

**ASSESSMENTS OF FUELS FOR MILITARY USE
PREPARATION AND DISTRIBUTION OF SYNTHETIC
FUEL BLENDS**

**INTERIM REPORT
TFLRF No. 432**

**by
Edwin A. Frame
Ruben Alvarez**

**U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute[®] (SwRI[®])
San Antonio, TX**

**for
Patsy Muzzell
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan**

Contract No. W56HZV-09-C-0100 (WD0004–Tasks 1, 20, 21, 26, & 27)

UNCLASSIFIED: Distribution Statement A. Approved for public release

January 2013

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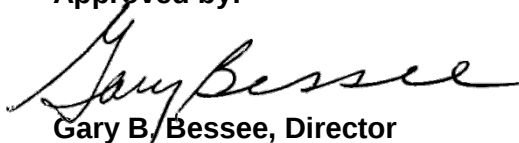
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Approved by:



**Gary B. Bessee, Director
U.S. Army TARDEC Fuels and Lubricants
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EXECUTIVE SUMMARY

TFLRF prepared, analyzed and distributed blends of synthetic fuel with JP-8. The size of the blends ranged from several hundred to over ten thousand gallons. The fuel blends were used by TARDEC in the evaluation of future fuels for military use. Ten thousand gallons of synthetic fuel blend consisting of 50%v synthetic JP-5 (HRJ-5) and 50%v JP-8 were prepared and delivered to Camp Grayling, MI for use in field exercises conducted by the Michigan National Guard during the summer of 2012.

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FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period April 2009 through January 31, 2013 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Eric Sattler served as the TARDEC contracting officer's technical representative. Ms. Patsy Muzzell of TARDEC served as project technical monitor.

The authors would like to acknowledge the contribution of the TFLRF technical support staff along with the administrative and report-processing support provided by Dianna Barrera.

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ACRONYMS AND ABBREVIATIONS

%v	Percent by Volume
°C	Degrees Centigrade
°F	Degrees Fahrenheit
ASTM	American Society for Testing and Materials
BOCLE	Ball-On Cylinder Lubricity Evaluator
cSt	Centistokes
DCN	Derived Cetane Number
HFRR	High Frequency Reciprocating Test Rig
HRJ	Hydrotreated Renewable Jet Fuel
JP-8	Jet Propulsion Fuel 8
kg	kilogram
lbs	Pounds
mL	milliliter
ppm	parts per million
FT-SPK	Fischer-Tropsch Synthetic Paraffinic Kerosene
SLBOCLE	Scuffing Load Ball-On Cylinder Lubricity Evaluator
SwRI®	Southwest Research Institute®
TARDEC	Tank Automotive Research, Development and Engineering Center
TFLRF	TARDEC Fuels and Lubricants Research Facility
ULSD	Ultra-Low Sulfur Diesel
DLA	Defense Logistics Agency
CoA	Certificate of Analysis
WPAFB	Wright Patterson Air Force Base

1.0 BACKGROUND AND OBJECTIVE

Fuel supplies are evolving as more highly-processed petroleum fuels, unconventional fuels, and non-petroleum fuels are increasingly making their way into the marketplace worldwide. Some of this evolution began several years ago when, for instance, environmental legislation in the U.S. mandated cleaner tailpipe emissions and as a result, the need for more highly-processed fuels, i.e., lower sulfur and lower aromatic content fuels such as California Air Resources Board (CARB) Diesel and Ultra-Low Sulfur Diesel (ULSD) fuels. The move towards developing and using non-petroleum fuels, such as biodiesel, renewable diesel/jet fuel, or Fischer-Tropsch fuels, is occurring in many countries as spurred by high volatility in the oil market, especially since 2006. In addition, much of the impetus behind transitioning to alternative fuels is tied to the desire of nations to better secure their energy supply by reducing dependence on foreign sources of oil through conversion of in-country energy resources such as tar sands, shale oil, coal, natural gas, biomass/waste streams (renewable) into transportation fuels. Furthermore, power and mobility systems are also evolving that might require non-traditional fuels/energy carriers as sources of energy, e.g., hydrogen for fuel cells. As these changes in the supply of fuels occurs around the world, and also in the fuels specified for future engines/equipment designs, the U.S. Military needs to understand the extent and nature of these changes and the implications regarding current and future military use. There will be some subtle and not so subtle changes in fuel compositions and associated physicochemical properties that can impact engine performance and durability, or compatibility with current (petroleum) fuels and the fuel distribution systems found in engines/vehicles such as fuel pumps, injectors, and high pressure common rail systems, or in fuel storage, distribution, or handling equipment. The U.S. Army is investigating assessments of the changing worldwide fuels supply with a focus on kerosene and diesel boiling range fuels, and of the impacts that varying fuel properties may have on current and future military equipment and systems.

2.0 APPROACH

As part of the U. S. Army investigation of future fuels, the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) has prepared, and shipped fuel blends for engine and component testing. The target fuel blend was 50%v synthetic fuel: 50%v JP-8. Some minor adjustment to this blend ratio was allowed to achieve a blend density of at least 0.773 kg/L and a blend aromatic content of at least 6%v. Each blend contained between 48 to 50%v synthetic fuel.

3.0 RESULTS

3.1 FUEL BLENDS PREPARED

A listing of the fuel blends prepared and shipped is presented in Table 1.

