FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Alternative Jet Fuel Test and Evaluation

Project 31a

Steve Zabarnick, Matthew DeWitt, Richard Striebich, Linda Shafer,
John Graham, Joshua Heyne, and Zachary West
University of Dayton Research Institute

FAA Program Manager- Nate Brown

ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- Cost effective, coordinated performance testing to ASTM D4054 for promising candidate alternative fuels
- Many previous evaluations funded by AFRL – no longer
- UDRI has been performing most of these evaluations at AFRL and on-campus under AFRL funding
- Continue work with FAA COE funding

Objectives

- Identify candidate alternative jet fuels
- Perform engine, component, rig, or laboratory tests to ASTM D4054
- Identify and conduct unique testing beyond D4054
- Obtain data for baseline and alt fuels effects on performance, maintenance, and reliability
- Report relevant performance data to FAA, ASTM, etc.

Outcomes and Practical Applications

- Outcomes
  - Increased supply of secure, safe alternative fuels
  - Research report data for ASTM committee for approving candidate fuels as Appendices in ASTM D7566
- Practical applications
  - Collaboration with NJFCP Area 6 Referee combustor (Project 30) and Database (Project 33)

Lanzatech / PNNL HT-ETJ

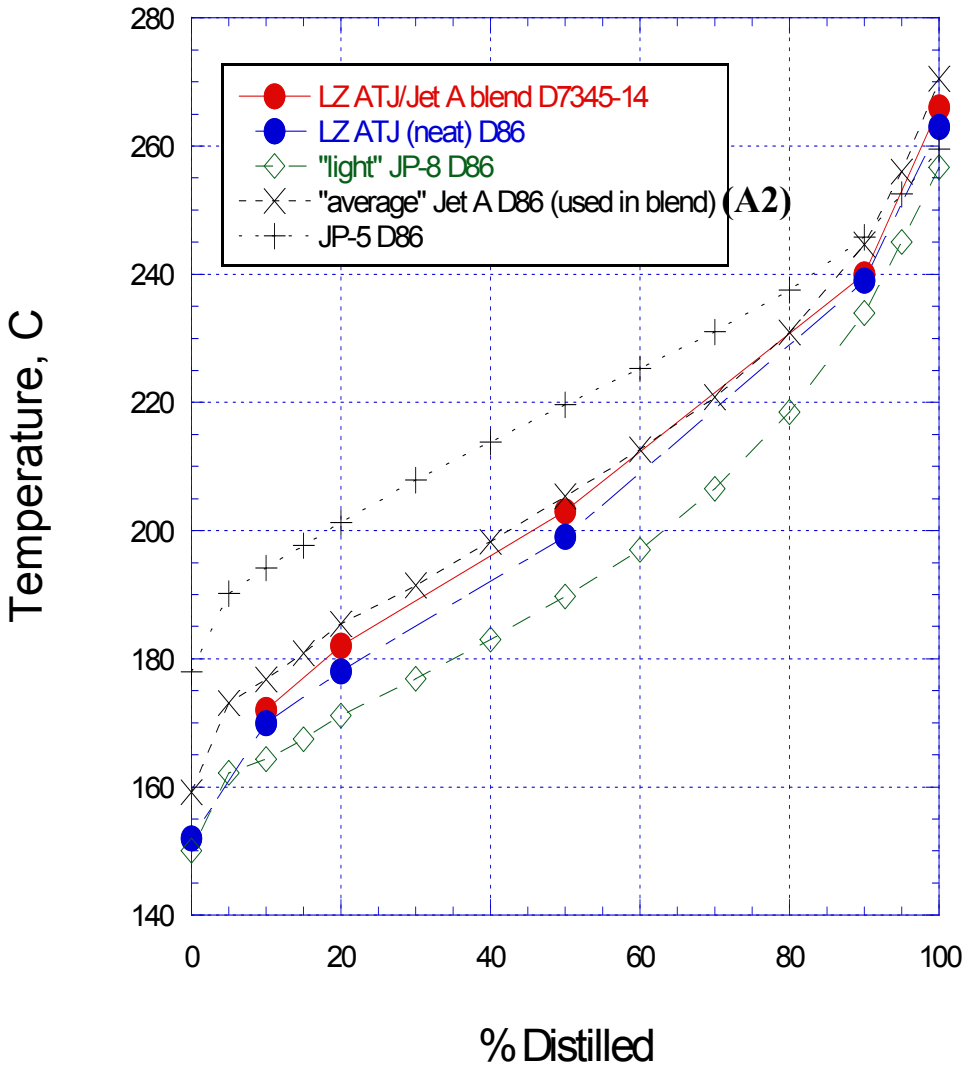
- HT-ETJ
  - Hydro-treated– ethanol to jet (ATJ)
- Identification numbers
  - Lanzatech ATJ- POSF-12381
  - Nominal Jet A (A2) used for blending- POSF-10325
    - A2 fuel in the National Jet Fuels Combustion Program
  - 50/50 ATJ/A2- POSF-12382
- Specification tests conducted (ASTM D-7566)
  - Selected tests due to small volumes available
- Non-specification tests
  - GC, GC-MS, GCxGC
  - Hydrocarbon type (ASTM D2425 and GCxGC)

