

Test	Method	Unit	FO 1	FO 2	Dist. 1	Dist. 2	Dist. 3	Dist. 4	RD 1	RD 2
Density @ 15°C	D4052	g/cm ³	1.010	0.9720	0.876	0.855	0.836	0.8377	0.778	0.796
Kinematic Viscosity (KV) @ 40°C	D445	mm ² /s					3.565		2.65	3.739
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	473.0	12.38	9.8531	4.2735	2.943	3.0*	2.229	3.076
CCAI	Calculated	-	868	822	793	795	789	790*	741	746
Distillation - Average Boiling Point	D86	°C					287		290	305
Distillation - Average Boiling Point	D7169	°C			381	325				
Distillation - Average Boiling Point	AM-S 1847	°C		541						
Aromatics	2DGC	wt%			43.2	36.8	21.9	16.2*		
Aromatics	D5186	wt%								
Aromatics	EN 12916	wt%							0.8	5
Sulfur	ISO 8754	wt%		0.58						
Carbon Residue, Micro	D4530	wt%	19.20	11.2						
Heptane Insolubles	D3279	wt%		4.3						
BMCI	Calculated	-	83.4	63.8	32.9	29.9	26.5	27*	-1.7	4.5
Toluene Equivalence (TE)	AM-S 79-004	-	73	41	0	0	0	0	0	0
BMCI - TE	-	-	10.9	22.8	32.9	29.9	26.5	27	-1.7	4.5
Oil Compatibility Test	AM-S 1999-011									
Solubility blending number (S _{BS})		-	100		30*	30*	26*	27*		
Incompatibility number (I _N)		-	78		0	0	0	0		
S _{BS} - I _N		-	22		30	30	26	27		
Compatibility - Rofa Test	ASTM D7157									
S-value		-		1.74						
S ₉		-		0.67						
S ₁₀		-		0.57						
R ²		-		1.00						
Solubility blending number (S _{BS})		-		57						
Incompatibility number (I _N)		-		33						
S _{BS} - I _N		-		24						

*Estimated values

FIG. 1

Test	Method	Unit	FAME1	FAME2	FAME3	FAME4	FAME5	FO1	FO2	FO3	FO4
Density @ 15°C	D4052	g/cm ³	0.881	0.882	0.875	0.881	0.877	1.010	0.972	0.963	0.987
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	3.734	4.369	3.739	3.612	3.566	473.0	1238	217.3	375.5
Distillation - Average Boiling Point	D1160	°C	348	351	341	50					
Distillation - Average Boiling Point	D7169	°C								483	492
Distillation - Average Boiling Point	AM-S 1847	°C							541		
CCAI	Calc.	-	825	821	819	827	823	868	822	830	848
Sulfur	ISO 8754	wt%							0.58	0.48	0.46
Carbon Residue, Micro	D4530	wt%						19.20	11.2	6.16	9.84
Asphaltenes	IP 143	wt%								1.8	2.9
Heptane Insolubles	D3279	wt%							4.3		3.6
BMCI	Calc.	-	39.1	39.4	37.3	39.9	39*	83.4	63.8	64.1	74.8
Toluene Equivalence (TE)	AM-S 79-004	-	0	0	0	0	0	73	41	43	43
BMCI - TE	-	-	39.1	39.4	37.3	39.9	39	10.9	22.8	21.1	31.8
Oil Compatibility Test	AM-S 1999-011										
Solubility blending number (S _{BN})		-	89*			68*		100		61	
Incompatibility number (I _N)		-	0			0		78		38	
S _{BN} - I _N		-	89			68		22		23	
Compatibility - Rofa Test	ASTM D7157										
S-value		-							1.74	1.82	1.93
S ₉		-							0.67	0.66	0.59
S ₀		-							0.57	0.63	0.8
R ²		-							1.00	1.000	0.998
Solubility blending number (S _{BN})		-	68*	84*	71*		116*		57	61	79
Incompatibility number (I _N)		-	0	0	0		0		33	34	41
S _{BN} - I _N		-	68	84	71		116		24	27	38
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%								0.01	<0.01
Spot Test - Cleanliness Rating	D4740	-								1	