Table 1. Fuel Blends Prepared by TFLRF

Date	Fuel Blend Code	Fuel Blend Description	Gallons	Shipped To	Density of Blend, kKg/L	KVIS, 40°C, cSt	BOCLE Wear Scar, mm	Aromatics %v
Jun 09	AF 6934	JP-8/SPK	6,200	TARDEC	0.7809	1.12	0.55	10.5
Jun 10	AF 7117	JP-8/SPK	7,000	TARDEC	0.7741	1.23	0.55	9.3
Jul 10	AF 7117	JP-8/SPK	2,600	TARDEC	0.7741	1.23	0.55	9.3
Oct 10	AF 7117	JP-8/SPK	165	TARDEC	0.7741	1.23	0.55	9.3
Dec 10	AF 7744	JP-8/HRJ-8	4,400	TARDEC	0.7823	1.5	0.47	10.7
July 11	CL11-2644	JP-8/HRJ-8	7,000	TARDEC	0.7752	1.4	0.61	11.4
Feb 12	CL12-3384	JP-8/HRJ-8	6,700	TARDEC	0.7787	1.34	0.47	8
Jun 12	AF 8252	JP-8/HRJ-8	6,500	TARDEC	0.7715	1.3	0.53	6
Jun 12	AF 8259	JP-8/HRJ-5	5,000	Grayling	0.7736	1.4	0.56	6
Jun 12	AF 8261	JP-8/HRJ-5	5,000	Grayling	0.7736	1.4	0.56	6

3.2 FT-SPK BLENDS

A 6,200 gallon blend of 50/50%v FT- SPK and JP-8 (Jet A+ additives) was prepared and designated AF-6934. The FT-SPK was received from the U. S. Air Force. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The fuel blend properties for AF-6934 are presented in Table 2. This blend was shipped to TARDEC in June 2009.

Table 2. Properties of Fuel Blend AF-6934

Analysis of Sythetic Fuel Blend Property	Test Method	AF-6934
Density, 15°C (g/mL)	D4052	0.7809
Kinematic Viscosity, 40°C (cSt)	D445	1.12
Sulfur (wt%)	D2622	0.0069
Hydrocarbons by FIA	D1319	
Aromatic (vol%)		10.5
Olefin (vol%)		1
Saturates (vol%)		88.5
Heat of Combustion	D240	
GROSS (BTU/lb)		19967
NET (BTU/lb)		18645
Flash Point (°F)	D93	124
(°C)		51
SLBOCLE (g)	D6078	2200
BOCLE (mm)	D5001	0.55
HFRR (µm)	D6079	631
Distillation (°C)	D86	
	IBP	161.4
	10	171
	20	174.4
	50	187.1
	90	223.1
	FBP	245.4
Cetane Number	D613	49.9
Calculated Cetane	D976	46.6
Derived Cetane Number	D6890	48.2
Particulate Contamination	D5452	
Total Volume (L)		1
Total Contamination (mg/L)		<0.1
Water Content (ppm)	D6304	69
Carbon (mass%)	D5291	85.46
Hydrogen (mass%)	D5291	14.49

A 17,000-gallon blend of 50%v FT-SPK and 50%v JP-8 was prepared and designated AF-7117. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. Properties of the fuel blend are shown in Table 3 below. The density at 15°C was 0.7741, with 9.3% aromatics, and a KVIS at 40°C of 1.23 cSt.

Table 3. Properties of Fuel Blend AF-7117

Property	Test Method	AF-7117
Density, 15°C (g/mL)	D4052	0.7741
Kinematic Viscosity, 40°C (cSt)	D445	1.23
Sulfur (wt%)	D2622	0.00044
Hydrocarbons by FIA	D1319	
Aromatic (vol%)		9.3
Olefin (vol%)		1
Saturates (vol%)		89.7
Heat of Combustion	D240	
GROSS (BTU/lb)		20,005
NET (BTU/lb)		18,695
Flash Point (°F)	D93	119.3
(°C)		48.5
SLBOCLE (g)	D6078	1900
BOCLE (mm)	D5001	0.55
HFRR (µm)	D6079	684
Distillation (°C)	D86	
IBP		161.4
10		169.9
20		172.8
50		184.9
90		219.1
FBP		239
Cetane Number	D613	48.8
Calculated Cetane	D976	46.6
Derived Cetane	D6890	48.8
Particulate Contamination	D5452	
Total Volume (L)		1
Total Contamination (mg/L)		2.4
Water Content (ppm)	D6304	69
Carbon	D5291	85.35
Hydrogen	D5291	14.35

TFLRF delivered 7,000 gallons of fuel blend AF-7117 to TARDEC during June 2010, and an additional 2,600 gallons were delivered to TARDEC during July 2010. Three (3) 55 gallon drums of AF-7117 fuel blend were supplied to the TARDEC propulsion group during October 2010. The balance of the fuel blend was used for testing at TFLRF.

3.3 HEFA-SPK (HRJ) BLENDS

TFLRF prepared several 50/50 % blends of hydrotreated renewable jet fuel (HRJ) and JP-8. Both HRJ-8 and HRJ-5 were received from DLA Energy. The HRJ-8 was sourced from Centuri Technologies LP. Three separate shipments of HRJ-8 fuel (18,450 gallons) were received from Centauri Technologies LP during October 4, 6, and 7, 2010. The HRJ-8 fuel was unloaded into Tank 125. Samples were obtained from each tanker prior to unloading into Tank 125. Selected analyses were requested from each sample obtained from the tankers and results were compared with the Certificates of Analysis provided with each shipment. The analyses are presented in Table 4. No anomalies were noted in the results.

