





Glenn Johnston

Vice President Regulatory Affairs Gevo Inc.

Session 3 – Next in the Production Line: What to Expect for Future Development and Production of Aviation Alternative Fuels



ICAO SEMINAR ON ALTERNATIVE FUELS 2017

ICAO Headquarters, Montréal, 8-9 February 2017







Alcohol to Hydrocarbons



ENVIRONMENT

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- Sugar to Isobutanol fermentation facility owned by Gevo and producing renewable isobutanol.
- Location Luverne, MN
- Creating the feedstock for our demonstration scale ATJ process in Silsbee, Texas





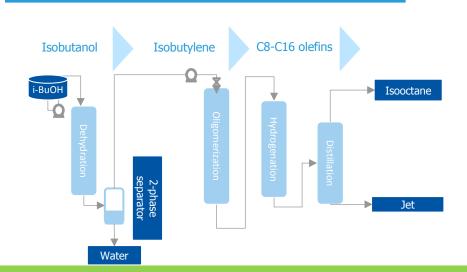
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- ICAO Headquarters, Montréal, 8-9 February 2017
- Proprietary processing based on standard unit operations in a typical petroleum refinery.
- Gevo has been producing jet fuel since 2011 with over 5 years of process performance data on process capability and feedstock, including QA/QC process control charts to 6 SIGMA.
- Process yields have been shown at 98% of theoretical.

Process Flow









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1 D7566 - 16

ASTM D7566 Annex 5

Standard Specification for Aviation Turbine Fuel Containing Synthesized

Hydrocarbons

A5. ALCOHOL-TO-JET SYNTHETIC PARAFFINIC KEROSENE (ATJ-SPK)



Aviation Turbine Fuel Containing Synthesized Hydrocarbons¹

His mandard has been approved for see by appraises of the U.S. Department of Belitter

- 1.1 This specification covers the manufacture of aviation
- 1.2.1 Aviation further fluct manufactured, certified, and

released to all the requirements of Table 1 of this specification (D7566), mosts the impatements of Specification D1655 and shall be regarded as Specification D1655 arbine fact. Duplicate testing is not necessary; the same data may be used for both 17500 and 131055 compliance. Once the fact is released to this specification (D7566) the unique requirements of this be done in accordance with Table 1 of Specification (01658).

1.2.2 Field Blending of synthesized paraffinic kerosin (SPK) blendstocks, as described in Armes Al (FT SPK) Americ A2 (HEFA SPK), Americ A3 (SIP), synthesized paraffinic forestine plus assembles (SPK/A), or Americ A5 (ATI) as described in Appex A4 with D1655 feet rivhich may on the whole or in part have originated as 197566 faels shall be completed batch origination in which case all of the regular mis of Table 1 of this specification (D7566) apply and shall be evaluated. Short from conferences and reprints com-The first shall be reparded as D1055 turbine fact after

- certification and release as described in 1.2.1. 1.2.3 Once a fact is redesignated as D1655 arriation turbine feet, it can be boadled in the same fashion as the appreciant
- 1.5 This specification defines specific types of aviation frend satisfactory for the operation of aircraft and outputs. The

"This specification is under the jurisdiction of ASTM Committee DRI on Transcolor-Produce, Logist Facts, and Latricipes and is the direct exponeithing of Subsecurities DRI, 800 on Females, Tarkine Park.

pecification is intended to be used as a standard in describing components at the place of manufacture but can be used to transfer at all points in the distribution system.

1.4 This specification does not define the quality assurance distribution system continues to comply with this specification after batch certification. Such procedures are defined disentents, for example in ICAO 9977, IEURIC Standard 1530. JIG 1, JIG 2, API 1543, API 1595, and ATA-103.

1.5 This specification does not include all fauls sainfactory for aviation turbine engines. Certain equipment or condition of use may permit a wider, or require a narrower, range of characteristics than is shown by this specification.

