM Research Report

FAA & OEM Review & Approval



ASTM Balloting Process

ASTM D7566 Revision



ASTM Standard Practice D4054– Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

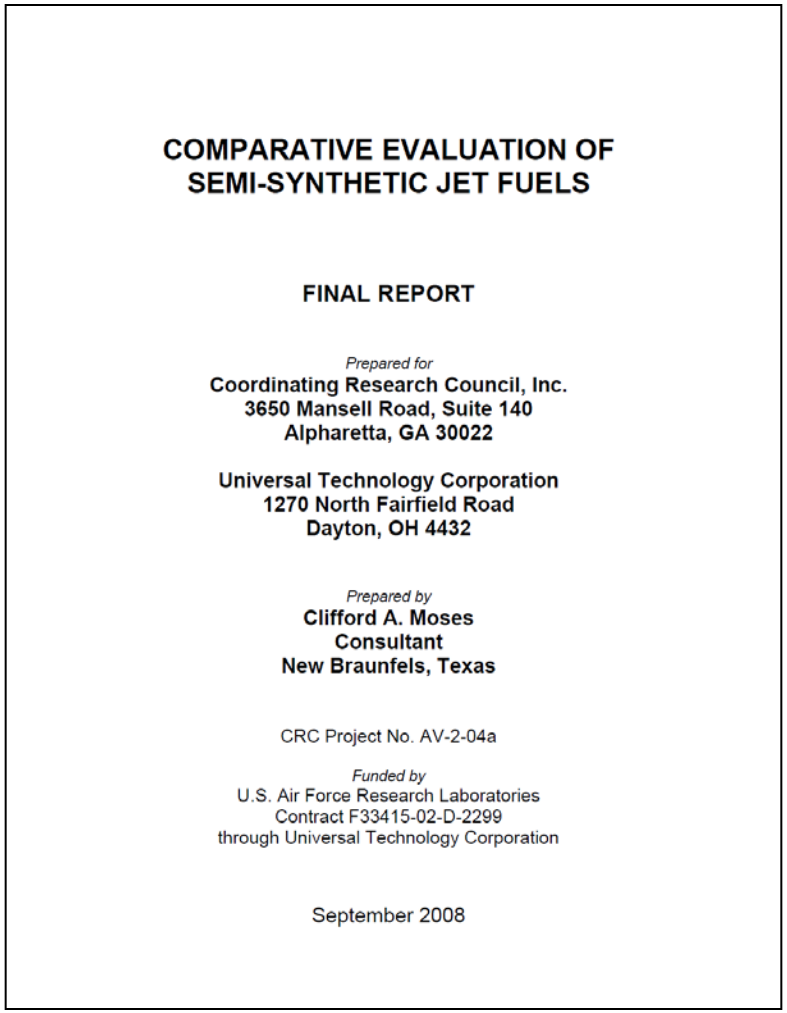
Evolving…

Fit-For-Purpose Properties -?

- **Specification used for quality control**
- **ASTM D4054-12: "Fit-for-Purpose Properties" refers to properties inherent of in a petroleum-derived fuel and assumed to be within a given range of experience. Fit-for-Purpose properties that are not controlled by specification but are considered critical to engine design. Examples include fuel lubricity, seal swell, and dielectric constant.**
- **Some pass/fail criteria given in ASTM D4054 – "Basis of Engine Manufacturers Experience"**
  - CRC Handbook
  - World Fuel Survey
  - Other data

FFP Data Collected in Research Reports

- Used to support commercial specifications (data also used for military certification)
  - Some DOD-unique: diesel engines, afterburners…
- Addresses whether "drop-in" fuels fall within experience base
- Coordinated with Commercial Aviation Alternative Fuel Initiative (CAAFI)
- Need representative set of fuels to show manufacturing range
  - F-T SPK fuel set = 5



COMPARATIVE EVALUATION OF SEMI-SYNTHETIC JET FUELS

FINAL REPORT

Prepared for
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Fit For Purpose Properties