A second shipment of HRJ-8 was received from Centauri Technologies, LP. Three separate shipments totaling 16,382 gallons were delivered to TFLRF on January 25, 26, and 27, 2011. The product was initially stored in a rented 12,000 gallon portable tank and a 6,000 gallon above ground tank. The separate shipments were from the same batch number and were segregated from the previous deliveries of HRJ-8 as was requested by TARDEC. The product was transferred from the portable storage tank to a permanent storage tank after completion of repairs required for standards compliance. Samples were obtained from each separate delivery tanker and selected analyses were performed on all samples to compare results of the Certificate of Analysis (COA), provided by Centauri Technologies, LP against results obtained by TFLRF laboratory. Results of Comparison analyses are presented in Table 5, and no anomalies found in any of the samples analyzed.

HRJ-8 and JP-8 fuel were blended at 50%:50% volumetric ratio and the blend attained a density value of 0.782 kg/L and an aromatic content of 10.5 % v. The blend met TARDEC's requirement of no less than 0.773 kg/L and an aromatic content of no less than 6.5 % v. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The 4,400 gallons of blended fuel were shipped to TARDEC in December 2010. Complete fuel analyses of the blend and both HRJ-8 shipments are presented in Table 6.

Table 4. Comparison of Analyses Results of 1st Shipment of HRJ-8 CAF- 7667

HRJ-8 CAF-7667 Comparison Analyses (1st Shipment, 18,450 gallons, 4,6,& 7 October 2010)						
Properties	Results, COA Tanker 1	Results, TFLRF Lab	Results, COA Tanker 2	Results, TFLRF Lab	Results, COA Tanker 3	Results, TFLRF Lab
ASTM D86 Distillation						
IPB (°C)	n/d	143.8	n/d	147.2	N/D	147.9
10% (°C)	165.0	165.3	167	167.6	165	168.3
50% (°C)	228	229.7	237.5	241.1	228	231.3
90% (°C)	273	274.3	274	275.9	273	274.5
End Point (°C)	280.5	278.6	281	279	280.5	278.5
Residue % Volume	1.2	1.5	1.2	1.5	1.2	1.5
Loss % Volume	0.9	1	0.9	1.6	0.9	1.1
ASTM D5453 Sulfur, ppm	0.45	N/D	0.37	N/D	0.45	N/D
ASTM D2622 Sulfur, ppm	N/D	<10	N/D	<10	N/D	<10
ASTM D445 Viscosity @ -20°C cST	6.01	6.01	6.7	6.7	6.01	6.01
ASTM D445 Viscosity @ 40°C cST	1.54	1.55	1.63	1.64	1.54	1.55
ASTM D4052 Density @ 15°C	762.8	765	764.8	766	762.8	764
ASTM D93 Flash Point °C (F°)	44.5 (112)	45 (113)	46.5 (115.7)	47 (116.5)	44.5 (112)	45.5 (113.9)

Table 5. Comparison of Analyses Results of 2nd Shipment of HRJ-8 CAF- 7815

HRJ-8 CAF-7815 Comparison Analyses (2nd Shipment, 16,382 gallons, 25, 26,& 27 January 2011)						
Properties	Results, COA Tanker 1	Results, TFLRF Lab	Results, COA Tanker 2	Results, TFLRF Lab	Results, COA Tanker 3	Results, TFLRF Lab
ASTM D86 Distillation						
IPB (°C)	n/d	138.6	n/d	133.3	n/d	137.4
10% (°C)	166.0	163.6	165	164.6	165	164.1
50% (°C)	226	225.4	225.5	224.8	222.5	224.8
90% (°C)	272.5	274.6	273.5	274.9	273.5	274.7
End Point (°C)	281	279.5	282	279.8	282	279.6
Residue % Volume	1.0	1.5	1.4	1.5	1.4	1.5
Loss % Volume	0.9	1	0.6	1.2	0.6	1.2
ASTM D5453 Sulfur, ppm	<.05	N/D	<.05	N/D	<.05	N/D
ASTM D2622 Sulfur, ppm	N/D	<10	N/D	<10	N/D	<10
ASTM D445 Viscosity @ -20°C cST	6.0	5.86	6.0	5.83	6.0	5.81
ASTM D445 Viscosity @ 40°C cST	1.55	1.52	1.56	1.54	1.55	1.51
ASTM D4052 Density @ 15°C	761.3	761.6	761.6	766	761.3	761.5
ASTM D93 Flash Point °C (F°)	44.5 (112)	46 (114.8)	44.5 (112)	46.5 (115.7)	44.5 (112)	47 (116.6)

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Table 6. Analyses of HRJ-8 Shipments Received at TFLRF and HRJ-8/JP-8 Blend Shipped to TARDEC

