FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Perspectives on Fully Synthesized SAF

Joshua Heyne (UD),
Gurhan Andac (GE), Stephen Kramer (P&W), Joseph Ellsworth (Boeing), Peter Herzig (Volpe), and Kristin Lewis (Volpe)

6 April 2022
FAA ASCENT
Alexandria, VA

ASCENT
AVIATION SUSTAINABILITY CENTER

Why 100% SAF?

- Aviation impact reduction:
  1. Environmental: CO_2 and (potentially) contrail reductions via nvPM seeding
  2. Human health: nvPM and (potentially) NO_x
- Required to meet industry's "net-zero carbon emissions" goals

A4A, https://www.airlines.org/airlines-fly-green/, accessed 30 March 2022

Current major needs regarding SAF:

- Prince competitiveness with conventional jet (cost, policy)
- Production: 1000X increase in SAF (availability)
- 100% SAF/Synthetic Standard: "drop-in" SAF (ASTM task force)

Drop-in: fleetwide and infrastructure compatible

Current issue:

- Nearly all currently commercially available SAF is non-drop-in unblended and not equivalent to Jet A/A-1 (i.e., drop-in) - demonstrations of "100% SAF" require special arrangements

Jet fuel must meet detailed specs for safety

Aircraft and engines are **certified** for fuel **specified in a standard**, such as Jet A/A-1 (ASTM D1655).


Designation: D1655 – 19

Standard Specification for Aviation Turbine Fuels[1]

Fuel Specification

Engine Operating Limitations
- fuel specification

Aircraft Operating Limitations
- engine limitations for aircraft limitations

Aircraft Operator (Airlines) Operating Rules
- must adhere to aircraft and engine limitations

Engine, aircraft, and infrastructure do not 'see' any difference between a SAF blend and a conventional fuel.

All approved SAF blends are currently "drop-in" or "equivalent" to Jet A/A-1

Drop-in = fleetwide infrastructure compatible

If a fuel were not "equivalent" to Jet A/A-1, the fuel will require its own fuel specification, the fuel would require separate handling, and the aircraft and the engine would require certification to that fuel

SAF Qualification Considers Many Issues

ASTM D4054 defines "fit-for-purpose" properties (properties not specified in D1655 but are limited to an expected range that is acceptable for jet fuels) in addition to Jet A specifications

Combustion and emissions related:

- Ignition, altitude relight
- Cold viscosity
- Freeze point
- Atomization
- Surface tension
- Density
- Lean Blowout
- Flash point
- Distillation curve
- Heat of combustion
- Heat capacity
- Thermal conductivity
- Hydrogen content, H/C ratio
- Aromatic content
- Sulfur content
- Smoke point
- Cetane number
- Combustion dynamics
- Combustion acoustics

Other components:

- Cold viscosity system performance and solidification
- Vapor pressure characteristics and impact on the performance of various pumps
- Bearing and gear cavitation potential
- Low lubricity performance
- Seal compatibility
- Thermal stability and tendency to varnish
- Effects on heat transfer performance
- De-congealing performance
- Buildups and deposits
- Dynamic shaft seals performance
- Icing characteristics
- Entrained air and bulk modulus
- Entrained water
- Biocide compatibility
- Filter life and pressure drop
- Matched valve compatibility
- Dynamics and stability
- Resistance to ignition, flammability

Colket M, Heyne J., Fuel Effects on Operability of Aircraft Gas Turbine Combustors. AIAA, 2021. https://doi.org/10.2514/4.106040

Edwards, T., "Reference Jet Fuels for Combustion Testing", https://www.caafi.org/news/pdf/Edwards_AIAA-2017-0146_Reference_Jet_Fuels.pdf

Unblended SAF vs Jet A: Is it 🍎, 🍏, or 🍌?

