

ERA24FA110

AIRWORTHINESS

Group Chair's Factual Report - Attachment 3
FAA Jet A Fuel Analyses (FAA AFRL 04-15-2024)
May 8, 2025

NTSB Jet A Fuels Analyses Report (Naples, FL)



Federal Aviation
Administration

Aviation Fuels Research Lab
Fuels and Energy Section ANG E-283
FAA Williams J. Hughes Technical Center
Atlantic City International Airport
NJ 08405

April 15, 2024



Fuel Sample Information (1)



Fuel Sample Information (2)



Fuel Sample Information (3)



Summary of Sample Information (4)

- ❖ Aviation Fuels Research Lab received from twelve (12) Jet-A fuel samples in glass jars from NTSB.
- ❖ Particle contamination has been found in Left Engine Heat Exchanger, Left Engine Fuel Filter Bowl, Right Engine Fuel Filter Bowl, Right Engine Fuel Pump & APU fuel samples.
- ❖ AFT Tail Tank fuel sample contains free water in the bottom of the fuel layer.
- ❖ The color of some fuel samples are darker than other samples, indicating that those fuels had partially been autoxidized at higher temperature.

Hydrogen Content Determination

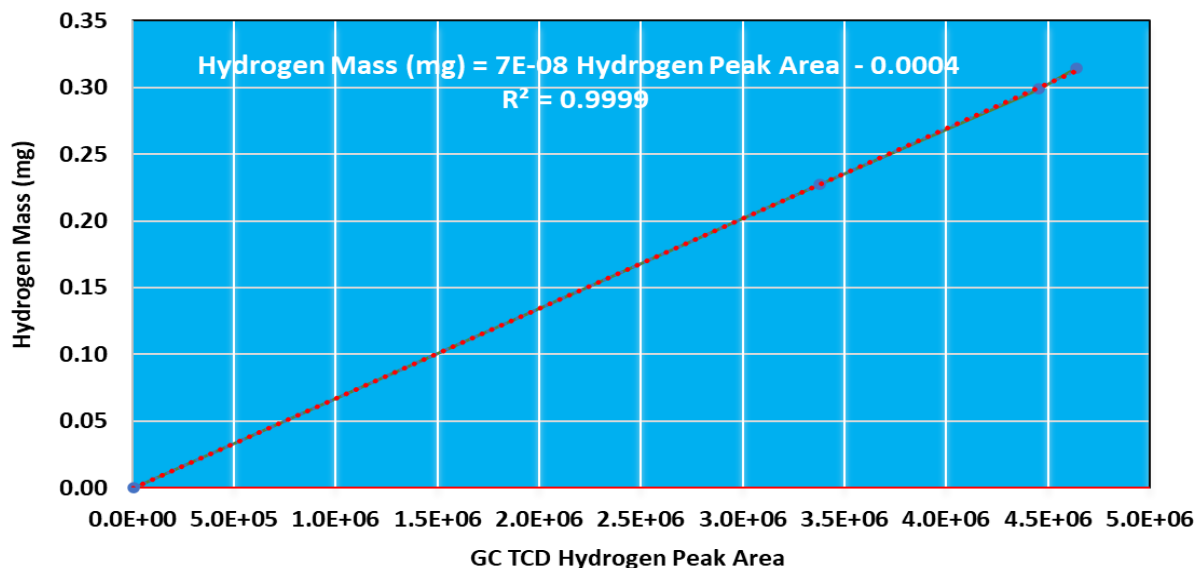
❖ **Purpose:** To determine the elemental hydrogen contents of three (3) Jet-A samples. The data will be used for calculating net heat of combustion of the Jet-A fuels.

❖ **Method:** ASTM D5291-21 (Standard Test Methods for Instrumental Determination of Carbon (C), Hydrogen (H), Nitrogen (N), Sulfur (S) & Oxygen (O) in Petroleum Products and Lubricants).

❖ **Instrument:** Flash 2000 Elemental Analyzer for Carbon (C), Hydrogen (H), Nitrogen (N), Sulfur (S) & Oxygen (O), equipped with a liquid automatic injection system (Thermo Fisher Scientific).