Property	Method	Units	HRJ-8 Received Oct 2010 Batch	HRJ-8 Received Jan 2011 Batch	HRJ-8/JP-8 Blended From Oct 2010 Batch
Color, Saybolt	ASTM D156	Referee	28	30	27
Total Acid Number	ASTM D3242	mg KOH/g	0.005	0.002	0.007
Hydrocarbons by FIA	ASTM D1319	Vol%			
Aromatics			0.5	0.6	10.7
Olefins			0.6	0.8	0.7
Saturates			98.9	98.6	88.6
Sulfur, total	ASTM D2622	Wt %	<0.001	<0.001	<0.001
Sulfur, mercaptan	ASTM D3227	Mass %	<0.0003	<0.0003	<0.0003
Distillation	ASTM D86	°C @ vol% evap.			
		IBP	145.1	133.8	156.2
		5	162.6	160.2	170
		10	166.5	163.3	170.2
		15	173.2	169.4	174.6
		20	180.6	176.8	177.1
		30	197.1	191.3	183.2
		40	214.9	208.4	190.3
		50	232.8	225.2	198
		60	247.8	241.2	208.3
		70	260.2	255.4	222.1
		80	269.1	266.6	243.1
		90	274.9	274.7	267.9
		95	277.7	278.5	275.4
		FBP	278.6	279.9	277.2
		Residue vol%	1.5	1.5	1.4
		Loss vol%	1.3	1.1	1.5
Flash point	ASTM D93	°C	46.5	45.5	48.5
Density @ 15°C	ASTM D4052	g/mL	0.764	0.761	0.782
Gravity, API @60°F			53.71	54.44	49.45
Freezing point	ASTM D2386	°C	-52.2	-58	-65
Viscosity at -20°C	ASTM D445	mm ² /s	6.18	5.86	4.35
Hydrogen	ASTM D3701	Mass%	15.25	15.33	14.5
Heat of combustion	ASTM D4809	MJ/kg			
Net			45.29	45.42	44.82
Gross			47.21	47.33	47.99
Hydrogen content	ASTM D5291	Mass%	15.25	15.23	14.33
Smoke point	ASTM D1322	mm	34.7	27.7	33.3
Naphthalenes	ASTM D1840	Volume %	0	0	0.16
Calculated Cetane index	ASTM D976		71.8	70.6	51
Copper strip corrosion, 2hr @100°C (212°F)	ASTM D130		1A	1A	1A
JFTOT @ 260°C	ASTM D3241	mm/mg	1	0	0
Existent gum	ASTM D381	mg/100mL	<0.5	<0.5	0.6
Particulate matter	ASTM D5452	mg /L	0.5	0	0.4
Filtration time		minutes	6.12	9	6.1
Water reaction interface rating	ASTM D1094	mL	1	1	1
Water separation index	ASTM D3948	Rating	48	98	33
FSII	ASTM D5006	Vol%	0	0	0.08
Electrical conductivity	ASTM D2624	pS/m	163	193	333

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Table 6. Analyses of HRJ-8 Shipments Received at TFLRF and HRJ-8/JP-8 Blend Shipped to TARDEC (continued)

Additional Analyses Required by WD004 Revision 3					
Property	Method	Units	HRJ-8 Received Oct 2010 Batch	HRJ-8 Received Jan 2011 Batch	HRJ-8/JP-8 Blended From Oct 2010 Batch
Hydrocarbon Types by Mass Spectrometry	ASTM D2425	Wt%	--	--	Not Required
Paraffin			--	--	--
Monocycloparaffins			94.5	93.7	--
Dicycloparaffins			5.5	6.1	--
Triycloparaffins			0	0.2	--
Napthalene			0	0.0	--
Saturates			5.5	6.3	--
			100	100	--
Aromatics			--	--	--
Alkybenzenes			0.0	0.0	--
Idans/tetralins			0.0	0.0	--
Idenes			0.0	0.0	--
Naphthalene			0.0	0.0	--
Napthalenes, alkyl			0.0	0.0	--
Acenapthenes			0.0	0.0	--
Acenaphtylenes			0.0	0.0	--
Tricyclic aromatics			0.0	0.0	--
Carbon Hydrogen	ASTM D5291	Mass%	--	--	--
Carbon			84.39	84.52	85.11
Hydrogen			15.25	15.23	14.33
Water Coulometric-KF	ASTM D6304	mg/kg	16	160	Not Required
Elements	ASTM D7111	ppb	--	--	Not Required
Al			321	252	--
Ba			>100	>100	--
Ca			>100	>100	--
Cr			>100	>100	--
Cu			>100	>100	--
Fe			>100	>100	--
Li			128	171	--
Pb			>100	>100	--
Mg			>100	>100	--
Mn			>100	>100	--
Mo			>100	>100	--
Ni			>100	>100	--
K			>1	>1	--
Na			>1	>1.1	--
Si			>100	>100	--
Ag			>100	>100	--
Ti			>100	>100	--
V			>100	>100	--
Zn			>100	>100	--
Derived Cetane Number	ASTM D6890		58.06	57.76	47.59
Viscosity at 40°C	ASTM D445	mm ² /s	1.58	1.5	1.3
BOCLE	ASTM D5001	mm	0.69	0.94	0.47
Bulk Modulus		psi@30°C	170743	169089	176317

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In July 2011, TFLRF supplied TARDEC with 7000 gallons of a 50/50% blend of HRJ-8 (2nd shipment) and Jet A (with JP-8 additives). The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. Complete fuel analyses of the blend and the 2nd HRJ-8 shipment are presented in Table 7.