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

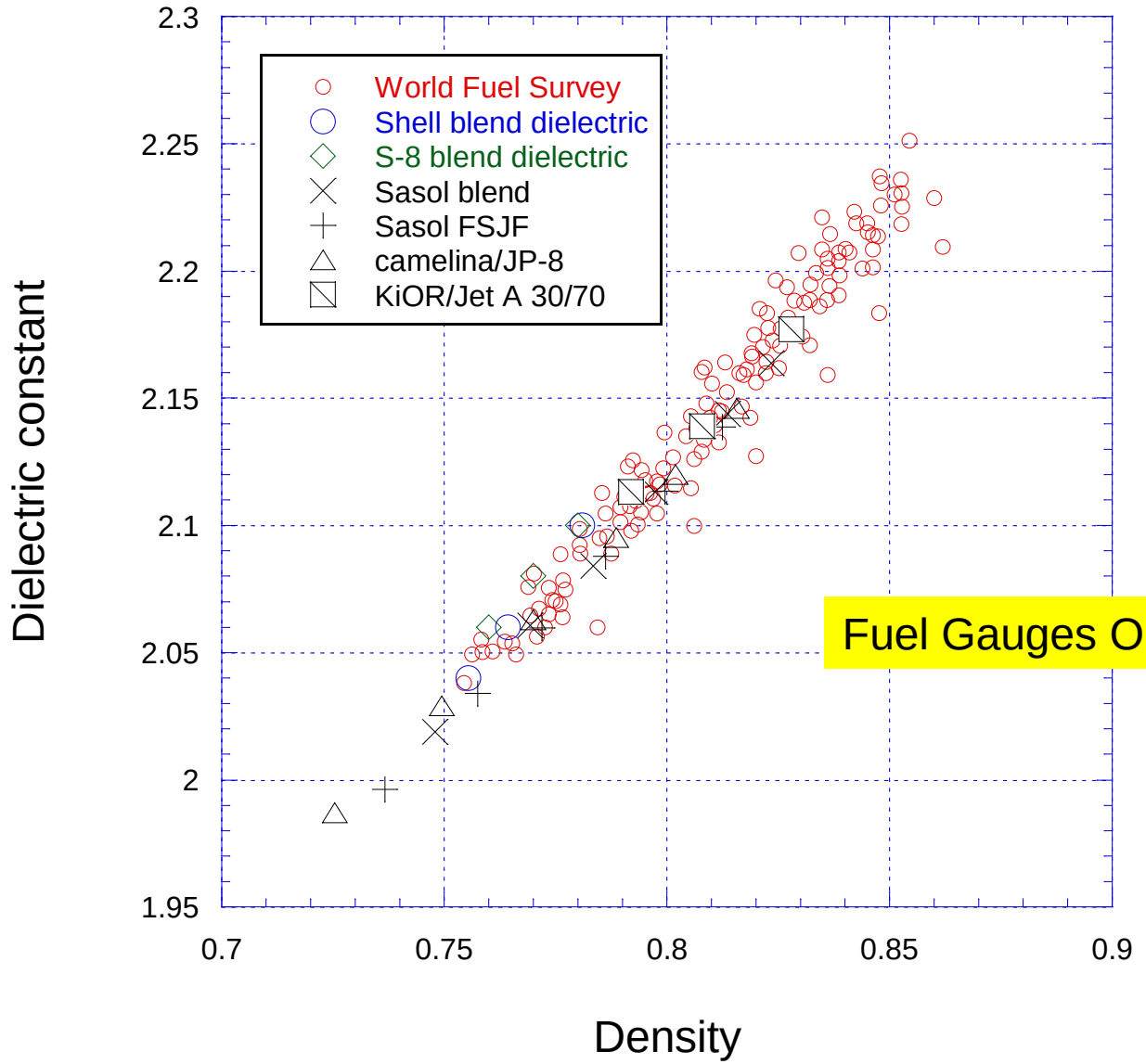
COMPATIBILITY

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

Fit-for-Purpose Overview

- **“Pass” can mean different things, e.g.**
  - Falls between upper and lower limits of experience base (e.g., density, hard limits at 16 C from spec)
  - Dielectric constant – falls within experience
  - Falls below upper limit or above lower limit (viscosity)
- **So, far, FFP properties appear to fall into categories**
  - Boring – density vs T, dielectric constant
  - Interesting – speed of sound, bulk modulus
  - Pathological – Cp
  - Questionable – pass/fail criteria not obvious (vapor P)
- **Several projects ongoing to improve existing data**

