

1/19

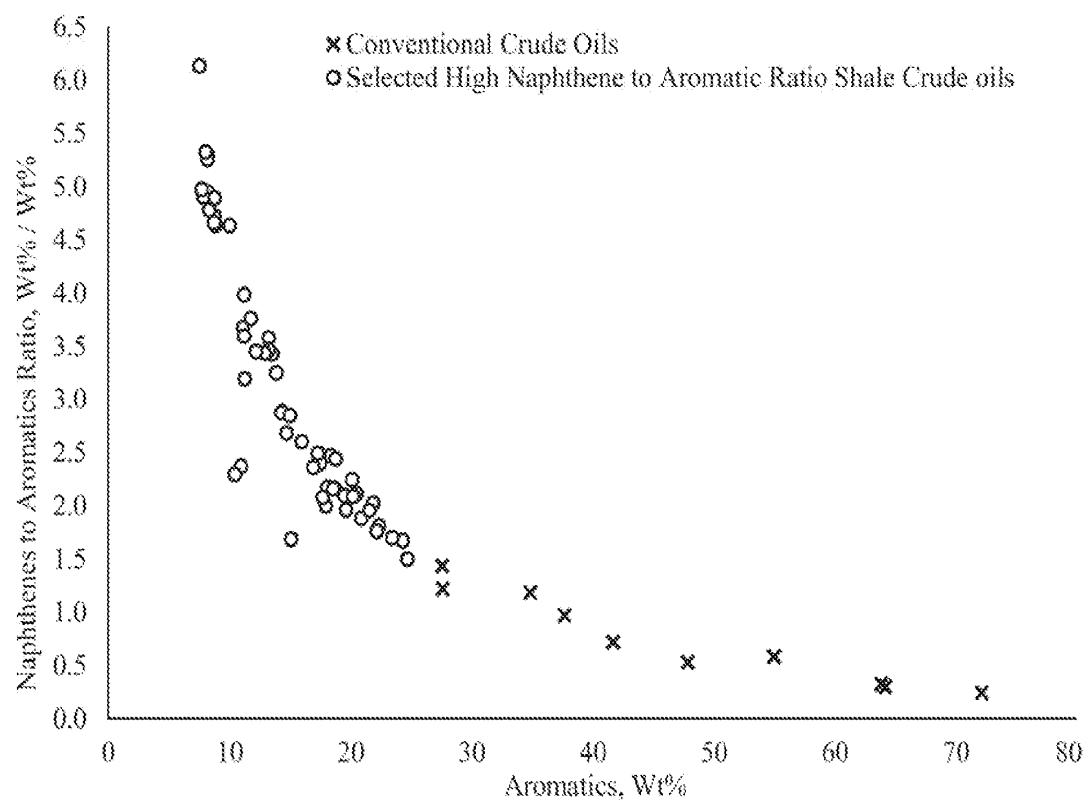
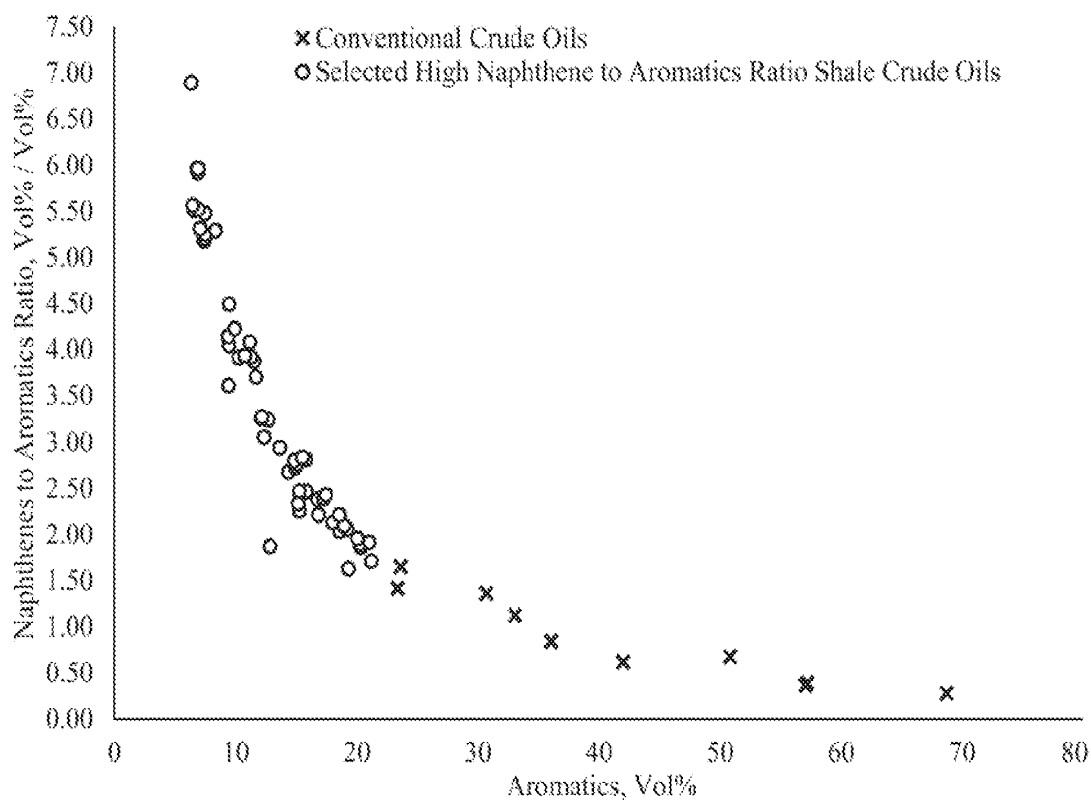
