Supplementary material

Empirical Models to Characterize the structural and physio-chemical properties of Vacuum Gas Oils with different saturate contents

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Table S1 Properties of the vacuum gas oils under study

feed number	feed name	Density at 15°C (g/ml)	Kw	MW	Kin. viscosity at 100°C	$T_{50\%}$, °C	CCR, wt. %	Hydrogen content (wt.%)	H/C atomic ratio	Total Nitrogen Content (wppm)	Basic Nitrogen Content (wppm)	Sulphur %
1	HCB [2]	0.8643	12.6	396	6.5	450		13.7	1.9	0.0	0.5	0.001
2	HT--VIR [2]	0.9252	12.2	490	20.1	520		12.3	1.7	460.0	51.0	0.098
3	RZ [2]	0.8988		366				12.8	1.8	800.0	240.0	0.917
4	HT-LCF [2]	0.9284	11.9	424	13.6	485		12.1	1.6	1090.0	148.0	0.088
5	HT-C [2]	0.9511	11.8	467	22.8	515		11.5	1.6	2150.0	439.0	0.429
6	HT-DA [2]	0.9430		600				11.8	1.6	2450.0	613.0	0.704
7	VIR [2]	0.9712	11.8	588	66.3	575		11.1	1.5	1930.0	610.0	3.250
8	LCF [2]	0.9562	11.5	376	12.0	462		11.2	1.5	3370.0	991.0	1.350
9	DA-LCF [2]	0.9642	11.7	470	27.0	520		11.2	1.5	4020.0	1212.0	1.520
10	DA-BIT [2]	0.9776	12.0	715	161.7	620		11.1	1.6	3050.0	815.0	3.540
11	BG LIGHT [3]	0.8640	12.2	295	2.6	376	0.1	13.4		367.0	103.0	0.5
12	PEMBINA [3]	0.8932	12.1	351	5.0	428	0.1	12.8		575.0	154.0	0.2
13	EKOFISK [3]	0.9019	12.1	371	5.0	444	0.0	12.6		790.0	325.0	0.3
14	BRENT [3]	0.8937	12.0	322	5.3	406	0.3	12.7		938.0	413.0	0.5
15	BOW RIVER [3]	0.9315	11.6	328	5.9	421	0.1	11.8		989.0	253.0	2.7
16	COLD LAKE [3]	0.9283	11.6	321	5.1	415	0.1	11.8		748.0	241.0	2.0
17	CANMENT [3]	0.9438	11.1	263	3.6	369	0.4	11.3		4122.0	1543.0	2.9
18	VISBROKEN [3]	0.9688	10.9	276	3.4	388	0.1	10.7		1537.0	346.0	1.9
19	COKER [3]	1.0077	10.7	313	11.4	429	2.2	9.8		2910.0	1144.0	4.6
20	VGO [4]	0.9110	11.9	345	5.3	428			1.686	595.0		3.0
21	HVDl [4]	0.8950	12.1	410	5.8	433			1.76	515.0		1.0

22	HVD2 [4]	0.8650	12.5	391	5.4	429			1.83	15.0		0.1
23	HVD3 [4]	0.8690	12.3	348	4.1	410			1.757	5.0		0.0
24	H-Oil VGO [32]	0.9355	11.7	366		450						
25	5%FCC SLO [32]	0.9455	11.5	362		450						
26	10% FCC SLO [32]	0.9555	11.4	358		450						
27	15% FCC SLO [32]	0.9655	11.2	355		450						
28	SCO-HGO [33]	0.9423	11.4	313		412				1501.0	240.0	0.331
29	HTC-HGO [33]	0.9324	11.5	321		416				342.0	16.0	0.037
30	CON-HGO [33]	0.9111	11.9	346		429				1225.0	232.0	0.929
31	HSVGO [34]											
32	Mixed feed [34]											
33	OHCU bottom [34]											
34	HVGO [34]											
35	Brass River [35]							12.72	1.75			
36	Lagomedio [35]							12.55	1.759			
37	Maya [35]							11.87	1.68			
38	Wilmington [35]							11.23	1.56			
39	Merey [35]							11.94	1.69			
40	DQ-VGO [36]	0.8010	13.5	426		427	0.1	15.59	2.23			
41	DG-CGO [36]	0.9100	11.7	308		393	0.1	11.69	1.63			
42	FCC SLO(CLO-1) [37]			259				6.91				
43	FCC SLO(CLO-2) [37]			300				6.88				
44	FCC SLO(CLO-3) [37]			266				7.51				
45	FCC SLO(CLO-4) [37]			258				7.58				