❖ **Injection volume:** 1.0 to 5.0 μL .

❖ **Carrier & Reaction Gases:** High purity helium (He) & oxygen (O_2).



Hydrogen Contents & Net Heat of Combustion

- ❖ Method: ASTM D4809-00 Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
- ❖ Instrument: Parr 6200 Precise Bomb Calorimeter with a Parr Water Handling System.
- ❖ Requirement of Net Heat of Combustion for a Jet-A fuel is min **42.8** MJ/kg (ASTM D1655 – Standard Specification for Aviation Turbine Fuels.).

Jet-A Fuel	Gross Heat (MJ/kg)	Hydrogen (Mass%)	Net Heat (MJ/kg)
ASTM D1665			Min. 42.8
Aft Tail Tank	46.038	14.46	43.0
Left Engine Heat Exchanger	45.949	14.44	42.9
Right Engine Heat Exchange	45.949	14.48	42.9



Water Contents of Jet-A Fuels

- ❖ Purpose: To determine the dissolved water in twelve (12) Jet-A samples.
- ❖ Method: ASTM D6304-20 (Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration).
- ❖ Instrument: 852 Titrand, Metrohm.
- ❖ The results are the average of two tests.



Fuel Sample	Water (ppm)	Fuel Sample	Water (ppm)
100 ppm Standard	102.2	R-Eng Fuel Flow Meter	32.7
FBO ACY Jet-A	33.3	AFT Tail Tank	89.9
R-Eng Heat Exchanger	40.7	L-Eng Heat Exchanger	47.5
R-Eng Fuel Filter Bowl	36.6	Left Main xxxx	41.1
R-Eng Fuel Pump	44.1	L-Eng Fuel Filter Bowl	36.0
APU	29.1	L-Eng Fuel Control Unit	37.1
R-Eng Fuel Control	36.3	L-Eng Fuel Flow Meter & Fuel Manifold	41.5

Fuel Existent Gum Test

- ❖ Instrument: A solid-state heater & a jet air evaporator.
- ❖ Method: ASTM D381-22 (Standard Test Method for Gum Content in Fuels by Jet Evaporation).
- ❖ Instrument: SETA Existent Gum Solid Block Tester
- ❖ Sample Volume: 50 mL
- ❖ Testing conditions: $T = 235\text{ }^{\circ}\text{C}$, Time = 30 min
- ❖ Jet Gas: Air (Note: AFRL does not have a steam generator, so air was used.)

Jet-A Fuel		Existent Gum (mg/100 mL Fuel)
ASTM D1665		Max 7
FBO ACY Jet-A		4
Aft Tail Tank		49
Left Engine Heat Exchanger		63
Right Engine Heat Exchange		51