*Estimated values

FIG. 2

Test	Method	Unit	FO1	FO2	FO3	80% FO1 + 20% FAME4	80% FO2 + 20% FAME5	80% FO3 + 20% FAME1	80% FO3 + 20% FAME2	80% FO3 + 20% FAME3
Density @ 15°C	D4052	g/cm ³	1.010	0.972	0.963	0.969	0.9531	0.947	0.947	0.945
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	473.0	1238	217.3		144.6	57.24	56.65	57.67
Distillation - Average Boiling Point	D7169	°C			483			463		
Distillation - Average Boiling Point	AM-S 1847	°C		541						
Distillation - Average Boiling Point	AM-S 1567	°C					518			
CCAI	Calc.	-	868	822	830	860		831	831	829
Sulfur	ISO 8754	wt%		0.58	0.48		0.47*	0.39*	0.39*	0.39*
Carbon Residue, Micro	D4530	wt%	19.20	11.2	6.16	15.8*	9.42	5.14	5.0*	5.0*
Asphaltenes	IP 143	wt%			1.8			1.5*	1.5*	1.5*
Heptane Insolubles	D3279	wt%		4.3			3.5*			
BMCI	Calc.	-	83.4	63.8	64.1	74.7	56.6	58.1	59.1	58.7
Toluene Equivalence (TE)	AM-S 79-004	-	73	41	43	73	41	47	47	48
BMCI - TE	-	-	10.9	22.8	21.1	2.2	15.6	11.1	12.1	10.7
Oil Compatibility Test	AM-S 1999-011									
Solubility blending number (S _{BN})		-	100		61	112		74		
Incompatibility number (I _N)		-	78		38	82		38		
S _{BN} - I _N		-	22		23	30		36		
Compatibility - Rofa Test	ASTM D7157									
S-value		-		1.74	1.82		2.43	1.88	1.85	1.74
S _a		-		0.67	0.66		0.66	0.66	0.64	0.64
S _o		-		0.57	0.63		0.82	0.63	0.66	0.62
R ²		-		1.00	1.000		1.000	0.999	0.999	0.999
Solubility blending number (S _{BN})		-		57	61		80	62	65	61
Incompatibility number (I _N)		-		33	34		34	34	36	36
S _{BN} - I _N		-		24	27		46	28	29	25
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%			0.01		0.01	<0.01	<0.01	<0.01
Spot Test -- Cleanliness Rating	D4740	-			1			1	1	1

*Estimated values

FIG. 3

Test	Method	Unit	FO2	FO4	50% FO2 + 50% FAME5	50% FO4 + 50% FAME1	50% FO4 + 50% FAME2	50% FO4 + 50% FAME3
Density @ 15°C	D4052	g/cm ³	0.972	0.987	0.9238	0.934	0.934	0.931
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	1238	375.5	21.04	17.12	16.76	16.19
Distillation - Average Boiling Point	D7169	°C		492		401	383	385
Distillation - Average Boiling Point	AM-S 1847	°C	541					
Distillation - Average Boiling Point	AM-S 1567	°C			457			
CCAI	Calc.	-	822	848	825	839	839	837
Sulfur	ISO 8754	wt%	0.58	0.46	0.31*	0.24*	0.24*	0.24*
Carbon Residue, Micro	D4530	wt%	11.2	9.84	5.97	5.2*	5.2*	5.2*
Asphaltenes	IP 143	wt%		2.9		1.5*	1.5*	1.5*
Heptane Insolubles	D3279	wt%	4.3	3.6	2.3*	1.9*	1.9*	1.9*
BMCI	Calc.	-	63.8	74.8	47.8	58.3	60.1	58.5
Toluene Equivalence (TE)	AM-S 79-004	-	41	43	44	44	46	43
BMCI - TE	-	-	22.8	31.8	3.8	14.3	14.1	15.5
Compatibility - Rofa Test	ASTM D7157							
S-value		-	1.74	1.93	2.67	1.94	2.08	2
S ₉		-	0.67	0.59	0.66	0.61	0.59	0.59
S ₁₁		-	0.57	0.8	0.9	0.76	0.84	0.81
R ²		-	1.00	0.998	0.990	0.969	0.996	1.000
Solubility blending number (S _{BS})		-	57	79	86	73	82	79
Incompatibility number (I _s)		-	33	41	34	39	41	41
S _{BS} - I _s		-	24	38	52	34	41	38
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%		<0.01	<0.01	0.01	<0.01	0.01