46	FCC SLO(CLO-5) [37]		287			9.18	
47	FCC SLO(CLO-6) [37]		307			9.22	
48	FCC SLO(CLO-7) [37]		343			9.08	
49	FCC SLO(CLO-8) [37]		377			9.96	
50	FCC SLO(CLO-9) [37]		353			9.82	
51	FCC SLO(CLO-10) [37]		337			10.2	
52	FCC SLO(CLO-11) [37]		345			10.17	
53	FCC SLO(CLO-12) [37]		346			9.98	
54	FCC SLO(CLO-13) [37]		365			10.55	
55	FCC SLO(CLO-14) [37]		446			11.37	
56	FCC SLO(CLO-15) [37]		437			11.7	
57	FCC SLO [38]	1.0116	352	22.5	11	9.45	1.28
58	FCC SLO -A1 [39]	1.038			5.54	9.05	1.21
59	FCC SLO -A2 [39]	1.005			4.45	9.81	1.32
60	FCC SLO -B [39]	1.065				7.8	1.03
61	FCC SLO -C [39]	1.0372			4.12	8.37	1.12
62	FCC SLO -D [39]	0.9881			4.03	9.93	1.34
63	FCC SLO -E [39]	0.9621			2.5	10.43	1.40
64	FCC SLO -F [39]	0.9954			1.66	9.38	1.25
65	FCC SLO -G [39]	0.993			2.83	9.5	1.27
66	LSVR [39]	0.928			10.2	12.5	
67	Bitumen GV-1 [15]	0.9336				11.9	1.62

68	Bitumen GV-2 [15]	0.9429				11	1.51
69	Bitumen GV-3 [15]	0.948				11.3	1.56
70	Bitumen GV-4 [15]	0.9489				11	1.51
71	Bitumen GV-5 [15]	0.9545				11	1.53
72	Bitumen GV-6 [15]	0.9755				10.7	1.51
73	VGO [34]	0.8386	12.6	309	380	14.4	
74	VGO [34]	0.996	11.1	389	481	9.9	

feed number	feed name	Aromatic Carbon Content, wt.%	Aniline Point, °C	Refractive Index at 20°C	Saturates	Paraffins	Cyclo-paraffins	Aro matic s	mono-ARO	di-ARO
1	HCB [2]	4.4	99.8	1.4747	90.1	21.7	68.4	9.3	6.9	1.2
2	HT--VIR [2]	17.6	74.2	1.5130	46.8	4.1	42.7	52.3	29.1	10.5
3	RZ [2]	14.6	89.4	1.4967	61.0	22.8	38.2	36.1	16.6	7.7
4	HT-LCF [2]	20.2	71.8	1.5153	45.7	7.4	38.3	52.3	27.6	11.9
5	HT-C [2]	24.7	63.6	1.5323	34.4	4.7	29.7	61.8	29.5	13.6
6	HT-DA [2]	20.9	81.0	1.5269	35.4	5.0	30.4	57.5	29.5	12.7
7	VIR [2]	25.4	50.8	1.5397	28.7	1.8	26.9	65.6	22.5	14.4
8	LCF [2]	30.1	58.0	1.5324	35.5	5.2	30.3	58.4	20.6	13.6
9	DA-LCF [2]	28.8	65.8	1.5370	29.1	4.3	24.8	59.1	26.3	13.1
10	DA-BIT [2]	24.4	62.8	1.5393	23.0	1.4	21.6	61.8	24.7	14.0
11	BG LIGHT [3]	9.9	87.8	1.4786	73.7	35.2	38.5	27.5	11.3	7.1
12	PEMBINA [3]	14.4	92.7	1.4936	71.7	30.2	41.5	30.5	10.8	8.4
13	EKOFISK [3]	15.7	87.2	1.5013	61.9	28.3	33.6	42.0	15.1	10.6
14	BRENT [3]	16.3	86.2	1.4990	62.9	24.6	38.3	40.1	12.9	10.2
15	BOW RIVER [3]	26.2	66.7	1.5171	48.2	15.2	33	54.8	17.6	14.0
16	COLD LAKE [3]	25.7	70.0	1.5154	50.0	16.1	33.9	52.2	15.4	14.6
17	CANMENT [3]	33.8	58.5	1.5297	47.4	19.5	27.9	58.8	14.5	16.0
18	VISBROKEN [3]	39.6	50.5	1.5588	40.3	16.4	23.9	62.6	9.6	16.6
19	COKER [3]	47.8	33.1	1.5695	25.3	2.4	22.9	84.0	17.1	19.6
20	VGO [4]		75.1		46.4			49.0	25.4	12.5
21	HVDl [4]		84.7		53.2			43.6	31.3	7.4