Existent Gum observation for Three Fuels

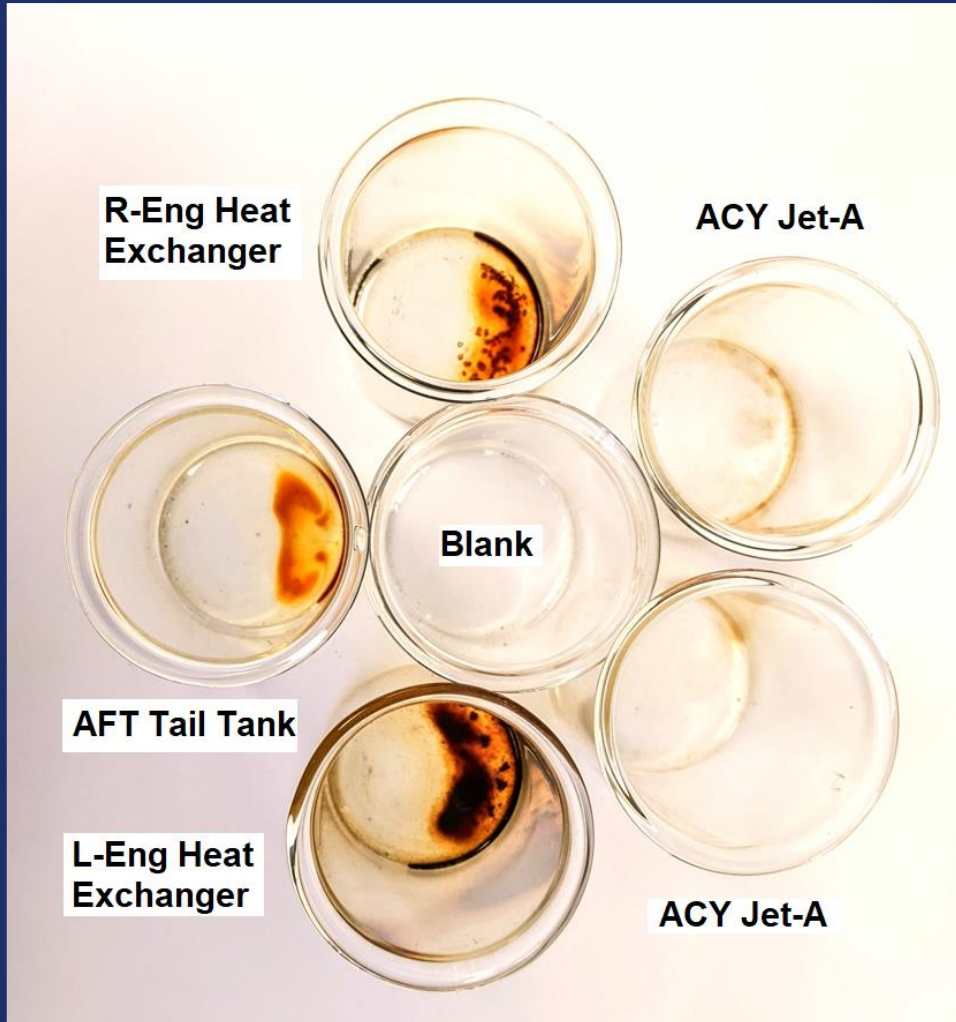


Right Engine Heat
Exchanger

Left Engine Heat
Exchanger

AFT Tail Tank

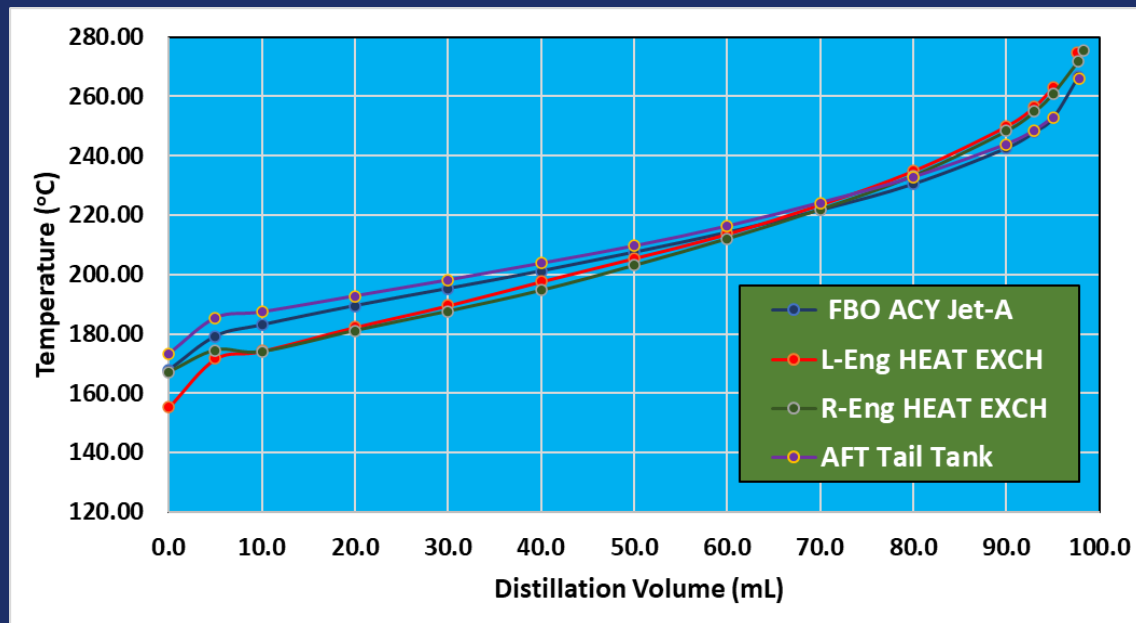
Comparison of Jet-A Fuel Existent Gums



Under existent gum testing conditions (235 °C, 30 min & jet air), significant existent gums have been observed for the three fuel samples compared with that for ACY FBO Jet-A fuel. The formation of fuel gum is resulted from fuel autoxidation during fuel storage or transportation from fuel tank to engines. It is noted that standard test requires steam as an evaporation gas. Currently, AFRL does not have a steam generator.

Distillation Performances of Four (4) Jet-A Fuels

- ❖ Test Method: ASTM D86-23ae1 (Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure) under Group 4 conditions.
- ❖ Instrument: Normal Lab NDI 450 Distillation Tester.
- ❖ Fuel Initial Volume: 100 mL.
- ❖ After 80 vol.% evaporation, L-Eng & R-Eng Heat Exchanger fuels require higher temperatures than ACY Jet-A. The result suggests that the two fuels contain higher weight components in the fuels.



Distillation Curves



Distillation Tester

Distillation Performances of Four Jet-A Fuels

Specification	D1665	ACY Jet A	L-Eng Heat Exchanger	R-Eng Heat Exchanger	AFT Tail Tank
10% Recovered Temp. (°C)	Max 205	183.03	174.23	173.909	187.38
50% Recovered Temp. (°C)	Report	207.48	205.47	203.03	209.58