Table 7. Analyses of HRJ-8 Shipment 2 Received at TFLRF & HRJ-8/JP-8 Blend Shipped to TARDEC

Property	Method	Units	HRJ-8 Received Jan 2011 Batch	HRJ-8/JP-8 Blended Jan 10 2011 Batch
Color, Saybolt	ASTM D156	Referee	30	-2
Total Acid Number	ASTM D3242	mg/KOH/gm	0.002	0.006
Hydrocarbons by FIA	ASTM D1319	Vol%		
Aromatics			0.6	11.4
Olefins			0.8	0.6
Saturates			98.6	88
Sulfur, total	ASTM D2622	Wt %	<0.001	0.0137
Sulfur, mercaptan	ASTM D3227	Mass %	<0.0003	<0.0003
Distillation	ASTM D86	°C @ vol% evap.		
		IBP	133.8	160.3
		5	160.2	172
		10	163.3	174.7
		15	169.4	178.2
		20	176.8	181.5
		30	191.3	188.1
		40	208.4	195
		50	225.2	203.6
		60	241.2	212.3
		70	255.4	223
		80	266.6	238
		90	274.7	258
		95	278.5	270
		FBP	279.9	277.7
		Residue vol%	1.5	1.3
		Loss vol%	1.1	0.5
Flash point	ASTM D93	°C	45.5	48.5
Density @ 15°C	ASTM D4052	g/mL	0.761	0.7752
Gravity, API @ 60°F			54.44	49.45
Freezing point	ASTM D2386	°C	-58	-62
Viscosity at -20°C	ASTM D445	mm ² /s	5.86	4.54
Hydrogen	ASTM D3701	Mass%	15.33	14.4
Heat of combustion	ASTM D4809	MJ/kg		
Net			45.42	43.44
Gross			47.33	46.5
Hydrogen content	ASTM D5291	Mass%	15.23	14.4
Smoke point	ASTM D1322	mm	27.7	33.3
Naphthalenes	ASTM D1840	Volume %	0	0.39
Calculated Cetane index	ASTM D976		70.6	51
Copper strip corrosion, 2hr @100°C (212°F)	ASTM D130		1A	1A
JFTOT @ 260°C	ASTM D3241	mm/mg	0	1
Existent gum	ASTM D381	mg/100mL	<0.5	7
Particulate matter	ASTM D5452	mg /L	0	1.6

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**Table 7. Analyses of HRJ-8 Shipment 2 Received at TFLRF & HRJ-8/JP-8 Blend
Shipped to TARDEC (continued)**

Property	Method	Units	HRJ-8 Received Jan 2011 Batch	HRJ-8/JP-8 Blended Jan 10 2011 Batch
Filtration time		minutes	9	4.44
Water reaction interface rating	ASTM D1094	mL	1	1
Water separation index	ASTM D3948	Rating	98	70
FSII	ASTM D5006	Vol%	0	23
Electrical conductivity	ASTM D2624	pS/m	193	0
Carbon Hydrogen	ASTM D5291	Mass%	--	--
Carbon			84.52	85.5
Hydrogen			15.23	14.4
Water Coulometric-KF	ASTM D6304	mg/kg	160	Not Required
Derived Cetane Number (IQT)	ASTM D6890		57.76	50.58
Viscosity at 40°C	ASTM D445	mm ² /s	1.5	1.34
BOCLE	ASTM D5001	mm	0.94	0.61
Bulk Modulus		psi@30°C	169089	178673

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In February 2012, TFLRF supplied TARDEC with 6,700 gallons of 50/50%v blend of HRJ-8 (comingled 1st and 2nd shipments) and Jet A with JP-8 additives. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The analyses of this blend are presented in Table 8.

Table 8. HRJ-8/JP-8 Blend CL12-3384

Property	Units	Method	Min	Max	Results
Color, Saybolt	Referee	ASTM D156			8
Total Acid Number	mg/KOH/gm	ASTM D3242		0.015	0.012
Aromatics	Volume %	ASTM D1319		25	8
Sulfur, total	Mass %	ASTM D2622		0.30	0.014
Sulfur, mercaptan	Mass %	ASTM D3227		0.002	<0.0003
Distillation	°C @ vol% evap.	ASTM D86			
	IBP				154
	10		157	205	171.1
	20				178.7
	50		168	229	205.3
	90		183	262	263.1
	FBP			300	278.9
	Residue			1.5	1.2
	Loss			1.5	0.7
Flash point	°C	ASTM D93	38	68	39.5
Density @ 15°C	kg/L	ASTM D4052	0.775	0.840	0.778
Viscosity at -20°C	mm²/s	ASTM D445		8.0	4.67
Viscosity at 40°C	mm²/s	ASTM D445			1.3
Heat of combustion	MJ/kg	ASTM D4809	42.8		
Net					42.5
Gross					39.7
Hydrogen content	Mass%	ASTM D3701	13.4		14.64
Smoke point	Volume %	ASTM D1322	25		24
Naphthalenes	Volume %	ASTM D1840		3.0	0.51
Calculated cetane index		ASTM D976	Report		55.6
Copper strip corrosion, 2hr @ 100°C (212°F)		ASTM D130		No. 1	1A
Hydrocarbons by FIA	Volume %	ASTM D1319			-
Aromatics					8
Olefins					2.9
Saturates					89.1
Filtration Time	minutes			15	7
Water reaction interface rating	mL	ASTM D1094		1	1
Water separation index	Rating	ASTM D3948	70		0
Fuel system icing inhibitor	Volume %	ASTM D5006	0.10	0.15	0.14
Fuel electrical conductivity	pS/m	ASTM D2624	150	600	540
Derived Cetane Number (IQT)		ASTM D6890			54.68
Bulk Modulus @ 30C	psi	ASTM D6793			175,144
BOCLE	mm	ASTM D5001			0.47
Specific Energy	MJ/kg	ASTM D3338			43.7
Carbon/Hydrogen	Mass %	ASTM D5291			85.22/14.64
Freeze Point (Auto)	°C	ASTM D5972			-51.6
HFRR	g	ASTM D6078			2850
SBOCLE	mm	ASTM D6079			72.5
Sulfur, Energy Dispersive	ppm	ASTM D4294			>100

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In June 2012, TFLRF supplied TARDEC with 6,500 gallons of 50/50%v blend of HRJ-8 (comingled all shipments) and JP-8. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The brief analyses of this blend are presented in Table 9.