22	HVD2 [4]		97.6	70.6			27.7	23.4	0.8
23	HVD3 [4]		91.3	65.2			33.1	17.0	12.1
24	H-Oil VGO [32]			47.7			44.2	13.7	10.4
25	5%FCC SLO [32]			46.5			45.9	12.5	9.8
26	10% FCC SLO [32]			44.0			49.2	11.3	9.9
27	15% FCC SLO [32]			42.5			51.5	11.2	9.6
28	SCO-HGO [33]	27	65.4	44.9	6.0	38.84	55.1	23.7	15.4
29	HTC-HGO [33]	24	71.8	50.7	6.8	43.92	49.3	20.9	14.9
30	CON-HGO [33]	20	89.4	57.9	21.6	36.26	42.2	14.3	11.4
31	HSVGO [34]			33.8	10.9	22.9	42.5	17.6	10.1
32	Mixed feed [34]			27.1	10.4	16.7	66.3	15.2	19.8
33	OHCU bottom [34]			84.6	31.4	53.2	15.2	12.1	0.7
34	HVGO [34]			54.0	33.8	20.2	42.9	15.1	11.6
35	Brass River [35]			64.7	22.4	42.3	32.3	9.1	7.8
36	Lagomedio [35]			46.7	11.0	35.7	35.0	9.5	6.8
37	Maya [35]			38.3	10.1	28.2	38.2	11.4	6.0
38	Wilmington [35]			46.8	0.0	46.8	44.3	9.8	12.9
39	Merey [35]			44.1	4.8	39.3	39.3	11.6	7.4
40	DQ-VGO [36]			83.0			15.5	7.5	3.5
41	DG-CGO [36]			60.8			30.5	6.9	13.5
42	FCC SLO(CLO-1) [37]	82		0.8			99.2		0.8
43	FCC SLO(CLO-2) [37]	79		0.9			99.1		
44	FCC SLO(CLO-3) [37]	76		2.3			97.7		2.6
45	FCC SLO(CLO-4) [37]	77		5.8			94.2		

46	FCC SLO(CLO-5) [37]	60	10.2			89.8		
47	FCC SLO(CLO-6) [37]	57	14.9			85.1		8.1
48	FCC SLO(CLO-7) [37]	59	15.8			84.2		5.9
49	FCC SLO(CLO-8) [37]	51	19.8			80.2		14.2
50	FCC SLO(CLO-9) [37]	52	22.4			77.6		6.8
51	FCC SLO(CLO-10) [37]	49	23.5			76.5		
52	FCC SLO(CLO-11) [37]	48	25.7			74.3		8.3
53	FCC SLO(CLO-12) [37]	50	21.9			78.1		
54	FCC SLO(CLO-13) [37]	45	29.6			70.4		34.2
55	FCC SLO(CLO-14) [37]	30	34.9			65.1		42.6
56	FCC SLO(CLO-15) [37]	37	38.9			61.1		24.9
57	FCC SLO [38]		38.08			47.82		
58	FCC SLO -A1 [39]	62	23			38		
59	FCC SLO -A2 [39]	58	30			42		
60	FCC SLO -B [39]	69	4			31		
61	FCC SLO -C [39]	67	8			33		
62	FCC SLO -D [39]	57	27			43		
63	FCC SLO -E [39]	55	39			45		
64	FCC SLO -F [39]	61	31			39		
65	FCC SLO -G [39]	59	36			41		
66	LSVR [39]	18	52			82		
67	Bitumen GV-1 [15]		46.5	6	40.5	48.6	23	15.9