90% Recovered Temp. (°C)	Repot	242.54	248.89	248.33	243.87
Initial Boiling Point (°C)		161.86	155.35	167.09	173.35
Final Boiling Point (°C)		266.81	274.79	275.49	265.88
Recovery (mL)		97.714	97.610	97.91	97.905
Residue (mL)	Max 1.5	1.5	1.5	1.3	1.5
Loss (mL)	Max 1.5	0.786	0.890	0.802	0.595

Fuel Density & Viscosity Analyses

- ❖ Test Method: ASTM D7042-21a (Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer) and the Calculation of Kinematic Viscosity.
- ❖ Instrument: Anton Paar SVM 3000 Stabinger Viscosity Meter with a Julabo FP50 Cooler to provide cryogenic cooling power.



Density of Jet-A Fuels

ASTM D1665 specification for Jet A density: 0.775 to 0.840 g/mL @ 15 °C.

Fuel Sample	Density (g/mL)		Fuel Sample	Density (g/mL)	
Temperature	-24 °C	24 °C		-24 °C	24 °C
FBO ACY Jet-A	0.8336	0.7992			
R-Eng Fuel Flow Meter	0.8315	0.7971	Aft Tail Tank	0.8369	0.8027
R-Eng Heat Exchanger	0.8316	0.7972	L-Eng Heat Exchanger	0.8316	0.7972
R-Eng Fuel Filter Bowl	0.8318	0.7971	Left Main xxxx	0.8315	0.7971
R-Eng Fuel Pump	0.8315	0.7969	L-Eng Fuel Filter Bowl	0.8316	0.7972
R-Eng Fuel Control	0.8317	0.7972	L-Eng Fuel Control Unit	0.8324	0.7979
APU	0.8317	0.7972	L-Eng Fuel Flow Meter & Manifold	0.8313	0.7968

Dynamic Viscosity (Absolute Viscosity) of Jet-A Fuels

Fuel's Dynamic Viscosity measures fuel flow resistance to the movement of one layer of a fluid over another.