LA While solution behind bulk defined by Table I of this specification can be used in applications other than availing turbine engines, requirements for such other applications have not been considered in the development of this specification 1.7 Symbolic blending components, synthetic fisels, and blands of symbolic flash with conventional potroleurs derived facts in this specification have been evaluated and approved in accordance with the principles established in Practice (14)54.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this rafety concerns. If any associated with its use. It is the constituting of the user of this standard to establish upp riste sigets and health practices and determine the applica-

hilly of regulatory Amsterious price to are.

D56 Test Method for Flath Point by Tag Closed Cup Tester

SYNTHETIC PARAPPING KEROSENI (ATLAPK)

of all C2 to C3 alcohols for production of BD committee to perset as of all C2 to C3 alcohols for production of AE3-BPK root sufficient to data is available for those other alcohols. A5.5 Detailed Batch Requirements

AS.5.1 Each back of synthetic blending component shall

conform to the requirements prescribed in Table A5.1. ASS 2 Test Methods-Determine the requirements enumer sted in this asses in accordance with the following lest A5.5.2.1 Denutry-Test Method D1299/IP 160, D4052 or IP

A5.5.2.2 Distillation-Test Methods D86 or IP 125, and

A5523 Flux Priv Test Method D56, D3828, IP 170, or

test methods may be used to certify and recertify jet fact. However, Test Method 132586(IP to its the referee method. An interfahoratory study (IDI:D02-1572**) that evaluated the ability of freezing point methods to detect jet fact comans by diesel fuel determined that Test Methods D5972/IP 435 and of freeze point charges cannot by contamination than Test Methods 11259/4P 16 and U7154/4P 528. It is recommended to certify and recently jet fact using either Test Method D597/3/1 435 or Test Method 17715 MP 529, or both, on the basis of the

espendiscibility and cross-cretaminative struction reported in RR:D02-1572.10 The came of freezing point results outside specification limits by automated methods should be toverdigated, but such results do not disqualify the faul from aviation use if the results from the referee method (Test Method D23864P 16) are within the specification limit. AS.3.2.5 Total Acidby—Test Method D32424P 354. A5.5.2.6 Thronal Stability-Test Method D3241/IP 323

A5.6.2.1 Cyclopuraffor-Tast Method D2425 ASA 2.2 Assentics—Test Method D2425. A5.6.2.3 Puroffier-Test Method D2425. A5.6.2.4 Carbon and Hydrogen-Test Method D5291 A5.6.2.5 Nitrogen—D46(SrIP 379. A5.6.2.6 Water—Test Method D6304 or IP 438. A5.6.2.7 Sulfar-Test Methods D5453 or D2622. Either of these test methods can be used to certify and recertify jet fact. However, Test Method 195453 is the referee method. A5:6:2.8 Metals-Test Method D7111 or DDP 389

A5.6.2.9 Halogens-Test Method D7393

"A Summery of Changes section appears at the end of this standard



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Property (Test Method)	ASTM D1655 Specification (Jet A/Jet A-1)	Typical Jet A-1 (CRC 647)	ATJ-SPK
Freezing Point (ASTM D2386)	-40°C max Jet A -47°C max Jet A-1	- 50°C	<-80°C
Flash Point (ASTM D3828)	38°C min	48°C	48°C
Energy Density (Net Heat of Combustion) (ASTM D3338)	42.8 MJ/kg min	42.9 MJ/kg	43.2 MJ/kg
Thermal Oxidation Stability (JFTOT) (ASTM D3241)	pass	pass	pass
Total Sulfur Content (ASTM D2622)	0.3% max	0.05%	<0.01%



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Extensive Quality Control Process of each lot which includes requirements from ASTM, Joint Inspection Group (JIG), DEFSTAN 91-91 and others.

- Analytical testing completed by Third Party per ASTM D7566 Annex 5 requirements.
- Chain of custody requirements on container cleaning procedures, transfer documents, etc. built in to Gevo standard SOPs.