68	Bitumen GV-2 [15]	47.3	4.4	42.9	47	23.7	16.7
69	Bitumen GV-3 [15]	43.5	3.4	40	50	24.4	17.5
70	Bitumen GV-4 [15]	44.6	3.8	40.8	49.4	25.9	17.9
71	Bitumen GV-5 [15]	40.5	3.2	37.3	52.6	27.9	18.4
72	Bitumen GV-6 [15]	32.5	1.9	30.6	58.5	28.9	22.2
73	VGO [34]	83.5			16.5		
74	VGO [34]	23.5			76.5		

feed number	feed name	tri-ARO	tetra- and greater ARO	Aromatic Sulfur	Polar Compounds
1	HCB [2]	0.3	0.5	0.3	0.7
2	HT--VIR [2]	3.9	4.0	2.8	0.9
3	RZ [2]	3.7	3.4	3.7	2.9
4	HT-LCF [2]	4.9	3.7	2.6	2.0
5	HT-C [2]	6.3	6.1	4.2	3.8
6	HT-DA [2]	5.4	5.1	3.4	7.1
7	VIR [2]	7.2	8.0	10.7	5.7
8	LCF [2]	7.3	8.4	6.8	6.1
9	DA-LCF [2]	6.0	6.6	5.4	11.8
10	DA-BIT [2]	5.7	6.3	9.1	15.2
11	BG LIGHT [3]	2.8	2.2	1.7	1.2
12	PEMBINA [3]	3.5	2.2	1.1	2.2
13	EKOFISK [3]	4.5	2.7	1.4	3.9
14	BRENT [3]	4.6	4.5	1.9	3.0
15	BOW RIVER [3]	5.9	4.3	7.1	3.0
16	COLD LAKE [3]	6.1	5.0	6.7	2.2
17	CANMENT [3]	5.3	3.0	7.6	6.2
18	VISBROKEN [3]	15.1	8.2	7.3	2.9
19	COKER [3]	10.0	9.2	9.5	9.3
20	VGO [4]		11.1		4.6
21	HVDl [4]		4.9		2.7

22	HVD2 [4]		3.5		1.0
23	HVD3 [4]		4.0		1.7
24	H-Oil VGO [32]	8.2	8.9		3.0
25	5%FCC SLO [32]	9.2	11.0		3.4
26	10% FCC SLO [32]	10.7	13.0		4.3
27	15% FCC SLO [32]	11.5	14.4		4.8
28	SCO-HGO [33]	9.1		3.6	3.3
29	HTC-HGO [33]	10.2		2.3	1.1
30	CON-HGO [33]	8.4		3.1	4.5
31	HSVGO [34]	3.8	11.2		
32	Mixed feed [34]	9.0			
33	OHCU bottom [34]	0.1			
34	HVGO [34]	6.1			
35	Brass River [35]	7.4	1.7		
36	Lagomedio [35]	9.4	3.2		
37	Maya [35]	9.5	6.9		
38	Wilmington [35]	9.8	6.5		
39	Merey [35]	9.5	4.8		
40	DQ-VGO [36]	4.5			1.3
41	DG-CGO [36]	10.1			8.7
42	FCC SLO(CLO-1) [37]	24.3	74.9		
43	FCC SLO(CLO-2) [37]				
44	FCC SLO(CLO-3) [37]	27.0	70.4		
45	FCC SLO(CLO-4) [37]				