Table 9. HRJ-8/JP-8 Blend

Property	Units	Method	Min	Max	Result
Density @ 15°C	kg/L	ASTM D4052	0.775	0.840	0.772
Hydrocarbons by FIA	Vol%	ASTM D1319			6
Aromatics					1.5
Olefins					92.5
Saturates					
Viscosity at 40°C	mm ² /s	ASTM D445			1.3
Distillation	°C @ vol% evap.				
	IBP			Report	149.6
	10		157	205	165.1
	20				173.3
	50	ASTM D86	168	229	202.9
	90		183	262	264.1
	FBP			300	279.6
	Recovered				98.6
	Residue			1.5	1.1
	Loss			1.5	0.3
BOCLE	mm	ASTM D5001			0.53
SBOCLE	g	ASTM D6078			2150
HFRR	mm	ASTM D6079			0.763

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In February 2012, TFLRF received 5,000 gallons of HRJ-5 from Centuri Technologies, LP. The manufacturer supplied Certificate of Analysis is included in Appendix A. In June 2012, TFLRF supplied Camp Grayling, MI with 10,000 gallons of 50/50%v blend of HRJ-5 and purchased JP-8 . The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The analyses of this blend are presented in Table 10.

Table 10. Properties of Fuel Blend Supplied to Camp Grayling, MI

HRJ-5/JP-8 Fuel Properties, Camp Grayling Shipment					
Property	Units	Method	Min	Max	Results
Color, Saybolt	Referee	ASTM D156			22
Total Acid Number	mg/KOH/gm	ASTM D3242		0.015	0.11
Aromatics	Volume %	ASTM D1319		25	6
Sulfur, total	Mass %	ASTM D2622		0.30	0.014
Sulfur, mercaptan	Mass %	ASTM D3227		0.002	<0.0003
Distillation	°C @ vol% evap.	ASTM D86			
	IBP				159.6
	10		157	205	176.4
	20				184
	50		168	229	209.9
	90		183	262	262.9
	FBP			300	275.3
	Residue			1.5	1.2
	Loss			1.5	0.1
Flash point	°C	ASTM D56	38	68	44
Density @ 15°C	kg/L	ASTM D4052	0.775	0.840	0.7736
Freezing point	°C	ASTM D2386		-47	-54
Viscosity at -20°C	mm²/s	ASTM D445		8.0	5.05
Viscosity at 40°C	mm²/s	ASTM D445			1.4
Heat of combustion	MJ/kg	ASTM D4809	42.8		
Net					43.842
Gross					45.310
Hydrogen content	Mass%	ASTM D3701	13.4		14.76
Smoke point	Volume %	ASTM D1322	25		30.2
Naphthalenes	Volume %	ASTM D1840		3.0	0.036
Calculated cetane index		ASTM D976	Report		59.6
Copper strip corrosion, 2hr @ 100°C (212°F)		ASTM D130		No. 1	1A
Thermal stability pressure drop, heater tube deposit, visual rating	Mm Hg	ASTM D3241		25 <3	<1
Existent gum	mg/100mL	ASTM D381		7	0.5
Particulate matter	mg/L	ASTM D5452		1	0.6
Hydrocarbons by FIA	Vol%	ASTM D1319			-
Aromatics					6
Olefins					1.6
Saturates					92.4
Filtration time	minutes			15	7
Water reaction interface rating	mL	ASTM D1094		1	1
Water separation index	Rating	ASTM D3948	70		85
Fuel system icing inhibitor	Volume %	ASTM D5006	0.10	0.15	0.6
Fuel electrical conductivity	pS/m	ASTM D2624			20
Derived Cetane Number (IQT)		ASTM D6890			54.68
Bulk Modulus @ 30C		ASTM D6793			172,299
BOCLE	mm	ASTM D5001			0.56

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3.4 HRJ-8 LOSS

In August of 2011, a fuel handling error resulted in the loss of approximately 3500 gallons of HRJ-8. TARDEC's Project Technical Monitor, TACOM's contracting, and San Antonio DCMA were informed of the event. A Loss, Theft, Damage, Destruction (LTDD) report was submitted to TACOM contracting. The San Antonio DCMA, government property administrator visited SwRI to investigate the incident and confirm that corrective actions were put in place. On October 25th, 2011 SwRI received the results of this investigation. The government found that the fuel loss was not the result of willful misconduct or lack of good faith on the part of the contractor's managerial personnel. Therefore, SwRI was relieved for the loss/contamination amount. In February 2012, an additional 4,500 gallons of HRJ-8 were supplied by DLA Energy and added to the comingled HRJ-8 at TFLRF. The Certificate of Analysis for this shipment of HRJ-8 is included in Appendix B.