Specification Test Results

Specification Test	ASTM Method	D7566 Spec Requirement *(SPK)*	HT-ETJ POSF-12381	HT-ETJ/ Jet A Blend POSF-12382	Jet A POSF-10325 (A2)
Distillation:	**D86***			**D7345***	
10% recovered, °C		**≤205**	170	172	177
20% recovered, °C			178	182	184
50% recovered, °C			199	203	204
90% recovered, °C			239	240	244
EP, °C		**≤300**	263	266	270
Residue, % vol		**≤1.5**	1.4	1.4	1.2
Loss, % vol		**≤1.5**	0.7	0.5	0.8
T50-T10, °C		**≥15**	29	31	27
T90-T10, °C		**≥40** *(≥22)*	69	68	67
Density @ 15°C, kg/L	**D4052**	**0.775 - 0.840** *(0.730 - 0.770)*	0.763	0.782	0.803
Flash point, °C	**D93***	**≥38**	44	46	48
Freeze Point, °C	**D5972**	**≤-40**	<-75	-57	-50
Viscosity @ -20°C, cSt	**D445**	**≤8**	4.4	4.4	4.7
Viscosity @ -40°C, cSt	**D445**	**≤12**	9.3	9.1	9.2

- ATJ and 50/50 Blend subjected to a limited number of spec tests.
- ATJ and Blend met spec (D7566) requirements.
- Results of blend compared to those of the blend “nominal” Jet A.

Distillation Ranges



- ATJ, Blend, and Jet A distillation temperatures fall between the “light JP-8” and the JP-5.
- Blend distillation range is similar to “nominal” Jet A distillation range.

Specification Test Results

Specification Test	ASTM Method	D7566 Spec Requirement *(SPK)*	HT-ETJ POSF-12381	Jet A POSF-10325 (A2)
Thermal Stability @ 260°C: *(325°C)*	**D3241***			
Tube Deposit Rating		**≤3**	1	1
Change in Pressure, mm Hg		**≤25**	0	0
Existent Gum, mg/100mL	**D381***	**≤7.0**	<1	<1
Hydrogen Content, % mass	**D7171***	**≥13.4**	15.4	13.8
Heat of Combustion (measured), MJ/Kg	**D4809***	**≥42.8**	43.9	43.3
Lubricity (BOCLE), wear scar mm	**D5001***	**0.85**	0.64	0.59

- ATJ subjected to other indicator spec tests.
- ATJ met D7566 spec requirements including JFTOT at 325° C.
- All but JFTOT at 325° C are Blend requirements.
- If ATJ and Jet A both meet requirements, 50/50 Blend should meet the requirements.