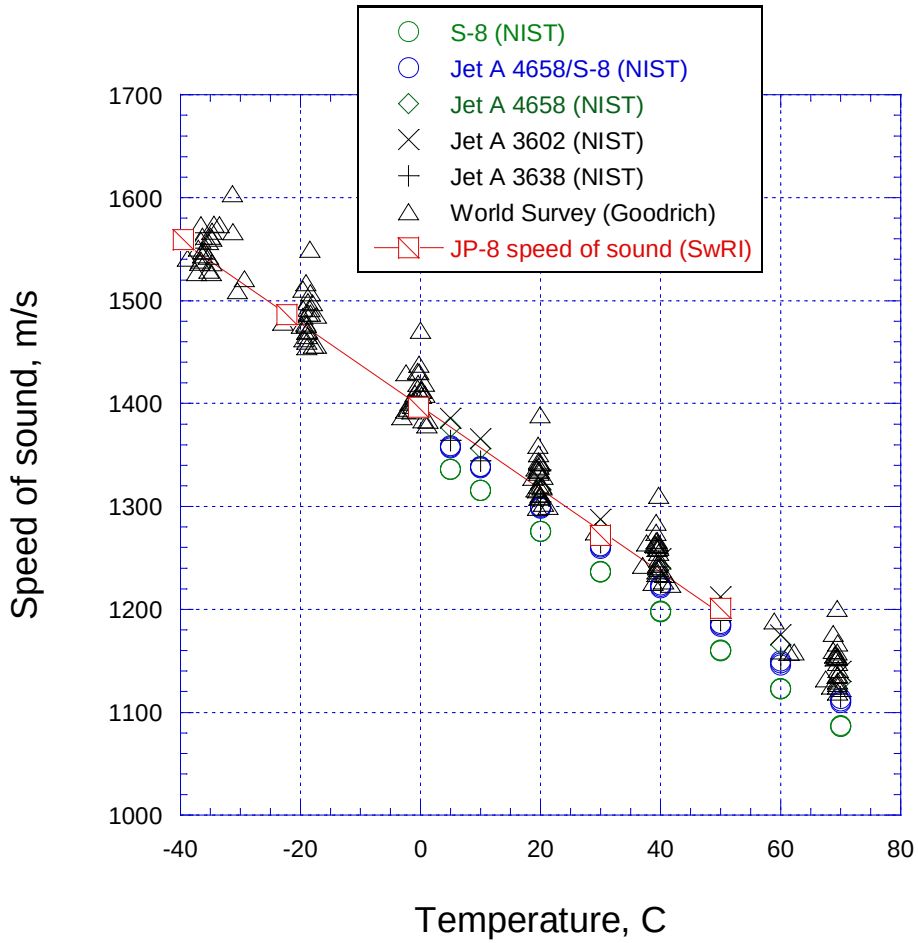
Dielectric Constant vs Density



Fuel Gauges Operate Correctly!