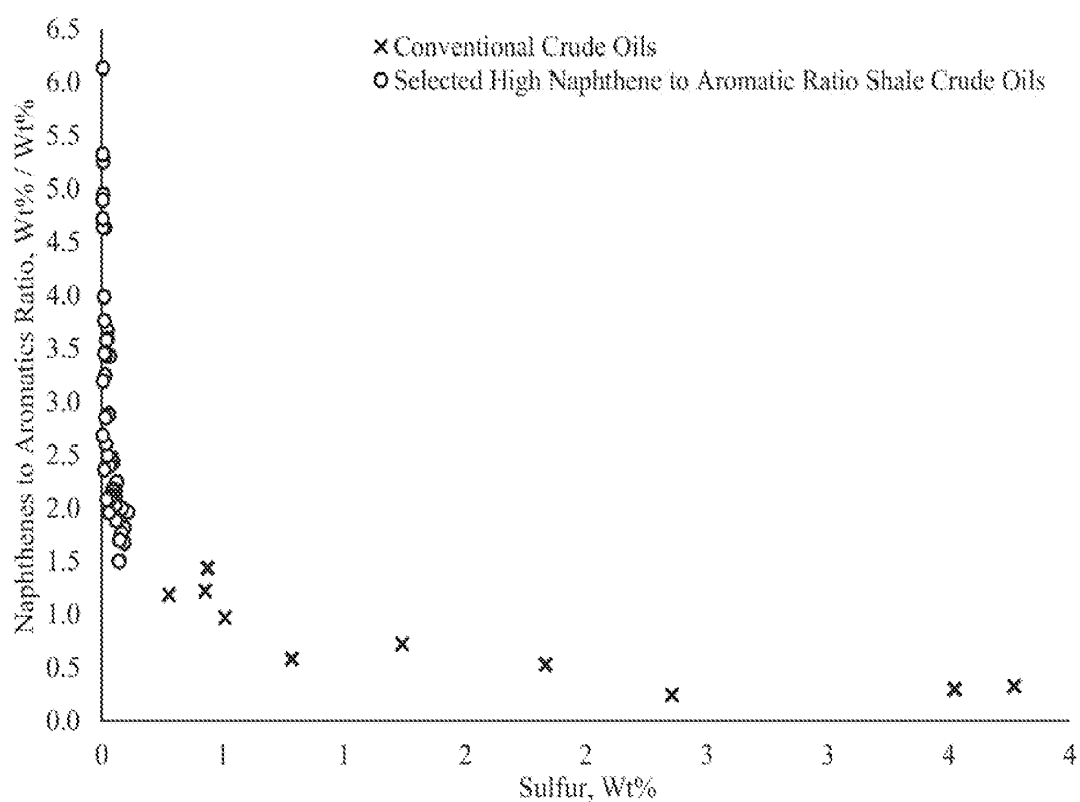
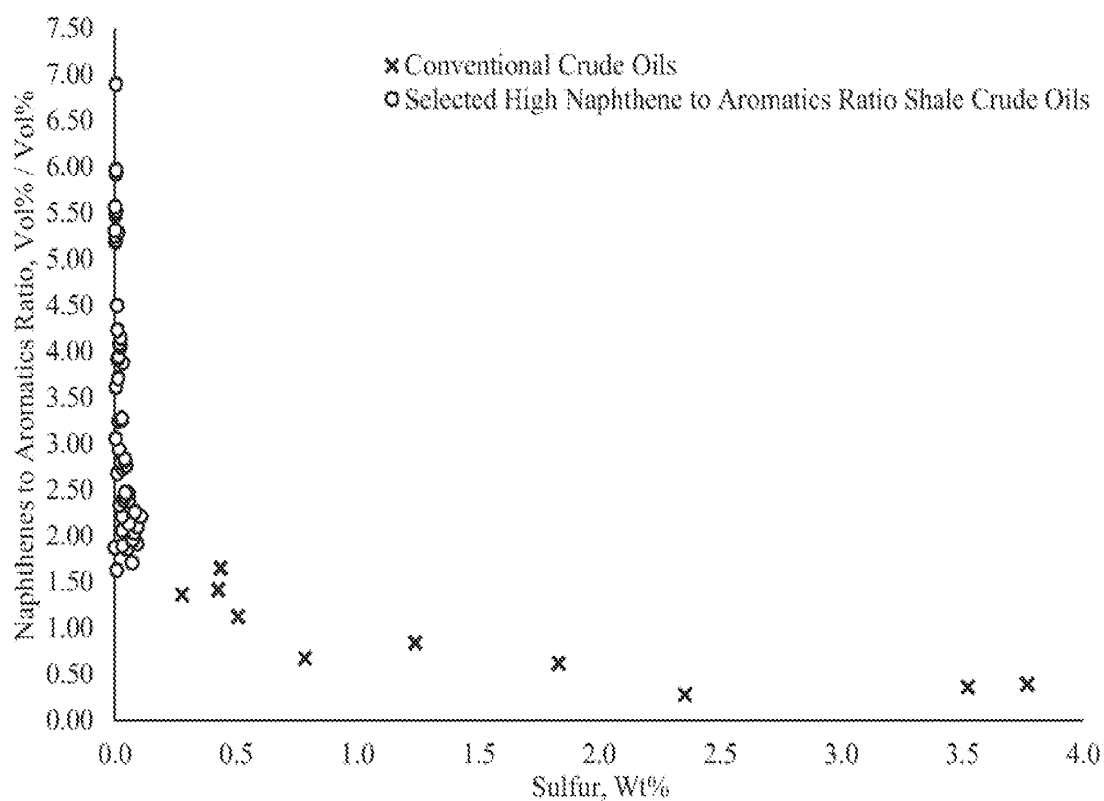