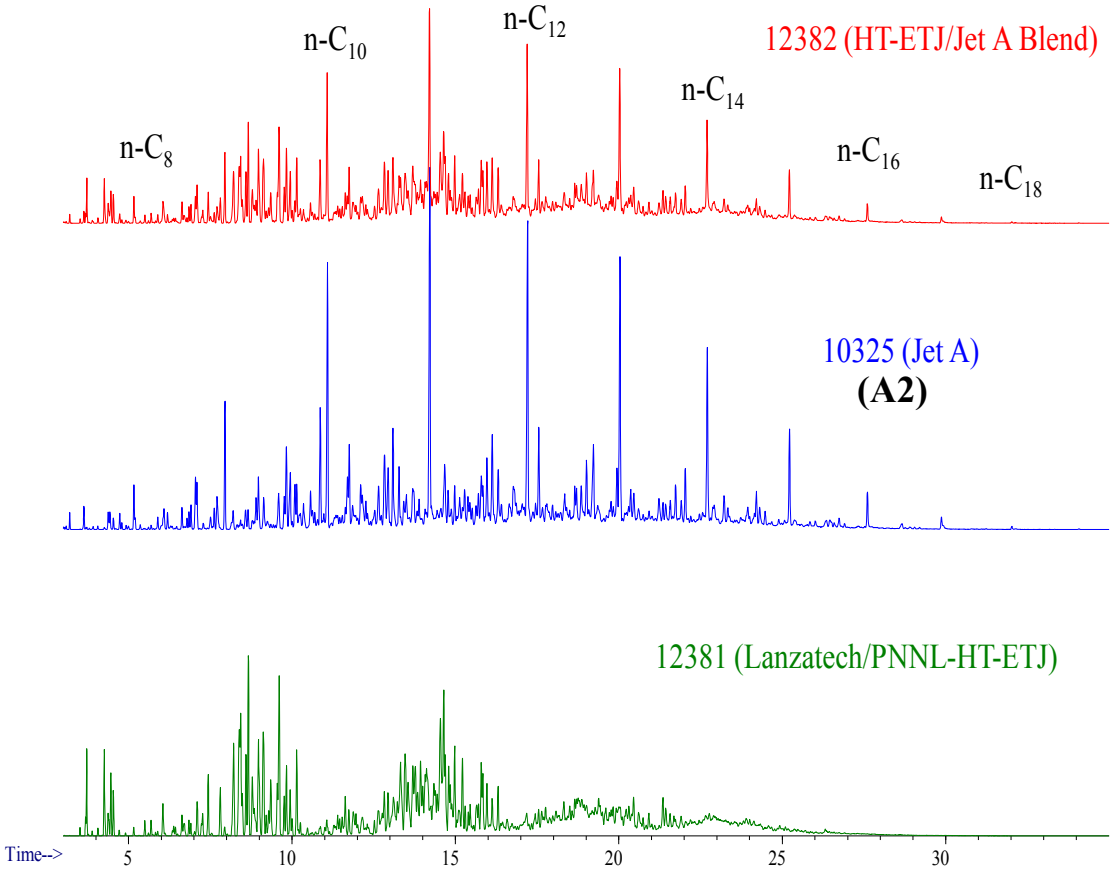
Hydrocarbon type

	D7566 Spec Requirement *(D1655)*	HT-ETJ/ Jet A Blend POSF-12382	Jet A POSF-10325 (A2)
D6379 (volume%)			
Monoaromatics		7.2	14.6
Diaromatics		0.9	1.8
Total Aromatics	**≥8.4** *(≤26.5)*	**8.1**	**16.4**

	D7566 Spec Requirements for SPK	HT-ETJ POSF-12381	50/50 Blend POSF-12382	Jet A POSF-10325 (A2)
D2425 (mass%)				
Paraffins (normal + iso)		**93**	**73**	**49**
Cycloparaffins	**≤15**	**7**	**18**	**34**
Alkylbenzenes		<0.2	6.2	11.6
Indans and Tetralins		<0.2	1.3	3.0
Indenes and C_nH_{2n-10}		<0.2	<0.2	0.3
Naphthalene		<0.2	<0.2	0.2
Naphthalenes		<0.2	0.9	1.9
Total Aromatics	**≤0.5**	**<0.2**	**8.7**	**17.2**

- ATJ passes SPK spec for aromatics and cycloparaffins

GC-MS Comparisons



- ATJ appears "lighter" (contains more front-end volatile compounds) than Jet A
- Non-normal distribution of compounds and low normal paraffins in ATJ