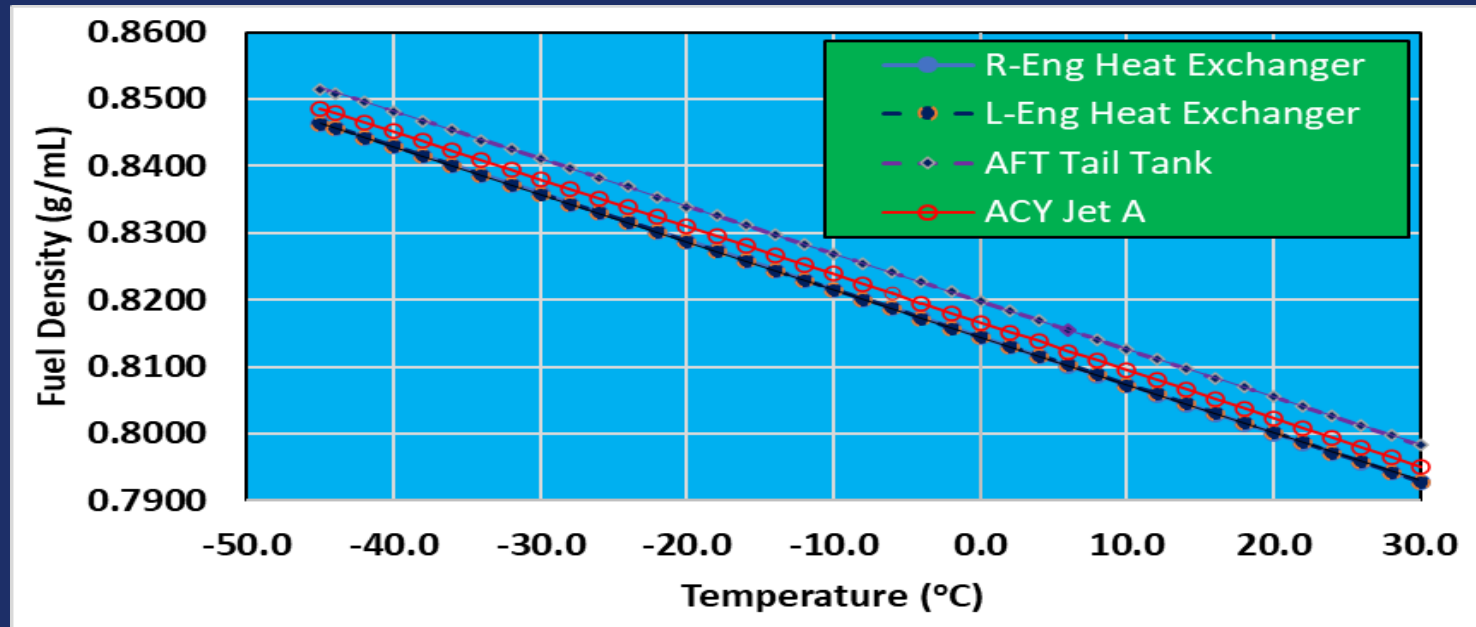
Fuel Sample	Dynamic Viscosity (mPa*s)		Fuel Sample	Dynamic Viscosity (mPa*s)	
Temperature	-24 °C	24 °C		-24 °C	24 °C
FBO ACY Jet-A	4.6775	1.4493			
R-Eng Fuel Flow Meter	4.1965	1.3491	Aft Tail Tank	4.9602	1.5046
R-Eng Heat Exchanger	4.2184	1.3633	L-Eng Heat Exchanger	4.2782	1.3816
R-Eng Fuel Filter Bowl	4.1965	1.3491	Left Main xxxx	4.2502	1.3345
R-Eng Fuel Pump	4.2133	1.3691	L-Eng Fuel Filter Bowl	4.1383	1.3476
R-Eng Fuel Control	4.2392	1.3691	L-Eng Fuel Control Unit	4.2612	1.3728
APU	4.2730	1.3817	L-Eng Fuel Flow Meter & Manifold	4.2136	1.3638

Kinematic Viscosity of Jet-A Fuels

Fuel's Kinematic Viscosity is the ratio of fuel Dynamic (Absolute) Viscosity to fuel's density (Kinematic viscosity = Dynamic viscosity/density mm²/s).
ASTM D1665 specification: Max 8.0 mm²/s kinematic viscosity @ 15 °C.