FIG. 1
SUBSTITUTE SHEET (RULE 26)

2/19

**FIG. 2**

SUBSTITUTE SHEET (RULE 26)

	Unit							
Boiling Point Range	°C	-	371 – FBP	371 – FBP	371 – FBP	371 – FBP	371 – FBP	371 – FBP
		Conventional RMG380 VLSFO	Shale Fuel Oil 1 (FO 1)	Shale Fuel Oil 2 (FO 2)	Shale Fuel Oil 3 (FO 3)	Shale Fuel Oil 4 (FO 4)	Shale Fuel Oil 5 (FO 5)	Conventional Light Sweet Crude
n-paraffins	vol%	-	5.6	9.67	4.89	3.95	5.72	4.03
i-paraffins	vol%	-	33.05	28.24	18.12	21.32	21.96	11.91
naphthenes	vol%	-	47.73	46.47	35.17	50.09	47.45	37.27
1-ring aromatic ring class	vol%	-	7.49	8.49	15.17	11.27	11.2	13.89
Aromatics	vol%	80.8	13.62	15.49	41.62	24.58	24.7	46.78
Density at 15°C	kg/m3	971.1	867.2	869.4	908.5	889.4	888	924.2
KV50	cSt	69.2	50.89	47.91	140.81	102.56	77.69	190
Aliphatic sulfur	wt%	-	0.01	0.011	0.075	0.044	0.037	0.223
Sulfur	wt%	0.475	0.014	0.017	0.217	0.057	0.049	0.97
Flash Point	°C	96	229	228	236	233	231	238
CCAI		853	753	756	781	765	768	793
Energy Content	MJ/kg	-	42.78	42.75	42.2	42.49	42.51	41.75
Carbon Intensity	g of CO2/kg of fuel	3.19	3.152	3.154	3.172	3.166	3.166	3.158
Carbon	wt%	-	85.98	86.03	86.52	86.33	86.36	86.12
Hydrogen	wt%	-	14	13.93	13.08	13.55	13.55	12.85
Basic Nitrogen	wppm	-	25	30	596	200	147	640
Nitrogen	wppm	-	71	101	1881	545	495	2079
Ratio of Hydrogen to Carbon		-	1.94	1.93	1.8	1.87	1.87	1.78
BMCI		68	22.2	23.6	39.8	31.8	31.8	46.9
N-Heptane Insolubles	wt%	2.2	0.05	0.05	0.07	0.01	0.02	0.28
MCR	wt%	5.96	0.06	0.15	2.45	0.56	0.8	4.32

FIG. 3

4/19

	Unit					
Boiling Point Range	°C			371 - FBP	371 - FBP	371 - FBP
Property		ISO 8217 RME180 VLSFO Limit	Conventional RMG380 VLSFO	Selected High Naphthene to Aromatic Ratio Shale Fuel Oils Min - Max	Other Shale Fuel Oils Min - Max	Conventional Fuel Oils Min - Max
Number of Samples			1	56	11	10
10% off	°C		-	368 - 401	356 - 393	382 - 456
50% off	°C		-		391 - 477	458 - 570
90% off	°C		-	523 - 615	436 - 608	576 - 709
95% off	°C		-	574 - 708	465 - 704	673 - 760
Final Boiling Point (FBP)	°C		-	1052 - 1163	1059 - 1160	1052 - 1080
Density	kg/m ³	Max 991.0	971.1	859.1 - 910.6	831.1 - 926.2	924.2 - 1026.8
KV at 50°C	mm ² /s	Max 180.0	69.2	26 - 231	14 - 215	166 - 142285
Sulfur	wppm	Max 0.50	0.475	73 - 2356	431 - 8730	7295 - 51038
Flash Point	°C	Min 60	96	219 - 238	201 - 235	229 - 262
CCAI		Max 860	853	752 - 793	733 - 800	793 - 845
Aliphatic Sulfur	wppm		-	63 - 1764	227 - 2111	2575 - 17808
Aliphatic Sulfur to Sulfur Ratio	wppm / wppm		-	0.32 - 1.00	0.24 - 0.79	0.21 - 0.53
Nitrogen	wppm		-	30 - 2065	83 - 1825	2079 - 5711
Basic Nitrogen	wppm		-	10 - 596	50 - 557	640.1 - 1385
Basic Nitrogen to Nitrogen Ratio	wppm / wppm		-	0.07 - 1.00	0.12 - 0.6	0.24 - 0.31
Aromatics	wt%		80.8	12.5 - 45.0	38.9 - 49.9	50.2 - 83.8
Paraffins	wt%		-	18.4 - 38.9	19.7 - 26.7	3.0 - 17.7
Naphthenes	wt%		-	33.9 - 51.9	29.0 - 39.0	13.2 - 35.5
Cyclic Hydrocarbons (Aromatic + Naphthenes)	wt%		-	61.0 - 81.5	73.3 - 79.9	81.2 - 97.0
Saturated Hydrocarbons (Paraffins + Naphthenes)	wt%		-	54.9 - 87.4	49.8 - 61.1	27.4 - 53.3
Naphthenes to Aromatics Ratio	wt% / wt%		-	0.75 - 3.87	0.58 - 0.96	0.16 - 0.71
CCAI to Aromatics Ratio	-		-	17.4 - 60.4	15.9 - 19.8	10.1 - 15.8
Hydrogen to Carbon Molar Ratio	wt% / wt%		-	1.84 - 1.95	1.79 - 1.94	1.83 - 2.27
Microcarbon Residue	wt%	Max 15	5.96	0.04 - 3.03	0.060 - 4.2	3.9 - 17.7
N-Heptane Insolubles	wt%		2.2	0.00 - 1.5	0.00 - 0.84	0.28 - 14.1
BMIC	-		68	18.4 - 39.6	10.5 - 48.0	45.3 - 87.7