FIG. 4

Test	Method	Unit	FO2	FO3	30% FO2 + 30% D4 + 40% FAME5*	40% FO2 + 20% RD1 + 40% FAME5*	75% FO3 + 25% D1*	75% FO3 + 10% FAME1 + 15% D1*	50% FO3 + 50% D1*	50% FO3 + 30% FAME1 + 20% D1*
Density @ 15°C	D4052	g/cm ³	0.972	0.963	0.894	0.896	0.941	0.942	0.919	0.921
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	1238	217.3	9.21	13.02	79.50	65.60	34.77	21.99
CCAl	Calc.	-	822	830	812	806	821	824	811	821
Sulfur	ISO 8754	wt%	0.58	0.48	0.19	0.25	0.37	0.37	0.25	0.25
Carbon Residue, Micro	D4530	wt%	11.2	6.16	3.7	4.9	4.7	4.7	3.2	3.2
Asphaltenes	IP 143	wt%		1.8			1.4	1.4	0.9	0.9
Heptane Insolubles	D3279	wt%	4.3		1.4	1.9				
BMCI	Calc.	-	63.8	64.1	44.3	41.2	56.3	56.9	48.5	50.3
Toluene Equivalence (TE)	AM-S 79-004	-	41	43	41	41	43	43	43	43
BMCI - TE	-	-	22.8	21.1	3.3	0.2	13.3	13.9	5.5	7.3
Oil Compatibility Test	AM-S 1999-011									
Solubility blending number (S _{BS})		-		61			53.25	59.2	45.5	63.2
Incompatibility number (I _S)		-		38			38	38	38	38
S _{BS} - I _S		-		23			15.3	21.2	7.5	25.2
Compatibility - Rofa Test	ASTM D7157									
S-value		-	1.74							
S ₀		-	0.67							
S ₀		-	0.57							
R ²		-	1.00							
Solubility blending number (S _{BS})		-	57		73	69				
Incompatibility number (I _S)		-	33		33	33				
S _{BS} - I _S		-	24		40	36				
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%								
Spot Test - Cleanliness Rating	D4740	-								

*Estimated values

FIG. 5

Fuel	Fuel to Water Ratio	Water (wppm) at Sampling Location				
		Neat Fuel	Upper	Middle	Lower	Dead Bottom
100% VLSFO	No water	719	-	-	-	-
	1000 to 1	-	744	794	623	1774
	500 to 1	-	2228	2197	2002	3650
	100 to 1	-	10753	10741	9628	16663
20% FAME / 80% VLSFO	10 to 1	-	83439	201056	ND*	ND*
	No water	567	-	-	-	-
	1000 to 1	-	681	724	702	975
	500 to 1	-	1658	1710	1572	2776
50% FAME / 50% VLSFO	100 to 1	-	6448	6362	6535	20054
	10 to 1	-	23211	30830	37978	59405
	No water	792	-	-	-	-
	1000 to 1	-	625	608	587	941
	500 to 1	-	1572	1592	1498	2225
	100 to 1	-	4630	6403	8359	19169
	10 to 1	-	8629	15154	23035	22525

*Unobtainable

FIG. 6

Fuel to Water ratio	Day	100% VLSFO (cfu/L)				80% VLSFO / 20% FAME (cfu/L)				50% VLSFO / 50% FAME (cfu/L)			
		Upper	Middle	Lower	Dead Bottom	Upper	Middle	Lower	Dead Bottom	Upper	Middle	Lower	Dead Bottom
1000 to 1	7	*	*	*	*	*	*	*	*	*	*	*	1.00E+05
	14	*	*	*	*	*	*	*	*	*	*	*	*
	21	*	*	*	*	*	*	*	*	*	*	*	*
	28	*	*	*	*	*	*	*	*	*	*	*	*
500 to 1	7	*	*	*	*	*	*	*	*	*	*	*	1.00E+05
	14	*	*	*	*	*	*	*	*	*	*	*	3.60E+06
	21	*	*	*	*	*	*	*	*	*	*	*	*
	28	*	*	*	*	*	*	*	*	*	*	*	*
100 to 1	7	*	*	*	*	*	*	*	*	*	*	*	3.00E+07
	14	*	*	*	*	*	*	*	*	*	*	2.22E+07	1.00E+08
	21	*	*	*	*	*	*	*	*	*	*	1.20E+06	4.19E+07
	28	*	*	*	*	*	*	*	*	*	*	*	3.08E+07
10 to 1	7	*	*	*	9.00E+05	*	*	*	*	*	*	*	1.00E+08
	14	*	*	*	4.60E+06	*	*	*	1.00E+09	*	*	1.00E+09	1.00E+09
	21	*	*	*	7.00E+05	*	*	*	1.76E+07	*	*	8.00E+05	5.00E+08
	28	*	*	*	*	*	*	*	*	*	*	*	1.84E+07