IAC Port Arthur 6175 Highway 347 Beaumont, Texas 77705-7657 United States of America T: 409-212 9322

F: 409-212-9327

Joh ID:

Client Reference

Terminal / Port / Office:

Certificate of Analysis Submitted Sample Sample Submitted By: South Hampton Refining --Analysis Performed By : IAC Port Arthur

South Hampton Refining - Silsbee, TX 577508-16-0054271 Serial# HGTU 962065-5 (Lot# F02SF47001) - Shore

Reported:	17-Nov-2
ilasion ID :	008-160
Tank 803	

		Submitted	1	
	Sample Number	008-1605125-01-001	1	
Method	Test	Regult	Specification	Pass-Fall
ASTM D3242	Acid Number , mg KOHig	0.000	0.015 Max.	Passed
ASTM D86	Observed Barometric Pressure . mm Hg / kPa	760 / 101.3		
	Inital Boiling Point, *C	169.3		- 1
	5% Recovered . *C	176.4		- 1
	10% Recovered , *C	176.8	205 Max.	Passed
	20% Recovered , *C	177.8		- 1
	30% Recovered , 'C	178.8		- 1
	40% Recovered , 'C	179.7		- 1
	50% Recovered , 'C	180.7		- 1
	60% Recovered , *C	181.1		- 1
	70% Recovered , *C	184.1		- 1
	80% Recovered , *C	189.2		- 1
	90% Recovered , *C	208.9		- 1
	95% Recovered , *C	236.5		- 1
	Endpoint , *C	258.5	300 Max.	Passed
	Recovery , %	98.4		- 1
	Residue, %	1.2	1.5 Max.	Passed
	Loss , %	0.4	1.5 Max.	Passed
	T90-T10 , *C	32.1	21 Min.	Passed
ASTM D56	Manual / Automated	Automatic		- 1
	Flash Point, * C	46.0	38 Min.	Passed
ASTM D1298	API Gravity @ 60°F , * API	55.0		- 1
	Density , kg/m²	758.1	730 - 770	Passed
	Reference Temperature	15.0°C (59°F)		- 1
MC ASTM D5972	Freezing Point, * C	<-75.0	-40 Max.	Passed
ASTM D3241	Test Temperature	325*C	325 Min.	Passed
	Pressure Drop , mm Hg	0.1	25 Max.	Passed
	Heater Tube Deposit Rating	<1	3 Max.	Passed
	Color	None	to peacock or abnormal color Mas	Passed
OL ASTM D2425	Paraffins , % Mass	86.9		- 1
	Aromatics , % Mass	0.1	0.5 Max.	- 1
	Cycloparaffins , % Mass	12.9	15 Max.	- 1
MI ASTM D5291 Method A	Carbon and Hydrogen , % Mass	100.0	99.5 Mn.	- 1
	Hydrogen , % Mass	15.4		- 1
	Carbon , % Mass	84.5		- 1
	Nitrogen , % Mass	<0.8		- 1
ASTM D4629	Nitrogen , ppm (mg/kg)	<0.3	2 Max.	Passed
ASTM D2622	Sulfur Content , ppm (mg/kg)	<3.0	15 Max.	Passed
⁰⁴ ASTM D7111	Aluminum , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Calcium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Phosphorous, ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Chromium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Palladium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Copper , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Iron , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Strontium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Potassium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Tin , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Lithium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
1	Cobait , ppm (mg/kg)	<0.01	0.1 Max.	Passed

IAC Port Arthu

E-409-212-922

Client Refere

Comments

Terminal / Port

Product:

Beaumont, Texas 77705-7657 United States of America T: 409-212 9322



Page 2 of 2

Certificate of Analysis

Tank:	Submitted Sample BioJet
C9 :	
t / Office:	South Hampton Refining Silebee, TX 577508-16-0041472
	Serial# HGTU 962065-5 (Lot# F02SF47001) -