FIG. 4
SUBSTITUTE SHEET (RULE 26)

5/19

Boiling Point Range, °C		-	145 - FBP	145 - FBP	145 - FBP	145 - FBP	145 - FBP	145 - FBP
	ISO 8217 RMA 10 VLSFO	Conventional RMG 380 VLSFO	Simple Fuel Oil (1)	Simple Fuel Oil (2)	Simple Fuel Oil (3)	Simple Fuel Oil (4)	Simple Fuel Oil (5)	Conventional Light Sweet Crude
n-paraffins (vol%)		-	16.77	19.69	12.73	13.65	15.41	12.07
i-paraffins (vol%)		-	30.58	27.95	21.09	22.85	22.80	16.77
naphthenes (vol%)		-	44.72	43.18	41.04	48.96	47.27	41.61
1-ring aromatic ring class (vol%)		-	5.36	6.28	12.16	8.51	8.36	12.50
Aromatics (vol%)		80.8	7.93	9.10	25.01	14.43	14.39	29.55
Density at 15°C (kg/m3)	Max 920.0	971.1	824.3	825.1	857.0	842.6	841.3	867.4
KV50 (cSt)	Max 10.00	69.2	3.62	3.53	6.07	4.68	4.41	7.9
Aliphatic Sulfur (wt%)		-	0.004	0.005	0.037	0.022	0.016	0.169
Sulfur (wt%)	Max 0.50	0.475	0.008	0.009	0.114	0.028	0.023	0.5960
Flash Point	Min 60	96	63	61	65	63	63	66
CCAI	Max 850	853	770	771	787	780	780	790
Energy content (MJ/kg)		-	43.28	43.28	42.87	43.07	43.08	42.58
Carbon Intensity (kg of CO ₂ /kg of fuel)		3.19	3.14	3.14	3.16	3.15	3.15	3.15
Carbon (wt%)		-	85.69	85.74	86.26	86.02	86.03	86.05
Hydrogen (wt%)		-	14.30	14.24	13.54	13.93	13.93	13.33
Basic nitrogen (ppm m/m)		-	8.4	10	259	73	54	~300
Nitrogen (ppm m/m)		-	23	32	808	210	184	964
Ratio of hydrogen to carbon		-	1.99	1.98	1.87	1.93	1.93	1.85
BMCI		68	22.0	22.7	32.7	29.0	28.1	36.0
N-Heptane Insolubles (wt%)		2.2	0.016	0.015	0.012	0.027	0.003	0.123
MCR (wt%)	Max 2.50	5.96	0.019	0.045	0.070	1.008	0.196	1.92

FIG. 5
SUBSTITUTE SHEET (RULE 26)

	Unit					
Boiling Point Range	°C	-	-	145 - FBP	145 - FBP	145 - FBP
Property		ISO 8217 RMA10 VLSFO Limit	Conventional RMG380 VLSFO	Selected High Naphthene to Aromatic Ratio Shale Simple Fuel Oils Min - Max	Other Shale Simple Fuel Oils Min - Max	Conventional Simple Fuel Oils Min - Max
Number of Samples		-	1	57	10	10
10% off	°C		-	177-221	137-217	195-400
50% off	°C		-	270-337	190-333	295-525
90% off	°C		-	401-496	261-496	446-671
Density	kg/m ³	Max 920.0	971.1	817-866	783-875	867-997
KV at 50°C	mm ² /s	Max 10.00	69.2	2.8-7.8	1.3-7.6	5.1-1895
Sulfur	wppm	Max 0.50	0.475	0.006-0.328	0.002-0.484	0.350-4.383
Flash Point	°C	Min 60	96	60-68	48-67	66-125
CCAI		Max 850	853	769-799	762-804	790-843
Aliphatic Sulfur	wppm		-	37-1090	11-1029	1690-15607
Aliphatic Sulfur to Sulfur Ratio	wppm / wppm		-	0.31-1.00	0.21-1.00	0.23-0.53
Nitrogen	wppm		-	17-921	2-824	964-4492
Basic Nitrogen	wppm		-	6-259	1-251	297-1232
Basic Nitrogen to Nitrogen Ratio	wppm / wppm		-	0.08-0.59	0.24-0.98	0.24-0.31
Aromatics	wt%		80.8	8.7-31.8	9.0-37.4	33.1-74.9
Paraffins	wt%		-	27.7-49.7	27.6-68.1	4.7-29.6
Naphthenes	wt%		-	33.5-50.8	22.8-41.2	17.5-41.5
Cyclic Hydrocarbons (Aromatic + Naphthenes)	wt%		-	50.3-72.2	31.9-72.1	69.6-94.7
Saturated Hydrocarbons (Paraffins + Naphthenes)	wt%		-	68.1-91.3	62.4-91.0	25.1-66.9
Naphthenes to Aromatics Ratio	wt% / wt%		-	1.3-5.8	0.9-4.6	0.2-1.2
Hydrogen to Carbon Ratio	wt% / wt%		-	1.85-2.00	1.82-1.92	1.82-2.21
Microcarbon Residue	wt%	Max 2.50	5.96	0.0-1.1	0.0-1.8	1.3-13.9
N-Heptane Insolubles	wt%		2.2	0.0013-0.4234	0.0000-0.1087	0.1226-11.0111
BHCI			68	20-35	18-39	35-78