*Below Detection Limit of 1.00E+05 cfu/L

FIG. 7

Fuel to Water ratio	Day	100% VLSFO (cfu/mL)				80% VLSFO / 20% FAME (cfu/mL)				50% VLSFO / 50% FAME (cfu/mL)			
		Bacteria	Yeast	Mold	SRB	Bacteria	Yeast	Mold	SRB	Bacteria	Yeast	Mold	SRB
1000 to 1	7									1.22E+06	*	*	ND
	14									2.70E+05	*	*	ND
	21									3.30E+05	*	*	ND
	28									2.50E+05	20	*	ND
100 to 1	7					*	*	*	*	ND			
	14					*	*	*	*	ND			
	21					*	*	*	*	ND			
	28					*	*	*	*	ND			
10 to 1	7	8.60E+03	*	*	ND	9.40E+06	*	20	ND				
	14	2.10E+04	*	*	ND	1.40E+05	*	*	ND				
	21	5.50E+03	*	*	ND	9.80E+04	*	*	ND				
	28	2.90E+04	*	*	ND	2.60E+04	*	*	ND				

*Below Detection Limit of 20 cfu/mL
ND = Not Detected

FIG. 8

Fuel to Water ratio	Day	100% VLSFO (cfu/mL)				80% VLSFO / 20% FAME (cfu/mL)				50% VLSFO / 50% FAME (cfu/mL)			
		Bacteria	Yeast	Mold	SRB	Bacteria	Yeast	Mold	SRB	Bacteria	Yeast	Mold	SRB
1000 to 1	7	100	*	*	ND	200	*	*	*	2000	*	*	ND
	14	*	*	*	ND	*	*	*	*	*	*	*	ND
	21	*	*	*	ND	*	*	*	*	200	*	*	ND
	28	*	*	*	ND	*	*	*	*	*	*	*	ND
500 to 1	7	100	*	*	ND	100	*	*	ND	*	*	*	ND
	14	*	*	*	ND	1200	*	*	ND	*	*	*	ND
	21	100	*	*	ND	*	*	*	ND	*	*	*	ND
	28	*	*	*	ND	*	*	*	ND	*	*	*	ND
100 to 1	7	*	*	*	ND	*	*	*	ND	*	*	*	ND
	14	*	*	*	ND	*	*	*	ND	*	*	*	ND
	21	*	*	*	ND	*	*	*	ND	*	*	*	ND
	28	*	*	*	ND	*	*	*	ND	*	*	*	ND
10 to 1	7	*	*	*	ND	*	*	*	ND	*	*	*	ND
	14	*	*	*	ND	*	*	*	ND	*	*	*	ND
	21	*	*	*	ND	*	*	*	ND	*	*	*	ND
	28	*	*	*	ND	*	*	*	ND	*	*	*	ND
10 to 1	7	*	*	*	ND	*	*	*	ND	*	*	*	ND
	14	*	*	*	ND	200	*	*	ND	*	*	*	ND
	21	*	*	*	ND	*	*	*	ND	*	*	*	ND
	28	*	*	*	ND	200	*	*	ND	*	*	*	ND

*Below Detection Limit of 100 cfu/mL
ND = Not Detected

FIG. 9

	Blend Component 1, vol%	Blend Component 2, vol%	Blend Component 3, vol%	Blend Component 4, vol%	Blend Component 5, vol%	Fuel 1, vol%	Fuel 2 vol%	Fuel 3, vol%	Fuel 4, vol%	Fuel 5, vol%	Fuel 6, vol%
Resid-containing fraction, vol%	100					100	80	30	50	40	30
Distillate fraction, vol%		100						30			
Waste-based fatty acid methyl ester, default, vol%			100				20				
Waste-based fatty acid methyl ester, typical, vol%				100				40	50	40	70
Renewable diesel, vol%					100					20	
Conventional Fraction, vol%	100					100	80	60	50	40	30
Renewable Fraction, vol%			100	100	100		20	40	50	60	70
Reduction in life cycle GHG emissions versus fossil comparator, %			83	88	51						
Life cycle GHG emissions Factor (volume basis), kgCO ₂ /eq/l	3.31	3.24	0.47	0.352	1.396	3.31	2.742	2.0978	1.821	1.736	1.2254
Life cycle GHG emissions from consumption of 1000m ³ Fuel, kgCO ₂ -eq						3310000	2742000	2097800	1821000	1736000	1225400
Reduction in life cycle GHG emissions versus Fuel 1, from consumption of 1000m ³ Fuel, %							17%	37%	45%	48%	63%