Sample Submitted By: South Hampton Refining -- \$ Analysis Performed By : IAC Port Arthur 15-Sep-2016 04-Oct-2016

	Sample Number	008-1603881-01-006		
Method	Test	Result	Specification	Pass-Fall
ac ASTM 07111	Platinum , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Manganese , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Molybdenum, ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Sodium, ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Nickel , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Lead , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Titanium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Vanadium , ppm (mg/kg)	<0.01	0.1 Max.	Passed
	Zinc , ppm (mg/kg)	<0.01	0.1 Max.	Passed
ASTM D7359	Fluorine , ppm (mg/kg)	<1.0	1 Max	Passed
	Chlorine , ppm (mg/kg)	<1.0	1 Max	Passed
ASTM D6304 Proc. B	Water Content , ppm (mg/kg)	36	75 Max.	Passed
Analysis performed by alter	native IAC laboratory.			•

Lib Analysis performed by External Laboratory

Note Product meets specification per ASTM D7566-16b Annex 5

Narendhar Anumandia, Quality Manag



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True carbon reduction comes from using renewable carbon and not emitting petroleum carbon back into the atmosphere

 Through ASTM D6866 carbon 14 analysis we show our customers that our product is 100% renewable carbon and does not contain petroleum derived carbon.



Biobased and Biogenic Carbon Testing Laboratory ISO/IEC 17025-2005 Accredited

4985 SW 74 Court Miami, FL 33155 USA Tel: 305-667-5167 Fax: 305-663-0964 info@betalabservices.com www.betalabservices.com

Reta Analytic Inc



Biobased and Biogenic Carbon Testing Laboratory ISO/IEC 17025:2005 Accredited

4985 SW 74 Court Mami. Fl. 33155 USA Tel: 305-667-5167 Fax: 305-663-0964 info@hetalabsenices.com www.betalabservices.com

Summary of Results - % Biogenic Carbon Content; ASTM D6866-16 Method B(AMS)

Ms. Maureen Sullivar

December 02 2016 December 00 2016

Percent Biogenic Carbon 100 % Laboratory Number Beta-452315

D6866-16 Method B(AMS) Percent modern carbon (pMC) 103.4 +/- 0.3 pMC 101.5; =pMC/1.015







x 1mm scale)

Required Disclosures

1. All work was done at Beta Analytic in its own chemistry lab and AMS. No sub-contractors were used.

- 2. Beta's chemistry laboratory and AMS do not react or measure artificial C14 used in biomedical and environmental AMS studies Beta is a C14 tracer-free facility
- 3. Validating quality assurance is verified with a Quality Assurance report posted separately to the web library containing the PDF downloadable copy of this report.

* ASTM D8886-16 quotes precision on Percent Biogenic Carbon as +/- 3% (absolute). The cited precision on the analytical measure (pMC) is 1 sigma (1 relative standard deviation). The reported result only applies to the analyzed material. The accuracy of the % bionesic carbon result relies on the carbon present in the analyzed material having been in recent equilibrium with CO2 in the air and/or fossil carbon (from living systems more than 40,000 years old). "Percent biogenic carbon" specifically relates % renewable (i.e. non-fossil) organic carbon to total carbon (TC), not to total mass. Percent biogenic carbon is calculated by dividing pMC by the applicable REF adjustment factor specified in ASTM-D6866-16. % biogenic carbon = ([pMC

Analytical Measure - % Biogenic Carbon Content: ASTM D6866-16 Method B(AMS)