	Method	Distillate 1	Distillate 2	Distillate 3	Distillate 4	Distillate 5
API Gravity	D4052	34.8	35.9	38.3	35.8	38.3
Specific Gravity (g/ml)	Calc. from API Gravity	0.85	0.85	0.83	0.85	0.83
Sulfur (wt%)	D2622	0.094	0.023	0.007	0.023	0.0075
Nitrogen (wppm)	D4629	145	73	<5	58	6.5
Cloud Pt (°C)	D5773	-1	-4	-3	0	-1
Pour Pt (°C)	D5949	-	-4	-2	1	0
Derived Cetane Number	D7668* D6890	62, 59	62, 61	66, 64	64, 62	68, >64
10% off	D2887	296	295	293	300	300
50% off	D2887	323	322	320	326	326
90% off	D2887	354	353	353	356	356

	Method	Distillate 6	Distillate 7
API Gravity	D4052	36.6	33.6
Specific Gravity (g/ml)	Calc. from API Gravity	0.84	0.86
Sulfur (wt%)	D2622	-	-
Nitrogen (wppm)	D4629	48	82
Cloud Pt (°C)	D5773	1	4
Pour Pt (°C)	D5949	-1	3
Derived Cetane Number	D7668* D6890	70.57*	64.00*
10% off	D2887	293	298
50% off	D2887	327	328
90% off	D2887	361	361

FIG. 7

	Units	Distillate 8	Distillate 9	Distillate 10	Distillate 11	Distillate 12	ISO 8217 DMA Limit
Flash Point	°C	63	62	64	63	63	Min. 60
Density at 15°C	kg/m ³	813.4	814.1	832.7	826.5	826.6	Max. 890.0
Viscosity at 40°C	cSt	2.6	2.5	2.8	2.7	2.7	2 - 6
Viscosity at 50°C	cSt	2.2	2.2	2.4	2.3	2.3	-
Sulfur Content	mass%	0.00543	0.00563	0.05926	0.01716	0.01366	Max 1.00 / By Regulation Max: 0.1, 0.05, 0.001- 0.0015
Carbon Content	mass%	85.61	85.65	86.15	85.92	85.93	-
Hydrogen Content	mass%	14.38	14.34	13.77	14.05	14.06	-
Nitrogen Content	mg/kg	6	4	128	53	42	-
Energy Content	MJ/kg	43.2	43.2	42.9	43.0	43.0	-
Cloud Point	°C	8	-2	2	5	0	-
Pour Point	°C	3	-6	-3	0	-5	Summer 0 Winter -6 (Max)
Cetane Index, 4-number	-	55	54	50	50	51	Min. 40
Cetane Index, 2-number	-	57	56	52	52	53	-
Acid Number	mgKOH/g	0.04	0.02	0.06	0.04	0.05	Max. 0.5
Atmospheric Distillation (D86)							
10% off Temp.	°F	374	371	377	373	375	-
50% off Temp.	°F	487	483	502	485	495	-
90% off Temp.	°F	697	700	713	705	707	-
n-paraffins	vol%	20	22	17	17	19	-
i-paraffins	vol%	31	29	24	25	24	-
cyclo-paraffins	vol%	43	42	43	47	46	-
1-ring	vol%	32	29	30	32	32	-
Aromatics	vol%	6	7	16	11	10	-
Saturates	vol%	94	93	84	89	89	-

FIG. 8

		Comparative Example Distillate 1	Comparative Example Distillate 2	Comparative Example Distillate 3	ISO 8217 DMA Limits
Flash Point	°C	87	65	93	Min. 60
Density at 15°C	kg/m ³	909.6	838.1	887.8	Max. 890
Viscosity at 40°C	cSt	8.3	3.4	7.0	2 - 6
Viscosity at 50°C	cSt	6.2	2.8	5.3	-
Sulfur Content	mass%	2.2536	0.3653	0.3258	Max 1.00 / By Regulation Max: 0.1, 0.05, 0.001- 0.0015
Carbon Content	mass%	85.57	86.03	87.03	-
Hydrogen Content	mass%	12.17	13.61	12.58	-
Nitrogen Content	mg/kg	421	184	193	-
Energy Content	MJ/kg	41.3	42.8	42.2	-
Cloud Point	°C	-31	5	9	-
Pour Point	°C	-35	1	5	Summer 0 Winter -6 (Max)
Cetane Index, 4- number	-	34	49	42	Min. 40
Cetane Index, 2- number	-	39	51	44	
Acid Number	mgKOH/g	0.69	0.05	0.98	Max. 0.5
Atmospheric Distillation (D86)					
10% off Temp.	°F	448	377	470	-
50% off Temp.	°F	609	510	605	-
90% off Temp.	°F	736	716	734	-
Composition					
n-paraffins	vol%	1	17	5	-
i-paraffins	vol%	10	21	15	-
cyclo-paraffins	vol%	45	43	44	-
1-ring	vol%	20	28	24	-
Aromatics	vol%	41	19	36	-
Saturates	vol%	56	81	64	-

FIG. 9

	Units	Distillate 13	Distillate 14	Distillate 15	Distillate 16	Distillate 17	ISO 8217 DMA Limit
Flash Point	°C	64	62	65	63	64	Min. 60
Density at 15°C	kg/m ³	816.1	816.9	836.9	829.8	829.8	Max. 890.0
Viscosity at 40°C	cSt	2.8	2.8	3.2	3.0	3.1	2 ~ 6
Viscosity at 50°C	cSt	2.4	2.4	2.7	2.5	2.6	-
Sulfur Content	mass %	0.00558	0.00591	0.06660	0.01946	0.01511	Max 1.00 / 0.1, 0.05, 0.001- 0.0015
Carbon Content	mass %	85.63	85.68	86.19	85.95	85.95	-
Hydrogen Content	mass %	14.36	14.32	13.72	14.02	14.02	-
Nitrogen Content	mg/k g	8	7	173	66	54	-
Energy Content	MJ/k g	43.1	43.1	42.9	43.0	43.0	-
Cloud Point	°C	14	5	9	11	6	-
Pour Point	°C	9	0	4	7	2	Summer 0 Winter -6
Cetane Index, 4- number	-	54	53	49	50	51	Min. 40
Cetane Index, 2- number	-	57	57	52	52	54	-
Acid Number	mgK OH/g	0.04	0.03	0.07	0.04	0.06	Max. 0.5
Atmospheric Distillation (D86)							
10% off	°F	377	373	380	375	377	-
50% off	°F	499	496	520	499	510	-
90% off	°F	736	739	758	748	748	-
n-paraffins	vol%	19	21	16	17	18	-
i-paraffins	vol%	31	29	24	25	24	-
cyclo- paraffins	vol%	43	43	43	47	46	-
1-ring	vol%	32	30	29	32	32	-
Aromatics	vol%	6	7	17	11	11	-
Saturates	vol%	93	93	83	89	88	-