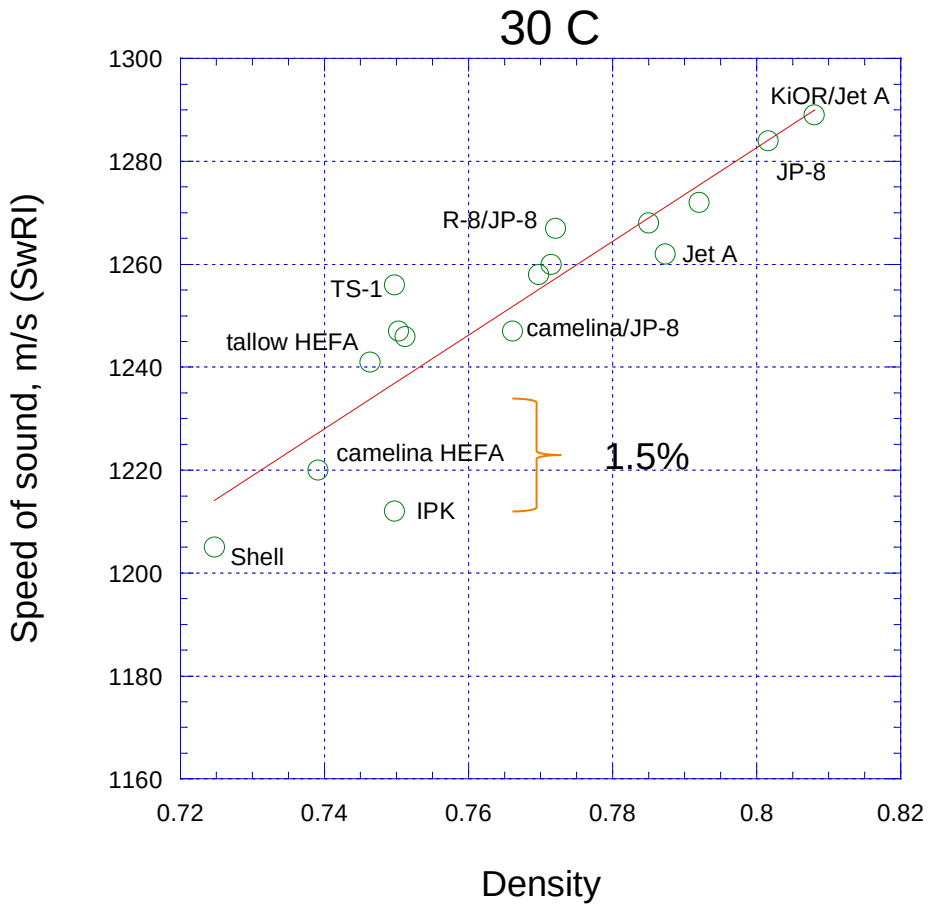
Speed of Sound (vs T)

- **Not in D4054, but….**
- **Important for fuel gauges employing ultrasonic probes**
- **Multiple labs appear to get consistent data**
- **Scatter is data due to density range allowed in spec**