46	FCC SLO(CLO-5) [37]			
47	FCC SLO(CLO-6) [37]	31.5	60.4	
48	FCC SLO(CLO-7) [37]	34.6	59.6	
49	FCC SLO(CLO-8) [37]	44.8	41.1	
50	FCC SLO(CLO-9) [37]	32.8	60.4	
51	FCC SLO(CLO-10) [37]			
52	FCC SLO(CLO-11) [37]	37.7	54.1	
53	FCC SLO(CLO-12) [37]			
54	FCC SLO(CLO-13) [37]	28.0	37.8	
55	FCC SLO(CLO-14) [37]	16.2	41.2	
56	FCC SLO(CLO-15) [37]	45.3	29.8	
57	FCC SLO [38]			
58	FCC SLO -A1 [39]			
59	FCC SLO -A2 [39]			
60	FCC SLO -B [39]			
61	FCC SLO -C [39]			
62	FCC SLO -D [39]			
63	FCC SLO -E [39]			
64	FCC SLO -F [39]			
65	FCC SLO -G [39]			
66	LSVR [39]			
67	Bitumen GV-1 [15]	8	1.3	0.4

68	Bitumen GV-2 [15]	5.1	1	0.4
69	Bitumen GV-3 [15]	5.1	2.2	0.7
70	Bitumen GV-4 [15]	4.4	1	0.1
71	Bitumen GV-5 [15]	4.8	1	0.5
72	Bitumen GV-6 [15]	5	1.1	1.3
73	VGO [35]			
74	VGO [35]			

Table S2 Empirically modeled characterizing parameters of the vacuum gas oils under study

VGO number	feed name	CA (ndM)	CN (ndM)	CP (ndM)	P (API)	N (API)	A (API)	Hydrogen content, wt. (Goosens)	Hydrogen content, wt.% (COP)	C_A, wt.% (COP)	I/d	ARI
1	HCB	1.8	31.9	66.2	67.1	26.1	6.8	13.7	13.6	4.3	0.33	0.7
2	HT--VIR	23.7	20.1	56.2	64.3	20.6	15.1	12.3	12.2	16.7	0.32	2.0
3	RZ	26.6	20.9	52.5	60.4	23.2	16.4	12.1	12.0	20.3	0.33	1.3
4	HT-LCF	22.3	34.2	43.5	57.0	23.2	19.8	11.5	11.5	24.6	0.32	1.9
5	HT-C	36.5	7.8	55.7	67.7	11.4	20.8	11.1	11.1	25.9	0.33	2.5
6	HT-DA	37.8	16.1	46.0	53.6	25.2	21.1	11.2	11.2	30.2	0.33	2.7
7	VIR	38.2	12.3	49.5	59.8	19.1	21.2	11.2	11.1	28.1	0.32	3.1
8	LCF	30.5	15.6	53.9	74.4	4.9	20.7	11.1	11.0	24.2	0.32	2.2
9	DA-LCF	38.9	14.2	46.9	56.1	17.4	26.6	10.17	10.1	40.1	0.32	2.6
10	DA-BIT	24.9	18.1	57.0	66.8	16.3	17.0	11.84	11.7	20.7	0.32	3.6
11	BG LIGHT	11.7	25.3	62.9	65.6	26.5	8.0	13.3	13.4	9.9	0.33	0.8
12	PEMBINA	13.6	29.3	57.1	64.7	24.9	10.4	12.9	12.8	14.4	0.33	1.2
13	EKOFISK	17.6	23.6	58.8	66.0	23.0	11.0	12.8	12.6	15.7	0.33	1.4
14	BRENT	20.2	19.9	59.9	62.8	25.5	11.7	12.7	12.7	16.3	0.33	1.3
15	BOW RIVER	23.3	24.2	52.5	56.9	26.4	16.7	11.6	11.8	26.2	0.32	1.7
16	COLD LAKE	23.0	26.1	50.9	55.5	27.4	17.1	11.6	11.8	25.7	0.33	1.6
17	CANMENT	34.3	18.7	47.0	42.6	33.8	23.5	10.6	11.3	33.8	0.33	1.7
18	VISBROKEN	54.3	-6.2	51.8	37.6	33.3	29.1	10.1	10.7	39.6	0.33	2.3
19	COKER	47.6	10.4	42.0	35.8	31.8	32.3	9.5	9.8	47.8	0.33	2.6
20	VGO				56.3	28.7	15.0	12.2	12.2	20.6	0.33	
21	HVDl				63.3	26.0	10.7	12.8	12.7	15.5	0.33	
22	HVD2				75.3	21.2	3.5	13.8	13.4	7.0	0.33	
23	HVD3				72.1	22.0	5.9	13.4	13.3	9.7	0.33	