FIG. 10

		Comparative Example Distillate 1	Comparative Example Distillate 2	Comparative Example Distillate 3	ISO 8217 DMA Limits
Flash Point	°C	87	65	93	Min. 60
Density at 15°C	kg/m ³	909.6	838.1	887.8	Max. 890
Viscosity at 40°C	cSt	8.3	3.4	7.0	2 - 6
Viscosity at 50°C	cSt	6.2	2.8	5.3	-
Sulfur Content	mass%	2.2536	0.3653	0.3258	Max 1.00 / By Regulation Max: 0.1, 0.05, 0.001- 0.0015
Carbon Content	mass%	85.57	86.03	87.03	-
Hydrogen Content	mass%	12.17	13.61	12.58	-
Nitrogen Content	mg/kg	421	184	193	-
Energy Content	MJ/kg	41.3	42.8	42.2	-
Cloud Point	°C	-31	5	9	-
Pour Point	°C	-35	1	5	Summer 0 Winter -6
Cetane Index, 4- number	-	34	49	42	Min. 40
Cetane Index, 2- number	-	39	51	44	
Acid Number	mgKOH/g	0.69	0.05	0.98	Max. 0.5
Atmospheric Distillation (D86)					
10% off	°F	448	377	470	-
50% off	°F	609	510	605	-
90% off	°F	736	716	734	-
Composition					
n-paraffins	vol%	1	17	5	-
i-paraffins	vol%	10	21	15	-
cyclo-paraffins	vol%	45	43	44	-
l-ring	vol%	20	28	24	-
Aromatics	vol%	41	19	36	-
Saturates	vol%	56	81	64	-

FIG. 11

	Method	Units	Distillate 1	Distillate 2	Distillate 3	Distillate 4	Distillate 5
API Gravity	D4052	-	27.3	29.5	32.7	29.6	32.9
Specific Gravity	Calc. from API Gravity	g/ml	0.8911	0.8789	0.8618	0.8783	0.8607
Density at 15°C	D7042		0.8866	0.8737	0.8558	0.8729	0.8547
Viscosity at 60°C	D7042	mm ² /s	21.932	18.841	13.900	18.556	14.84
Viscosity at 100°C	D7042	mm ² /s	6.9585	6.2963	5.2090	6.3081	5.4272
VI	Calc from KV60 / KV100	-	91.0	97.341	117.9	103.5	113.6
Sulfur Content	D2622	mass%		0.040	0.012	0.039	0.010
Nitrogen Content	D4629	mg/kg		344	63	307	52
Hydrogen Content	AM11807	mass%	13.13	13.61	13.99	13.51	14.03
Pour Point	D5949	°C					
MCR	D4530	mass%	0.09	0.03	0.01	0.08	0.02
Saturates		mass%		76.99	89.06	78.95	87.59
ARC1		mass%		9.86	6.26	9.93	5.67
ARC2		mass%		4.45	2.53	5.53	2.14
ARC3		mass%		2.94	1.5	3.87	1.12
ARC4		mass%		2.5	0	0	0
Sulfides		mass%		2.32	0.65	1.72	1.59
Polars		mass%		0.95	0	0	1.9
10% off	D2887	°F	708	701	696	713	708
50% off	D2887	°F	820	811	802	815	807
90% off	D2887	°F	954	949	944	946	940

FIG. 12

	Method	Units	Distillate 6	Distillate 7
API Gravity	D4052	-	30.1	27.2
Specific Gravity	Calc. from API Gravity	g/ml	0.8756	0.8916
Density at 15°C	D7042		0.8705	0.8871
Viscosity at 60°C	D7042	mm ² /s	17.78	21.772
Viscosity at 100°C	D7042	mm ² /s	6.1592	7.0177
VI	Calc from KV60 / KV100	-	91.437	97.502
Sulfur Content	D2622	mass%		
Nitrogen Content	D4629	mg/kg		
Hydrogen Content	AM11807	mass%		
Pour Point	D5949	°C		
MCR	D4530	mass%		
Saturates		mass%		
ARC1		mass%		
ARC2		mass%		
ARC3		mass%		
ARC4		mass%		
Sulfides		mass%		
Polars		mass%		
10% off	D2887	°F	717	712
50% off	D2887	°F	820	826
90% off	D2887	°F	958	963