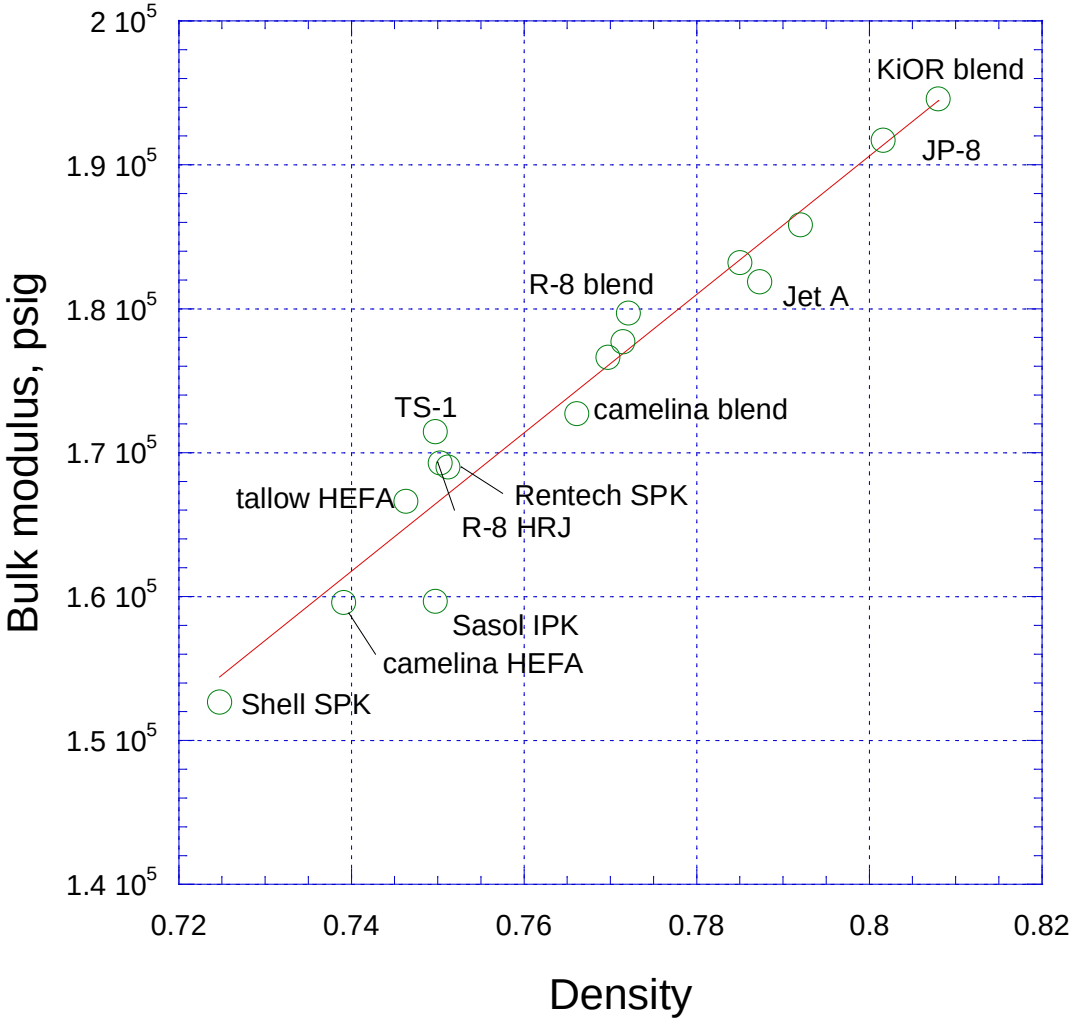
Density Effect on Speed of Sound

- **Density the primary factor in variations amongst jet fuels**
- **Highly isoparaffinic fuels show greatest deviations from density relationship**



Bulk Modulus (vs Density)

- **Explain ~ density * speed of sound squared**
- **2013: Army/DLA round robin to verify isentropic approach using measured speed of sound**



Heat Capacity (vs T) (1)

- **Single line shown for jet fuel, but density effect evident**

Watson and Nelson, Ind Eng Chem, 25, 880 (1933)