3.5 FUEL PICKUP FROM WPAFB

TFLRF made arrangements to transport 1,000 gallons of FT SPK AF7618 from WPAFB. Selected analyses were requested on a sample obtained from the tanker that delivered the 1,000 gallons of FT SPK from WPAFB. Results were compared with findings obtained at WPAFB laboratory to insure that fuel properties had not changed significantly. TFLRF analyses results indicated that the fuel received had a slightly lower flash point and IBP. Other properties were as expected. Results of Comparison analyses are presented below in Table 11.

Table 11. Results of Comparison Analyses

WPAFB FT SPK CAF-7618 Comparison Analyses		
Properties	Results, WPAFB Lab	Results, TFLRF Lab
ASTM D86 Distillation		
IPB (°C)	156	149
10% (°C)	162	161
20% (°C)	164	164
50% (°C)	169	169
90% (°C)	185	185
End Point (°C)	200	202
Residue % Volume	1	1
Loss % Volume	0.7	1
ASTM D2622 Sulfur, ppm	3.00	<10
ASTM D445 Viscosity @ -20°C cST	2.6	2.5
ASTM D4052 Density @ 15°C	0.737	0.737
ASTM D93 Flash Point °C (F°)	46/(115)	42/(108)

This FT SPK was used in various alternative fuels projects at TFLRF.

4.0 SUMMARY AND CONCLUSIONS

TFLRF completed fuel blending and delivered synthetic fuels blends as requested by TARDEC during the period June 2009 through January 2013.

5.0 REFERENCES

Military Specification, MIL-DTL-83133E, "Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8), NATO F-35, and JP-8+100"

Qualified Products List of Products Qualified Under Performance Specification MIL-PRF-25017 Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

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APPENDIX A
HRJ-5 Certificate of Analysis

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CENTAURI Technologies, LP
HRJ-5 Certificate of Analysis for UOP, LLC.

AF-8183
 TK-208B
 2-28-12

Material Name	: Hydro-treated Renewable Jet, "HRJ5" – Camelina
Customer Name	: UOP, LLC
Lot Number	: Lot No. 1211-C10818/19/20 (<i>from R/C TILX 250190</i>)
Shipping Date	: 28-February-2012
Container Identification	: Suttles DANA T/T No. 1426
Sample Identification	: S-20212-6180
Approximate Shipping Load	: 30,802 lbs (4,822 gallons) (<i>subject to correction</i>)
Customer Order Number	: 4500329445
Bill of Lading Number	: SP06000000922

Measured Properties	Units	Test Method	Specification		Measured Value	Measured By	Reference Document
			Minimum	Maximum			
Flash Point	°C	D 93	60		62.5	Dixie Services	No. 139812
Density at 15°C	kg/L	D 1298	0.760	0.845	0.7660	Dixie Services	No. 139812
Total Water	ppm	D 6304		75	28	Dixie Services	No. 139812
Particulate <i>Filtration Time</i>	mg/L	D 5452		1.0	0.12	Dixie Services	No. 139812
	minutes			15	6	Dixie Services	No. 139812
Kinematic Viscosity at -20°C	mm ² /sec	D 445		8.5	7.448	Dixie Services	No. 139812
Cetane Number		D 613	40		62.3	Dixie Services	No. 139812
Distillation							
IBP	°C	D 86	Report		173.5	Dixie Services	No. 139812
10%, (T10)				205	190.0	Dixie Services	No. 139812
50%, (T50)			Report		230.5	Dixie Services	No. 139812
90%, (T90)			Report		270.5	Dixie Services	No. 139812
Final Boiling Point				300	276.5	Dixie Services	No. 139812
Residue	vol %			1.5	1.5	Dixie Services	No. 139812
Loss				1.5	0.5	Dixie Services	No. 139812
T90-T10	°C		25		80.5	Dixie Services	No. 139812
Copper Strip Corrosion at 100°C		D 130		No. 1	1b	Dixie Services	No. 139812

CENTAURI Technologies, LP
HRJ-5 Certificate of Analysis for UOP, LLC.

Measured Properties	Units	Test Method	Specification		Measured Value	Measured By	Reference Document
			Minimum	Maximum			
Freezing Point	°C	D 2386		- 46	-53.0	Dixie Services	No. 139812
Hydrogen Content	mass %	D 7171	13.4		15.24	UOP, LLC	LIMS No. 260400721
Heating Value	MJ / kg	D 4809	42.6		43.935	Dixie Services	No. 139812
MSEP		D 3948	85		95	Dixie Services	No. 139812
Total Acid Number	mg KOH/g	D 3242		0.015	0.004	Dixie Services	No. 139812
JFTOT at 280°C <i>Tube Deposit Rating</i> <i>dP</i>							
	visual	D 3241		3	1	Dixie Services	No. 139812
	mm Hg			25	0	Dixie Services	No. 139812
Additives							
<i>Antioxidant, AO-37</i>	ppm	P 487	17.2	24	20	Calculated	
<i>Corrosion Inhibitor, DCI-4A</i>			9	24	15	Calculated	
Hydrocarbon Composition							
<i>Paraffins (n- and iso-)</i>	mass %	D 2425	Balance		96	UOP, LLC	UDRI Dec. 29, 2011
<i>Cycloparaffins</i>				15	4	UOP, LLC	UDRI Dec. 29, 2011
<i>Total Aromatics</i>		D 6379		0.5	< 0.3	UOP, LLC	UDRI Dec. 29, 2011
Sulfur Content	ppm	D 5453		15	< 0.05	Dixie Services	No. 139812
Nitrogen Content	ppm	D 4629		10	< 0.10	Dixie Services	No. 139812
Metals <i>Ca, Cu, Fe, Mg, Mn, Ni, P, Pb, V, Zn</i>	ppm	D 7111		0.5, total	0.04	Dixie Services	No. 139812
Alkali Metals and Metalloids <i>B, Na, K, Si, Li</i>	ppm	D 7111		1.0, total	0.05	Dixie Services	No. 139812