GCxGC results summary

	HT-ETJ POSF-12381	50/50 Blend POSF-12382	Jet A POSF-10325
Ave Molecular Wt (g/mole)	166	163	159
	Weight %	Weight %	Weight %
Aromatics			
Alkylbenzenes	<0.01	6.52	12.90
Alkylnaphthalenes	<0.01	1.14	2.33
Cycloaromatics	<0.01	1.65	3.43
Total Aromatics	**<0.01**	**9.32**	**18.66**
Paraffins			
iso-Paraffins	97.31	68.17	29.45
n-Paraffins	0.64	10.35	20.03
Total Paraffins	**97.94**	**78.52**	**49.47**
Cycloparaffins			
Monocycloparaffins	2.03	9.24	24.87
Dicycloparaffins	0.02	2.87	6.78
Tricycloparaffins	<0.01	0.05	0.21
Total Cycloparaffins	**2.05**	**12.17**	**31.86**
Ave Molecular Formula - C	11.7	11.6	11.4
Ave Molecular Formula - H	25.4	23.9	22.1

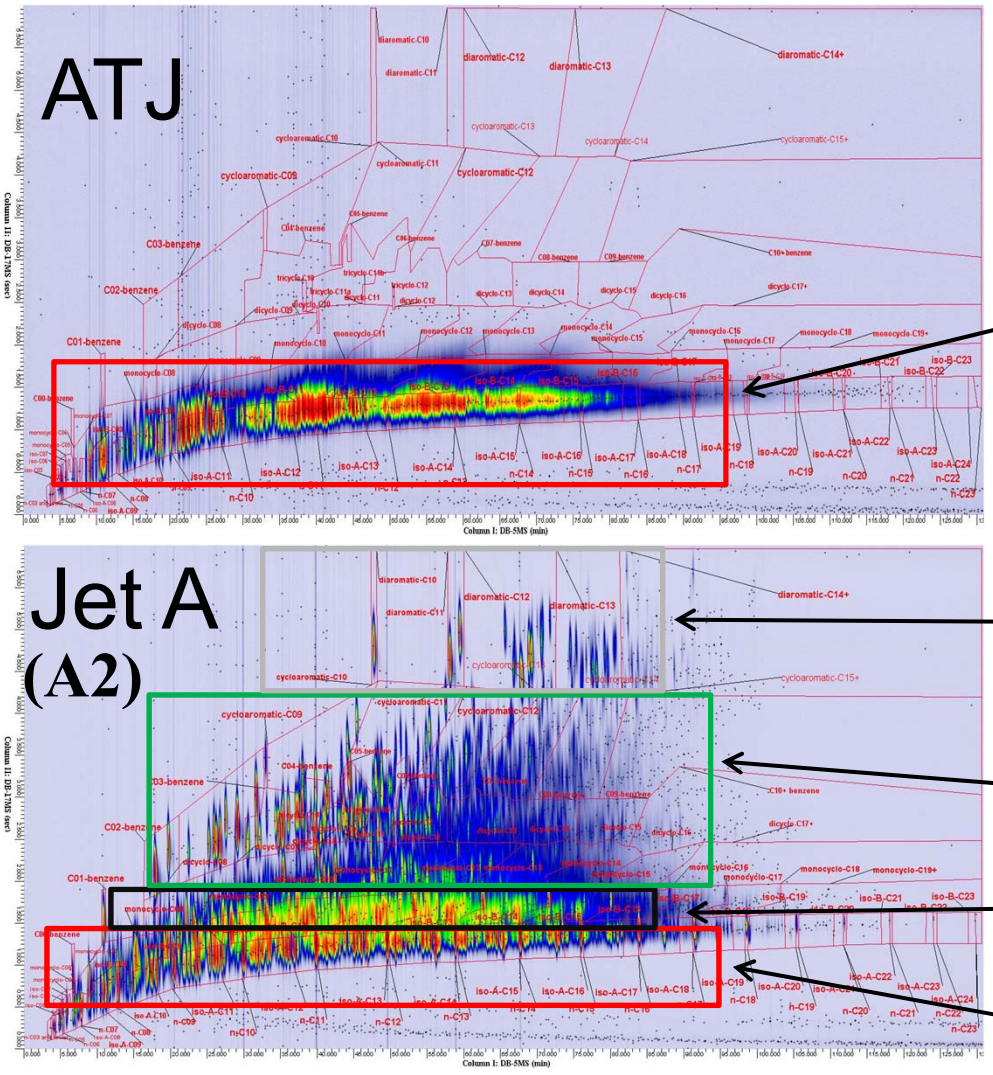
- ATJ contains primarily iso-paraffins
- ATJ cycloparaffins are lower by GCxGC than by D2425
- Highly branched iso-paraffins can cause cycloparaffins to be over-predicted by D2425.
- Molecular weight and carbon/hydrogen ratio can be calculated from GCxGC data.