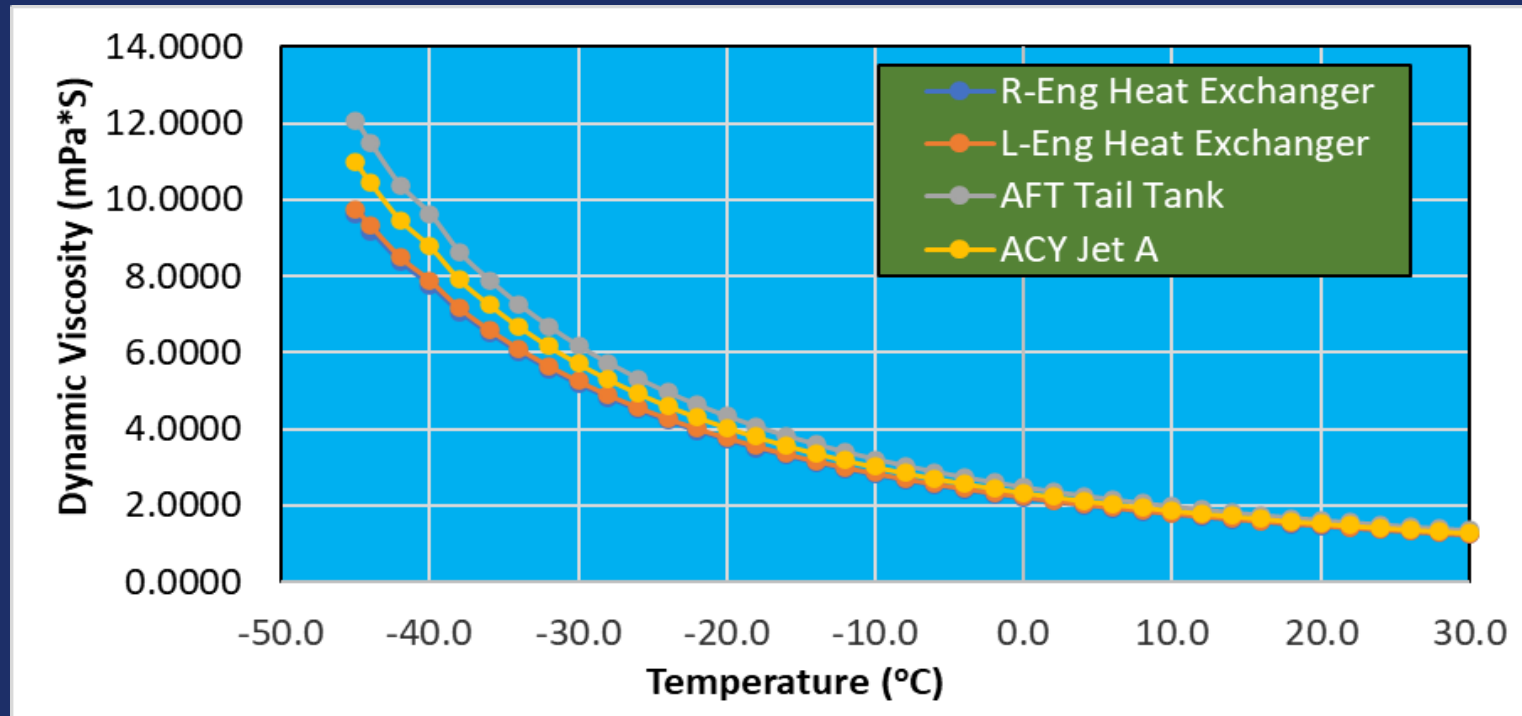
Fuel Sample	Kinematic Viscosity (mm ² /s)		Fuel Sample	Kinematic Viscosity (mm ² /s)	
Temperature	-24 °C	24 °C		-24 °C	24 °C
FBO ACY Jet-A	5.6111	1.8135			
R-Eng Fuel Flow Meter	5.1113	1.7203	Aft Tail Tank	5.9266	1.8744
R-Eng Heat Exchanger			L-Eng Heat Exchanger	5.1446	1.7330
R-Eng Fuel Filter Bowl	5.0452	1.6925	Left Main xxxx	4.8729	1.6725
R-Eng Fuel Pump	5.0726	1.7102	L-Eng Fuel Filter Bowl	4.9778	1.6913
R-Eng Fuel Control	5.0726	1.7102	L-Eng Fuel Control Unit	5.1243	1.7223
APU	5.0911	1.8744	L-Eng Fuel Flow Meter & Manifold	1.7114	5.0681