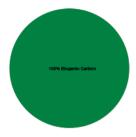
Submitter Gevo

Laboratory Number Reta-452315 Riogenio Maferial Biobased Material

Data Received, December 02, 2016 Date Reported December 09, 2016

Percent Biogenic Carbon 100 % *

Proportions Biogenio Carbon vs. Fossil-Based Carbon Indicated by 14C content



* ASTM D6866-16 quotes precision on Percent Biogenic Carbon as +/- 3% (absolute). The cited precision on the analytics measure (pMC) is 1 sigma (1 relative standard deviation). The reported result only applies to the analyzed material. The accuracy of the % biogenic carbon result relies on the carbon present in the analyzed material having been in recent equilibrium with CO2 in th air andior fossil carbon (from living systems more than 40,000 years old). "Percent biogenic carbon" specifically relates renewable (i.e. non-fossil) organic carbon to total carbon (TC), not to total mass. Percent biogenic carbon is calculated by dividin pMC by the applicable REF adjustment factor specified in ASTM-D6865-16. % bloognic carbon = (IpMC / REF) +/- 3 % absolute).

Page 2/3 Page 1/3



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SUPPLY CHAIN



FOREST RESIDUES

dues from logging and thinning operations. We are also considering mill residues and discarded woody material from construction and







site to a conversion facility. Chipping can take polymers (polysaccharides) accessible to de- (deave) the polysaccharides and generate indes into isobutanol. place at the loading or in a preprocessing fa- grading enzymes. These processes allow the simple sugars (monosaccharides).





& CO-PRODUCTS

form molecules derived from wood sugars. Lignin can be used to generate co-products such as epoxies, structural materials and biobased plastics. As an alternative, lignin can be burned to produce renewable energy.







United States Department of Agriculture National Institute of Food and Agriculture

First History Commercial Flight with 20% Blend ATJ Cellulosic Renewable Jet Fuel



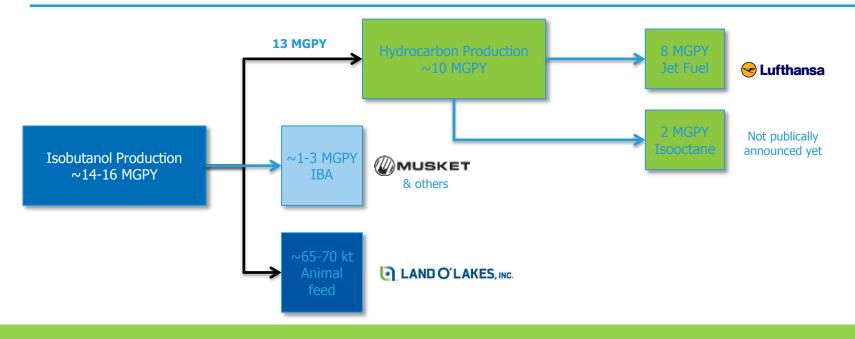
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• Strategy: Leverage installed assets at Luverne and adding the capability to produce 7-10 MGPY of hydrocarbons. Luverne is a proving ground for products and supply chain development.

Potential Buildout Overview







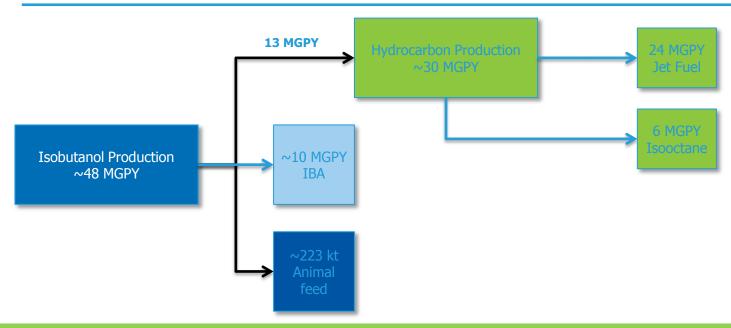
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• Those participating at Luverne will be advantaged for future volumes from future expansion

Commercial Buildout Overview (Beyond Luverne)





ENVIRONMENT

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• If you had the chance to make 3 policy requests to States to facilitate the development and deployment of alternative fuels, what would they be?

- 1-Stability
- 2-Simple
- 3-Support





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