Example criteria for indistinguishable and Jet A/A-1-like:

- 🍎 Indistinguishable from Jet A/A-1, ***drop-in****
- 🍏 Like Jet A/A-1, *limited fleet compatible,* ***non-drop-in***
- 🍌 Not-like Jet A/A-1 *not acceptable as a stand-alone jet fuel*

ASTM D7566 qualified pathways:

	Blend limit	
FT-SPK	50% →	🍏
HEFA-SPK*	50% →	🍏
HFS-SIP	10% →	🍌
FT-SKA	50% →	🍎
ATJ-SPK	50% →	🍏 🍌 (depends on the process/ feedstock)
CHJ	50% →	🍎
HC-HEFA-SPK	10% →	🍏

**Example criteria for indistinguishable and Jet A/A-1-like:*

	🍎	🍏
aromatics	~17%	~0%
energy cont.	~43.2MJ/kg	+ 0-2%
density	~800kg/m^3	- 0-8%
Cetane #	~45	± 20-30%
Sulfur	~0ppm (synth.) 500-800ppm (conv.)	~0ppm

Most available SAF blend component today

- ***There is variation of composition among pathways and even among producers for a pathway***
- ***Pathways are not all equivalent to Jet A/A-1 unblended.***

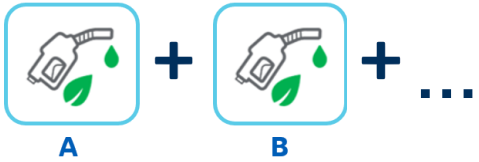
**Drop-in: fleetwide and infrastructure compatible*

Two paths for 100% drop-in SAF qualification

1) Single 100% pathway or…

or

2) Blending of (two or) more blend components



Possible future pathways:

(ATJ, HEFA, or HTL)-SKA → 🍎

HDO-SAK → 🍌

CPK-0 → 🍎 or 🍏 (TBD)

HEFA-SPK + HDO-SAK → 🍎

🍏 🍌

Example criteria for indistinguishable and Jet A/A-1-like:

🍎 Indistinguishable from Jet A/A-1, ***drop-in***

🍏 Like Jet A/A-1, *limited fleet compatible,* ***non-drop-in***

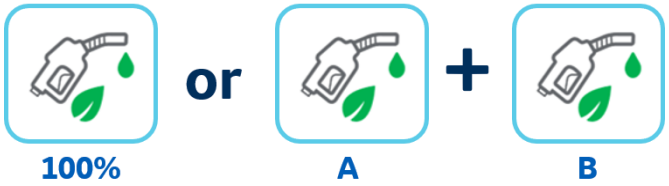
🍌 Not-like Jet A/A-1 *not acceptable as a stand-alone jet fuel*

Blending of *approved* blend components will open a door to get to drop-in 100% SAF by blending non-drop-in blend components

More pathways on the way…initially most, if not all, will be approved at 50% but could meet 100% drop-in SAF requirements when defined

Drop-in vs Non-Drop-in SAF implications

	Drop-in	Non-Drop-in
Composition:	Fully formulated Jet A/A-1	**Not** Jet A/A-1
Applicability:	**Infrastructure and fleet wide drop-in**	**Designated** aircraft/engines only
Specification:	ASTM D7566	**New standard** needed
Regulatory Certification:	**Not required**	**Required** for each intended aircraft/engine model
Infrastructure:	**No impact**	**Separate** supply chain/handling/storage required
Candidate pathways:	CHJ (D7566 Annex A6), FT-SKA (D7566 Annex 4), future: ATJ-SKA, HEFA-SPK + HDO-SAK	FT-SPK (D7566 Annex A1) HEFA-SPK (D7566 Annex A2) ATJ-SPK (D7566 Annex A5) *certain types*



ASTM Standardization In Process

100% synthetic fuel standard*

Designation: D7566 – 21

Standard Specification for
Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

ASTM Task Force formed in Q1 ’21,
Chair: G. Andac (GE),
Vice-Chair: M. Rumizen (FAA)

“Standardization of Jet Fuel Fully Comprised of Synthesized* Hydrocarbons”:

- Modify ASTM D7566 drop-in/Jet A equivalent standard to allow 100% synthetic fuel
  - Establish a new/additional set of requirements for 100% synthetic fuel (“fit-for-purpose” to insure drop-in nature)
  - Includes blending of approved synthetic blend components
  - Once approved, 100% synthetic fuel is reidentified as Jet A/A-1

A separate ASTM Task Force is expected to be formed on “non-drop-in” standardization

- ASTM DXXXX for 100% non-drop-in synthetic fuel (such as SPK)
  - No reidentification of SAF as Jet A/A-1, but development a standard that could be used by OEMs to certify their equipment with new standard
- Multi-year effort

*Standard is for synthetic fuels, sustainable or not