FIG. 13

	Unit						
Boiling Point Range	°C	371 - 538	371 - 538	371 - 538	371 - 538	371 - 538	
Name		VGO 1	VGO 2	VGO 3	VGO 4	VGO 5	ISO 8217 RMD80 Limits
Flash Point	°C	221	220	223	222	221	Min. 60
Density at 15°C	kg/m ³	862.6	863.7	890.1	880.2	878.4	Max. 975
Viscosity at 50°C	cSt	21.2	20.2	29.4	27.1	25.8	Max. 80
Sulfur Content	mass%	0.009	0.011	0.167	0.052	0.038	By Regulation Max: 0.1, 0.5
Carbon Content	mass%	85.97	86.02	86.52	86.36	86.35	-
Hydrogen Content	mass%	14.01	13.96	13.23	13.55	13.57	-
Nitrogen Content	mg/kg	51	59	832	308	277	-
Ratio of hydrogen to carbon	-	1.94	1.93	1.82	1.87	1.87	-
Energy Content	MJ/kg	42.84	42.82	42.45	42.61	42.64	-
Cloud Point	°C	44	37	39	42	36	-
Pour Point	°C	42	34	37	39	34	Max. 30
CCAI	-	764	766	785	777	776	Max. 860
Acid Number	mgKOH/g	0.08	0.07	0.11	0.08	0.11	Max. 2.5
MCR	mass%	0.02	0.04	0.19	0.09	0.07	Max. 15.00
BMCI	-	22.4	23.1	34.7	30.4	29.8	
N-heptane insolubles	mass%	0.00	0.00	0.00	0.00	0.00	
10% off	°F	732	731	737	734	733	-
50% off	°F	788	785	800	794	789	-
90% off	°F	904	902	910	907	905	-
n-paraffins	vol%	6.39	8.39	6.31	5.32	7.28	-
i-paraffins	vol%	35.07	31.17	23.80	26.45	25.98	-
cyclo-paraffins	vol%	47.82	47.71	38.72	48.10	46.35	-
l-ring	vol%	28.81	30.91	23.24	27.45	28.11	-
Aromatics	vol%	10.72	12.57	30.88	20.06	20.17	-

FIG. 14

	Selected High Naphthene to Aromatic Ratio Shale VGOs Min - Max	Other Shale VGOs Min - Max	Conventional VGOs Min - Max
No. Samples	54	13	10
Napthenes (wt%)	14.6 - 52	31.9 - 47.9	24.4 - 41.4
Aromatics (wt%)	6.3 - 33.7	28 - 40.3	37.3 - 69.2
Napthenes to Aromatics Ratio (wt%/wt%)	1.1 - 4.7	0.79 - 1.7	0.35 - 1.1
Density at 15°C (kg/m ³)	831.1 - 889.2	886.4 - 906.6	900.3 - 976.8
10% off (°C)	356 - 378	373 - 377	372 - 394
90% off (°C)	436 - 516	508 - 513	506 - 525
KV50 (cSt)	13.7 - 41.8	14.1 - 41.1	36.3 - 315.3
Sulfur (wt%)	0.0049 - 0.27	0.068 - 0.72	0.58 - 3.47
Aliphatic Sulfur (wt%)	0.0044 - 0.15	0.047 - 0.1477	0.18 - 1.13
Ratio Aliphatic to Total Sulfur	0.29 - 1.0	0.19 - 1.0	0.24 - 0.64
Flash Point	201 - 224	221 - 224	221 - 234
CCAI	733 - 784	780 - 805	790 - 840
Nitrogen (ppm m/m)	24.9 - 917.8	505.7 - 1233.4	857.3 - 2613.6
Basic Nitrogen (ppm m/m)	8.4 - 261.4	120.3 - 372.2	289.4 - 818.5
Ratio Basic Nitrogen to Nitrogen	0.12 - 1.00	0.24 - 0.38	0.29 - 0.38
Pour Point (°C)	21.1 - 42.1	32.9 - 40.2	-4.1 - 41.8

FIG. 15

		Comparative Example VGO 1	Comparative Example VGO 2	Comparative Example VGO 3	ISO 8217 RMD80 Limits
Flash Point	°C	229	224	226	Min. 60
Density at 15°C	kg/m ³	967.3	902.2	932.0	Max. 975
Viscosity at 50°C	cSt	233	45	73	Max. 80
Sulfur Content	mass%	3.467	0.703	0.688	By Regulation Max: 0.1, 0.5
Carbon Content	mass%	84.75	86.19	86.84	-
Hydrogen Content	mass%	11.48	12.98	12.25	-
Nitrogen Content	mg/kg	1756	1099	1087	-
Ratio of hydrogen to carbon	-	1.61	1.79	1.68	-
Energy Content	MJ/kg	40.37	42.12	41.74	-
Cloud Point	°C	-2	38	40	-
Pour Point	°C	-4	36	38	Max. 30
CCAI	-	833	790	813	Max. 860
Acid Number	mgKOH/g	1.29	0.10	1.79	Max. 2.5
10% off	°F	748	739	742	-
50% off	°F	824	804	811	-
90% off	°F	917	910	914	-
n-paraffins	vol%	0.44	6.06	4.21	-
i-paraffins	vol%	6.45	17.27	13.84	-
cyclo- paraffins	vol%	27.54	42.81	34.42	-
l-ring	vol%	8.71	23.67	18.22	-
Aromatics	vol%	64.79	33.85	47.45	-