Hieu T. Nguyen

UOP, LLC Technical Representative

28-February-2012

Date

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APPENDIX B

Certificate of Analysis for HRJ-8, February 2012

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UOP LLC - A Honeywell Company

Analysis Report

Material Name	:	Hydrotreated Renewable Jet, HR-J8
Customer Name	:	DLA (Army)
Centauri Lot Number	:	1211-C10825-26
Shipping Date	:	2012 FEB 14
Container Identification	:	Trailer 1371
Sample Identification	:	S-00212-6051
Estimated Shipping Load	:	4,522 gallons (estimated total load)
Customer Order Number	:	0001-00
Bill of Lading Number	:	SP06000000909

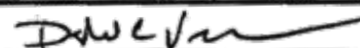
Measured properties	Units	Test Method	Specification		Measured Value	Measured By	Reference Document
			Minimum	Maximum			
Total Acidity	mg KOH/g	D3242		0.015	0.004	Dixie Services	139990R
Physical Distillation							
10%, (T10)	°C	D86		205	157.5	Dixie Services	139990R
50%, (T50)	°C		Report		208.0	Dixie Services	139990R
90%, (T90)	°C		Report		273.0	Dixie Services	139990R
Final Boiling Point	°C			300	281.5	Dixie Services	139990R
Residue	vol %			1.5	1.5	Dixie Services	139990R
Loss	vol %			1.5	0.5	Dixie Services	139990R
T90-T10	°C			22		115.5	Dixie Services
Simulated Distillation - D86 correlated data							
10%, (T10)	°C	D2877	Report		160.5	Dixie Services	139990R
50%, (T50)	°C		Report		210.0	Dixie Services	139990R
90%, (T90)	°C		Report		270.5	Dixie Services	139990R
Final Boiling Point	°C		Report		284.0	Dixie Services	139990R
Flash Point	°C	D56	38	68	40.5	Dixie Services	139990R
Density	kg/m³	D4052	751	840	756.6	Dixie Services	139990R
Freezing Point	°C	D2386		-47	-52.5	Dixie Services	139990R

File: UOP-AR. 004

UOP LLC - A Honeywell Company

Analysis Report

Measured properties		Units	Test Method	Specification		Measured Value	Measured By		Reference Document	
				Minimum	Maximum					
Viscosity at -20°C		mm ² /s	D445		8.0	4.816	Dixie Services		139990R	
Viscosity at +40°C		mm ² /s	D445	Report		1.335	Dixie Services		139990R	
Net Heat of Combustion		MJ/kg	D4809	42.8		43.946	Dixie Services		139990R	
Cetane Number			D613	40		58.4	Dixie Services		139990R	
JFTOT at 2.5h										
Temperature		°C	D3241	280		280	Dixie Services		139990R	
Tube Deposit Rating		visual			3	1	Dixie Services		139990R	
dP		mm Hg			25	0.0	Dixie Services		139990R	
Electrical Conductivity 23°C		µS/m	D2624	150	450	233	Dixie Services		139990R	
Additives										
Antioxidant, AO-37		ppm	P487	17	24	20	Calculated			
Static Dissipator Stadis 450		ppm				1	Calculated			
Corrosion Inhibitor DCI-4A		ppm				15	Calculated			
Hydrocarbon Composition										
Paraffins (n- and iso-)		mass %	D2425	Balance		96	UDRI		Letter dated Dec 29, 2011	
Cycloparaffins					15	4	UDRI		Letter dated Dec 29, 2011	
Total Aromatics					0.5	<0.3	UDRI		Letter dated Dec 29, 2011	
Carbon and Hydrogen			D5291	99.0		99.5	Dixie Services		139990R	
Nitrogen Content		mg/kg	D4829		5	<0.10	Dixie Services		139990R	
Water		mg/kg	D6304		75	27	Dixie Services		139990R	
Sulfur Content		mg/kg	D5453		15	<0.05	Dixie Services		139990R	
Water Separation Index without SDA			D3948	85		99	Dixie Services		140140	
Particulate Matter		mg/L	D5452		1.0	0.05	Dixie Services		139990R	
Filtration time		min			15	5	Dixie Services		139990R	
Volume		L		3.79		4.1	Dixie Services		139990R	
Metals		mg/kg	D7111				Dixie Services		139990R	
Measured Values	Ca	Cu	Fe	Mg	Mn	Ni	P	Pb	V	Zn
0.1 total max	BDL<0.01	BDL<0.01	BDL<0.01	BDL<0.01	BDL<0.01	BDL<0.01	BDL<0.01	0.02	BDL<0.01	BDL<0.01
Glass Metals report	Na	K	Si	Li						
	0.03	BDL<0.01	BDL<0.01	0.01						


UOP LLC Technical Representative

2.14.12
Date

File: UOP-AR. 004