Fuel Density as a Function of Temperature



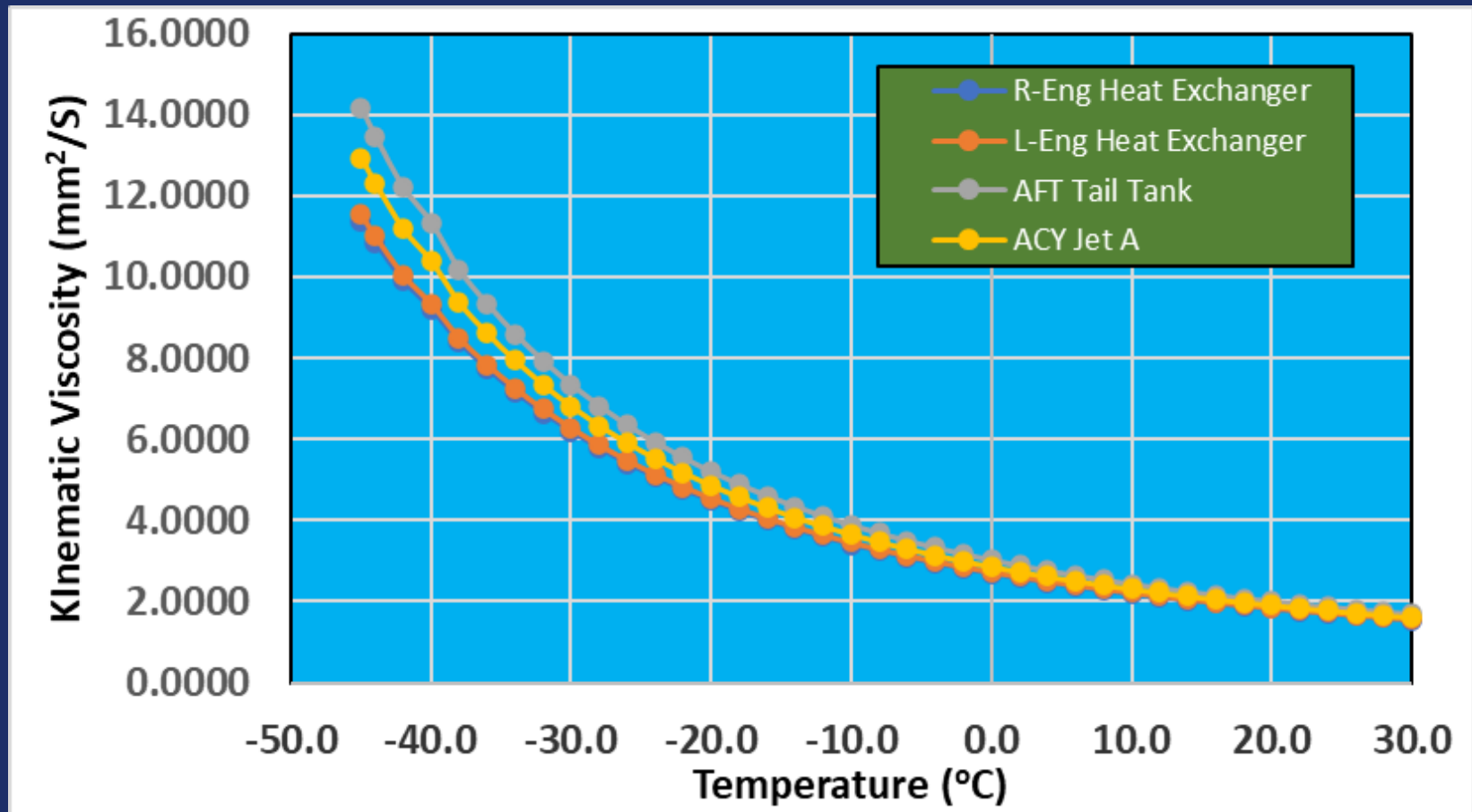
Fuel	Density	R ²
ACY Jet A	Density (g/mL) = -0.00007 · Temp(°C) + 0.8166	1.000
AFT Tail Tank	Density (g/mL) = -0.00007 · Temp(°C) + 0.8198	1.000
L-Eng Heat Exchanger	Density (g/mL) = -0.00007 · Temp(°C) + 0.8144	1.000
R-Eng Heat Exchanger	Density (g/mL) = -0.00007 · Temp(°C) + 0.8144	1.000