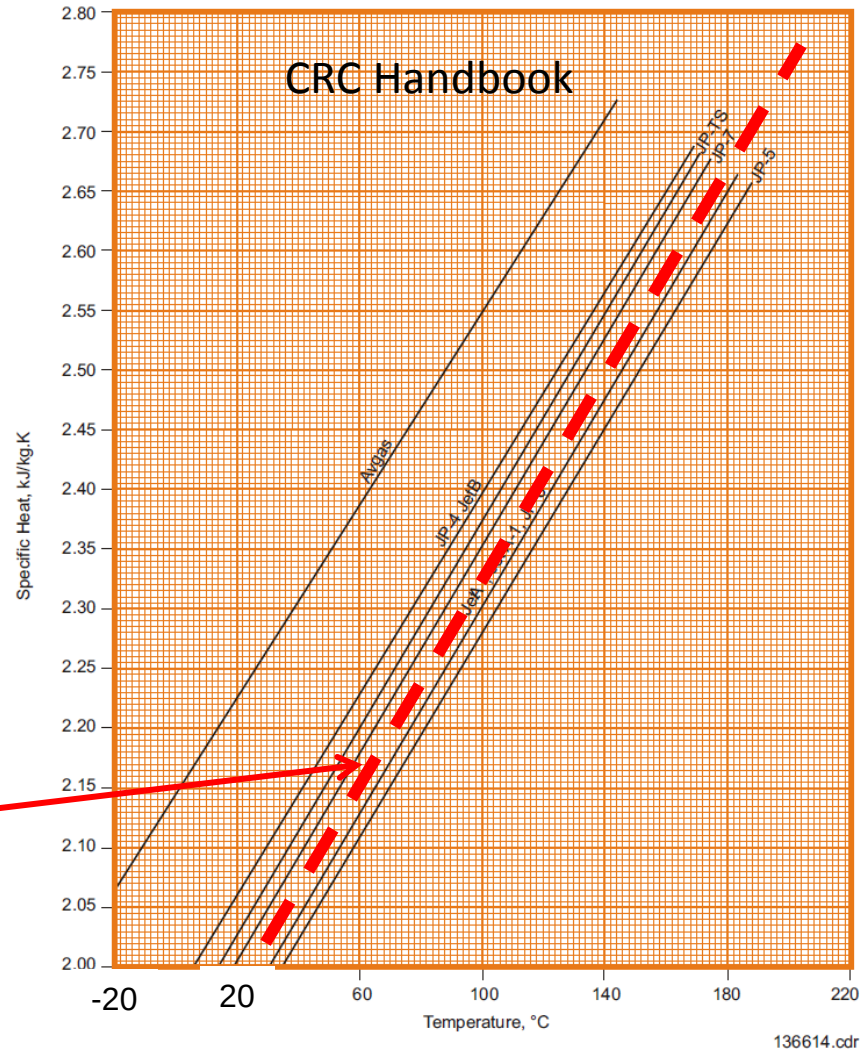


Figure 2-14. Typical Specific Heat Versus Temperature for Aircraft Fuels

Heat Capacity vs T (2)