Isoparaffin distribution

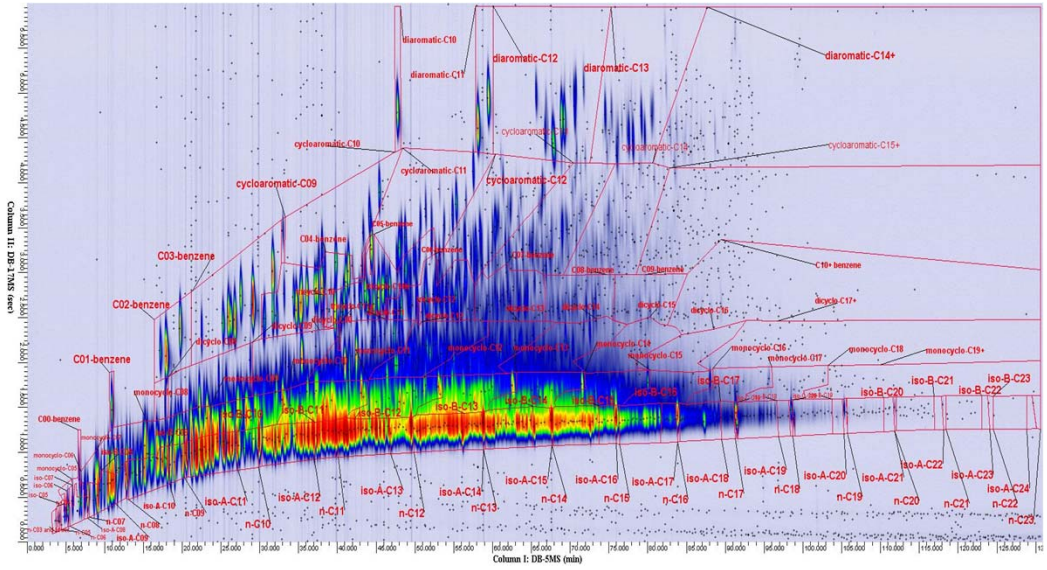
	HT-ETJ	50/50 Blend	Jet A
	POSF-12381	POSF-12382	POSF-10325
Paraffins	**Weight %**	**Weight %**	**Weight %**
iso-Paraffins			
C07 & lower -isoparaffins	0.03	0.1	0.18
C08-isoparaffins	3.44	1.96	0.55
C09-isoparaffins	2.52	1.73	1.2
C10-isoparaffins	20.42	12.74	4.07
C11-isoparaffins	10.14	8.71	5.68
C12-isoparaffins	25.68	16.74	5.41
C13-isoparaffins	12.88	8.82	4.27
C14-isoparaffins	10.25	8.42	4.16
C15-isoparaffins	7.59	5.7	2.41
C16-isoparaffins	2.95	2.14	0.98
C17-isoparaffins	0.92	0.72	0.38
C18-isoparaffins	0.32	0.24	0.11
C19-isoparaffins	0.11	0.09	0.05
C20-isoparaffins	0.03	0.05	0.01
C21-isoparaffins	0.01	<0.01	<0.01
C22-isoparaffins	<0.01	<0.01	<0.01
Total iso-Paraffins	**97.31**	**68.17**	**29.45**

- The iso-paraffin distribution of the ATJ appears to be shifted lower than Jet A
- Highly-branched iso-paraffins are known to elute two carbon numbers lower than those with 1 or 2 methyl groups (more common in Jet A)

GCxGC Chromatograms of ATJ & Jet A



GCxGC Chromatogram of Blend



- Blend appears “Jet A-like” with more iso-paraffins than and fewer cyloparaffins and aromatics than Jet A

Other Testing

- To be performed:
  - Dissolved Gases – oxygen
  - Water Solubility

- Testing at external labs (AFRL funded)
  - Metals Content
  - Derived Cetane Number

- More fuels to come?

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