FIG. 16

	Conven- tional VLSFO	VR Fuel Oil (1)	VR Fuel Oil (2)	VR Fuel Oil (3)	VR Fuel Oil (4)	VR Fuel Oil (5)	Comparative light sweet crude
n-paraffins (vol%)	-	2.76	14.43	1.86	0.37	0.87	0.54
i-paraffins (vol%)	-	25.85	17.36	5.97	7.87	9.52	2.66
naphthenes (vol%)	-	47.40	41.84	27.59	55.32	50.87	27.70
1-ring aromatic ring class (vol%)	-	13.25	11.60	13.60	13.46	12.33	14.40
Aromatics (vol%)	80.8 wt%	23.99	26.37	64.58	36.44	38.74	69.11
Density at 15°C (kg/m ³)	971.1	882.1	889.0	947.1	912.8	916.1	967.0
KV50 (cSt)	69.2	3449	4313	22866	20850	10706	10606
Sulfur (wt%)	0.475	0.029	0.034	0.317	0.071	0.078	1.449
Flash Point	96	331	333	336	337	333	341
CCAI	853	724	729	776	742	750	801
Energy content (MJ/kg)	-	42.59	42.51	41.66	42.19	42.15	41.03
Carbon (wt%)	-	86.00	86.05	86.53	86.27	86.37	86.00
Hydrogen (wt%)	-	13.95	13.83	12.79	13.55	13.48	12.62
Nitrogen (ppm m/m)	-	137	240	3940	1129	1110	3868
Ratio of hydrogen to carbon	-	1.93	1.92	1.76	1.87	1.86	1.75
BMCI	68	19.2	22.3	49.3	33.0	35.0	58.0
N-Heptane Insolubles (wt%)	2.2	0.22	0.22	0.19	0.03	0.07	0.78
MCR (wt%)	5.96	0.22	0.51	6.89	1.70	2.83	11.86

FIG. 17

	ISO 8217 RME180 VLSFO Limit	Conventional RMG380 VLSFO	Selected High Naphthene to Aromatic Ratio VR Fuel Oils Min - Max	Other VR Fuel Oils Min - Max	Conventional VR Fuel Oils Min - Max
No. Samples		1	56	11	10
Napthenes (wt%)	-	-	24.2 - 59.1	21.1 - 33.3	4.3 - 25.8
Aromatics (wt%)	-	80.8	17.8 - 69.6	50.7-74.1	71.3 - 95.4
Napthenes to Aromatics Ratio (wt%/wt%)	-	-	0.35 - 3.3	0.29 - 0.60	0.05 - 0.36
10% off (°C)			523 - 543	522 - 542	537 - 571
90% off (°C)			588 - 716	585 - 722	701 - 760
Density at 15°C (kg/m ³)	Max 991.0	971.1	844.0 - 949.3	950.7 - 981.1	967-1069.6
KV50 (cSt)	Max 180.0	69.2	176 - 89926	4680 - 113875	10606 - 9.98×10 ⁸
Sulfur (wt%)	Max 0.50	0.475	0.011 - 0.363	0.081 - 1.27	1.25 - 6.17
Aliphatic Sulfur (wt%)	-	-	0.011 - 0.25	0.081 - 0.37	0.345 - 2.3
Ratio Aliphatic to Total Sulfur	-	-	0.435 - 1.00	0.27 - 1.00	0.18 - 0.5
Flash Point	Min 60	96	307 - 340	306 - 339	335 - 357
CCAI	Max 860	853	701 - 790	777 - 806	801 - 854
Nitrogen (ppm m/m)	-	-	54 - 4604	192.8 - 4303	3868 - 9257
Basic Nitrogen (ppm m/m)	-	-	22.4 - 1144	68.4 - 998.4	1205 - 2589
Ratio Basic Nitrogen to Nitrogen	-	-	0.037 - 1.0	0.13 - 0.39	0.23 - 0.31
N-Heptane Insolubles (wt%)	-	2.2	0.03 - 1.2	0.12 - 4.76	0.78 - 23.3
MCR (wt%)	Max 15	5.96	0.21 - 7.6	1.41 - 12.9	11.9 - 28.7

FIG. 18

19/19

Blend with Fuel Oil 4	Distillate Blendstock 1, vol%	98	80	70	50	45		
	Shale Fuel Oil 4, vol %	2	20	30	50	55		
Property	Method	Result	Result	Result	Result	Result		
MCR, % mass	ASTM D4530	0.01	0.12	0.18	0.29	0.32	0.30	2.50
Density, kg/m ³	D4025	831.8	842.4	848.2	860.0	862.9	Max 900.0	Max 920.0
Sulfur, mg/kg	D4294 or D5453	16	124	183	299	327	<1000 or <5000	<1000 or <5000
KV50, cSt	D445	2.5	3.8	5.0	9.4	11.3	-	Max 10
KV40, cSt	D445	3.0	4.7	6.3	12.5	15.3	2 – 11	-

Blend with Fuel Oil 1	Distillate Blendstock 1, vol%	80	70	50	45	40		
	Shale Fuel Oil 1, vol %	20	30	50	55	60		
Property	Method	Result	Result	Result	Result	Result		
MCR, % mass	ASTM D4530	0.01	0.02	0.03	0.03	0.04	0.30	2.50
Density, kg/m ³	D4025	837.9	841.6	848.9	850.7	0.8526	Max 900.0	Max 920.0
Sulfur, mg/kg	D4294 or D5453	32	47	74	81	88	<1000 or <5000	<1000 or <5000
KV50, cSt	D445	3.6	4.5	7.7	8.9	10.4	-	Max 10
KV40, cSt	D445	4.4	5.6	10.1	11.8	14.0	2 – 11	-

Blend with Fuel Oil 3	Distillate Blendstock 1, vol%	90	80	55	50		
	Shale Fuel Oil 3, vol %	10	20	45	50		
Property	Method	Result	Result	Result	Result		
MCR, % mass	ASTM D4530	0.27	0.53	1.16	1.28	0.30	2.50
Density, kg/m ³	D4025	838.4	846.2	865.7	869.6	Max 900.0	Max 920.0
Sulfur, mg/kg	D4294 or D5453	239	470	1029	1138	<1000 or <5000	<1000 or <5000
KV50, cSt	D445	3.0	3.9	8.5	10.2	-	Max 10
KV40, cSt	D445	3.6	4.8	11.2	13.7	2 – 11	-

FIG. 19
SUBSTITUTE SHEET (RULE 26)