Dynamic Viscosity as a Function of Temperature



- ❖ The dynamic viscosity curves for Left & Right Engine Heat Exchanger fuels are almost overlapped, indicating that two fuels are from the same source & underwent a similar condition.
- ❖ AFT Tail Tank fuel shows slightly higher viscosities than those of ACY & two other fuels due to the higher water contamination at the measurement temperature range .

Kinematic Viscosity as a Function of Temperature



Summary of Testing Results (1)

Aviation Fuels Research Lab has performed the following tests for twelve (12) Jet-A fuel samples. An FBO Jet-A fuel sample taken from the Atlantic City International Airport was also tested as a reference fuel:

- (1). Fuel water content (13 fuel samples)
- (2). Fuel Density (13 fuel samples)
- (3). Fuel Dynamic & Kinematic Viscosity (13 fuel samples)
- (4). Fuel Distillation performance (4 fuel samples)
- (5). Fuel Existent Gum (4 fuel samples)
- (6). Hydrogen content (3 fuel samples)
- (7). Net Heat of combustion (4 fuel samples)

Summary of Testing Results (2)

- (1). The Density, Viscosity and Distillation of three Jet-A fuel samples, taken from Left Engine Heat Exchanger, Right Engine Heat Exchanger & AFT Tail Tank have indicated that three fuels were from a same fuel source.
- (2). Fuel density and viscosity as functions of temperature for the Left Engine Heat Exchanger & Right Heat Exchanger fuels are almost overlapped, suggesting that these two fuel samples have been undergone very similar oxidation conditions including temperature & time.
- (3). Under current testing conditions (235 °C 30 min & Jet Air Evaporation), fuel existent gum contents for Left Engine Heat Exchanger, Right Engine Heat Exchanger & AFT Tail Tank fuels are seven (7) to nine (9) times greater than the ASTM D1665 specification (max 7 mg/100 mL fuel). The fuel existent gum tests were carried out under jet air flow not under steam, more accurate results require additional tests. Fuel gums may result from (1) fuel oxidation during storage & under heat or (2) constatation from fuel tanks or fuel lines.

Summary of Testing Results (3)

- (4). Fuel densities for all twelve (12) fuels meet the ASTM D1665 requirement (**max 0.840 g/mL & min 0.775 g/mL of fuel** at 15 °C).
- (5). Fuel kinematic viscosities for all twelve (12) fuels are below the max 8.0 mm²/s at 15 °C specified in ASTM D1665.
- (5). Fuel water content tests have shown that fuel taken from AFT Tail Tank contains much higher water (**89.9 ppm**) than those from the other eleven (11) fuel samples. Free water has been observed in the bottom of the sample jar for this fuel.
- (6). Fuel net heat of combustion for three fuel samples (Left Engine Heat Exchanger, Right Engine Heat Exchanger & AFT Tail Tank) meet the net heat of combustion (**min 42.8 MJ/kg of fuel**) specified in the ASTM D1665.
- (7). Three fuel samples (Left Engine Heat Exchanger, Right Engine Heat Exchanger & AFT Tail Tank) have shown similar fuel distillation behaviors. Fuel distillation performances in terms of 10 vol.% recovery & residues & losses meet the requirements specified in the ASTM D1665.
- (8). Based on fuel viscosity data, no significant “Apple Jelly” contamination has been found for all twelve (12) fuel samples.