FIG. 10

	FO6	FAME6	FO7	Fuel 7 51% FO6 + 49% FAME6
FO7, vol%				
FO6, vol%	100		100	51
FAME6, vol%		100		49
Conventional Fraction, vol%	100		100	51
Renewable Fraction, vol%		100		49
Reduction in life cycle GHG emissions versus fossil comparator, %		89.4		
Life cycle GHG emissions Factor (volume basis), kgCO ₂ eq/l	3.31	0.293	3.31	1.832
Life cycle GHG emissions from consumption of 1000m ³ Fuel, kgCO ₂ eq			3310000	1831670
Reduction in life cycle GHG emissions versus FO7, from consumption of 1000m ³ Fuel, %				45

FIG. 11

Test	Method	Unit	FO2	FO2 + 50% Dist4	30% FO2 + 30% D4 + 40% FAME5	FO 2 + 33% RD1	40% FO2 + 20% RD1 + 40% FAME5
Density @ 15°C	D4052	g/cm ³	0.972			0.9088	0.8950
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	1238			52.12	12.34
CCAI	Calc.	-	822			794	807
Sulfur	ISO 8754	wt%	0.58	0.31*	0.19*	0.42*	0.25*
Carbon Residue, Micro	D4530	wt%	11.2			7.86	5.0
Heptane Insolubles	D3279	wt%	4.3			4.4	1.0
BMCI	Calc.	-	63.8			37.5	44.6
Toluene Equivalence (TE)	AM-S 79-004	-	41			TBD	TBD
BMCI - TE	-	-	22.8			TBD	TBD
Compatibility - Rofa Test	ASTM D7157						
S-value		-	1.74			1.61	1.74
S ₀		-	0.67			0.66	0.67
S ₀		-	0.57			0.55	0.58
R ²		-	1.00			1.00	0.99
Solubility blending number (S _{BN})		-	57			53	55
Incompatibility number (I _s)		-	33			34	33
S _{BN} - I _s		-	24			19	22
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%		<0.01	<0.01	0.16	<0.01
Spot Test - Cleanliness Rating	D4740	-				1	1

*Estimated values

FIG. 12

Test	Method	Unit	FO2	FO2 + 60% Dist3*	20% FO2 + 30% D3 + 50% FAMES*	FO2 + 67% Dist4*	20% FO2 + 40% D4 + 40% FAMES*
Density @ 15°C	D4052	g/cm ³	0.972	0.8905	0.8836	0.8820	0.8799
Kinematic Viscosity (KV) @ 50°C	D445	mm ² /s	1238	12.7	6.3	9.5	6.2
CCAI	Calc.	-	822	802	812	800	809
Sulfur	ISO 8754	wt%	0.58	0.25	0.13	0.21	0.13
Carbon Residue, Micro	D4530	wt%	11.2	4.9	2.5	4.1	2.4
Heptane Insolubles	D3279	wt%	4.3	1.9	0.9	1.6	0.9
BMCI	Calc.	-	63.8	41.4	40.7	40.8	40.5
Toluene Equivalence (TE)	AM-S 79-004	-	41	41	41	41	41
BMCI - TE	-	-	22.8	0.4	-0.3	-0.2	-0.5
Compatibility - Rofa Test	ASTM D7157	-					
S-value		-	1.74				
S ₁		-	0.67				
S ₂		-	0.57				
R ²		-	1.00				
Solubility blending number (S _{BN})		-	57	38	77	38	69
Incompatibility number (I _s)		-	33	33	33	33	33
S _{BN} - I _s		-	24	5	44	5	36
Total Sediment Potential (TSP)	ISO 10307-2 thermal aging	wt%					
Spot Test - Cleanliness Rating	D4740	-					

*Estimated values

FIG. 13