- **The plot thickens….**

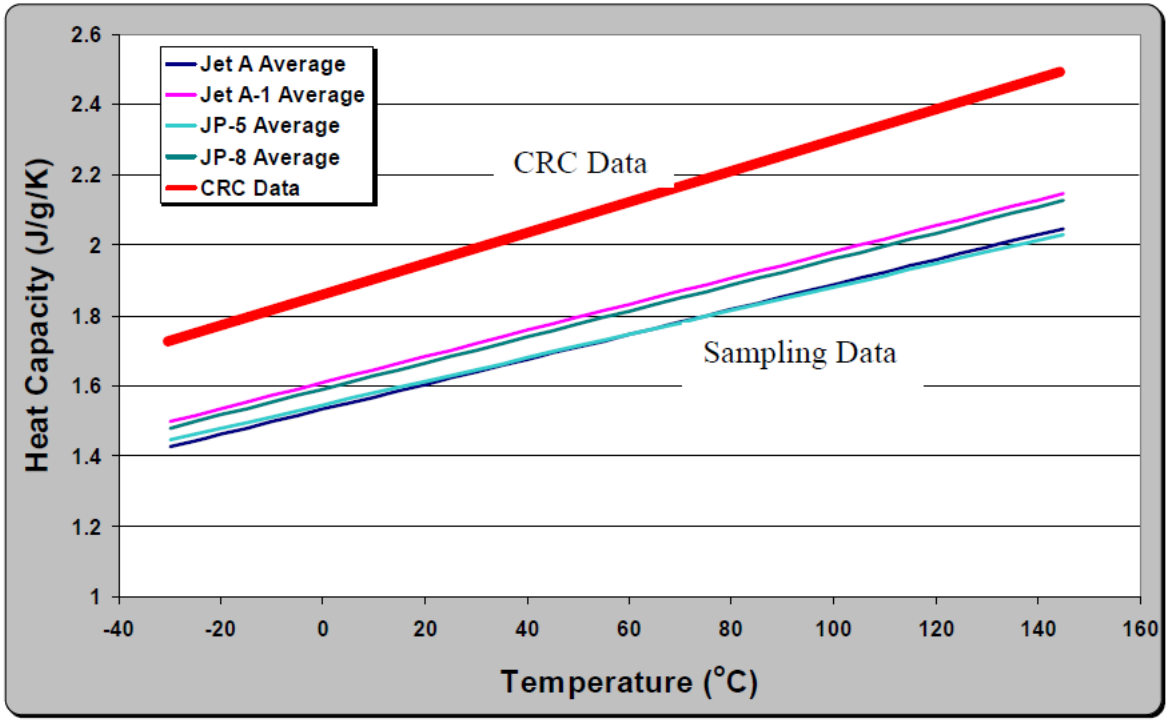
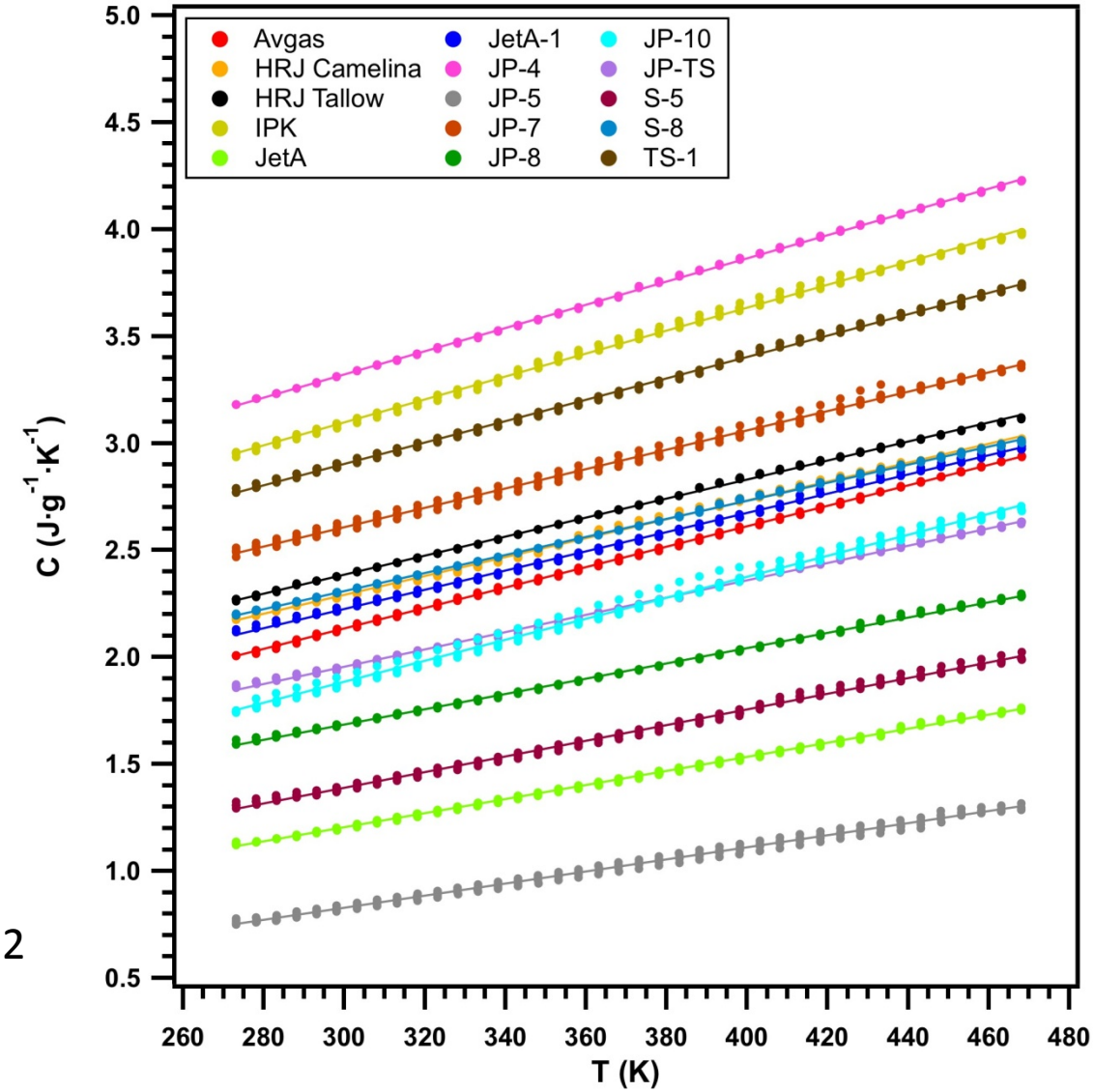


FIGURE 6.2.3. FUEL SAMPLING DATA COMPARED TO CRC DATA

World Fuel Sampling Program (CRC Report 647) 2006

Heat Capacity vs T (3)

- **The plot thickens and becomes murky……**



NIST DSC data, 2012

Heat Capacity vs T (4)

- **HEFA Research Report – data is internally consistent**

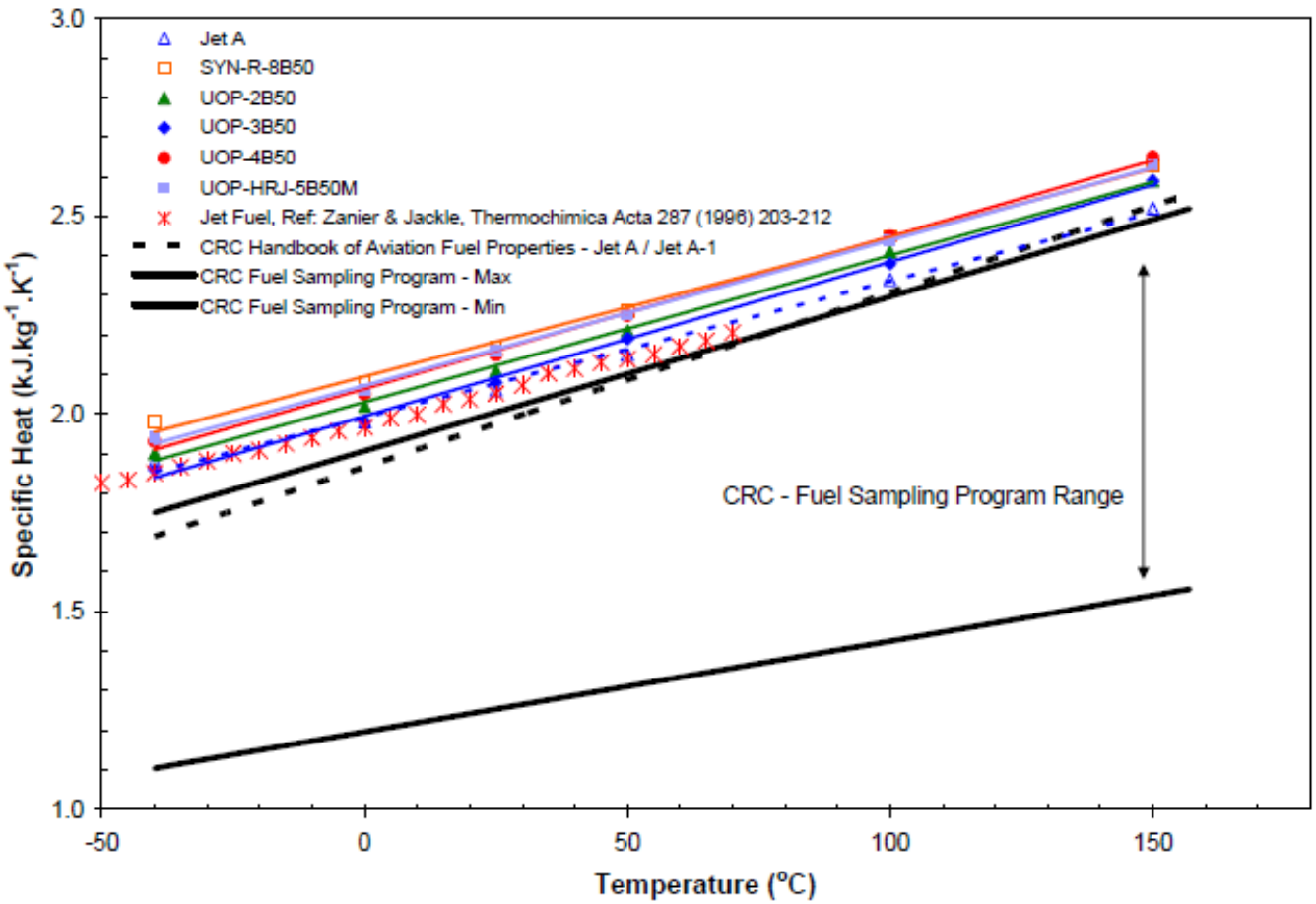


Figure 2-13. SPK Blends Specific Heat Capacity

Bio SPK/HRJ/HEFA Research Report

Summary

- **Fit-for-purpose evaluations of alternative fuels fairly well in hand**
  - Some methods need improvement
  - Some properties need a better “experience base” with conventional fuel

- **On to rig and engine testing!**

The End

Courtesy: Pierre Poitras, Canada QETE

Fuel has some unique challenges!