24	H-Oil VGO(IFP)	25.2	24.6	50.2	59.6	23.7	16.7	11.9	11.7	25.1	0.33	
25	5%FCC SLO	27.8	24.7	47.5	41.3	32.8	25.9	11.6	11.5	28.0	0.33	
26	10% FCC SLO	30.5	24.8	44.7	22.9	41.9	35.2	11.3	11.2	30.9	0.33	
27	15% FCC SLO	33.1	24.9	42.0	4.4	51.1	44.5	11.1	10.9	33.9	0.33	
28	SCO-HGO	34.4	17.7	47.9	49.1	29.2	21.8	11.2	11.4	30.0	0.33	
29	HTC-HGO	30.3	20.4	49.3	52.3	28.1	19.5	11.5	11.7	26.8	0.33	
30	CON-HGO	21.0	22.2	56.7	62.2	24.5	13.3	12.3	12.3	19.6	0.33	
31	HSVGO											
32	Mixed feed											
33	OHCU bottom											
34	HVGO											
35	Brass River											
36	Lagomedio											
37	Maya											
38	Wilmington											
39	Merey											
40	DQ-VGO	-34.2	70.7	63.5	-31.1	88.0	43.1	17.8	15.2	-12.4	0.31	-1.6
41	DG-CGO	30.8	11.1	58.1	-4.1	60.0	44.1	11.7	12.3	22.0	0.33	1.6
42	FCC SLO(CLO-1)	84.2	4.9	11.0	18.6	36.4	45.0	7.22	6.3	108.4	0.33	3.2
43	FCC SLO(CLO-2)	82.6	2.5	14.9	23.8	31.0	45.2	7.36	6.3	108.7	0.33	3.5
44	FCC SLO(CLO-3)	76.0	5.1	18.9	16.4	38.7	44.9	7.77	6.9	102.3	0.33	3.0
45	FCC SLO(CLO-4)	75.5	6.4	18.1	15.1	40.0	44.9	7.79	6.9	101.6	0.33	3.0
46	FCC SLO(CLO-5)	53.4	16.6	30.1	9.4	45.9	44.7	9.40	8.4	85.2	0.33	2.6

47	FCC SLO(CLO-6)	52.0	15.4	32.5	10.7	44.6	44.7	9.51	8.4	84.8	0.33	2.7
48	FCC SLO(CLO-7)	52.6	12.2	35.3	14.4	40.7	44.9	9.48	8.3	86.3	0.33	3.0
49	FCC SLO(CLO-8)	40.2	17.5	42.3	10.7	44.5	44.7	10.44	9.1	77.3	0.32	2.8
50	FCC SLO(CLO-9)	42.7	17.5	39.8	10.2	45.1	44.7	10.24	9.0	78.7	0.32	2.7
51	FCC SLO(CLO-10)	38.3	21.4	40.4	6.6	48.8	44.6	10.59	9.3	74.8	0.32	2.4
52	FCC SLO(CLO-11)	38.4	20.7	40.9	7.3	48.1	44.6	10.58	9.3	75.1	0.32	2.5
53	FCC SLO(CLO-12)	40.8	19.1	40.0	8.6	46.7	44.6	10.39	9.1	77.1	0.32	2.6
54	FCC SLO(CLO-13)	32.9	22.7	44.4	5.8	49.7	44.5	11.04	9.6	71.3	0.32	2.4
55	FCC SLO(CLO-14)	20.4	26.1	53.5	2.9	52.7	44.4	12.10	10.4	62.9	0.32	2.1
56	FCC SLO (CLO-15)	16.3	29.0	54.7	-0.2	55.9	44.3	12.47	10.7	59.5	0.32	1.9
57	FCC SLO										0.33	2.9
58	FCC SLO -A1										0.32	
59	FCC SLO -A2										0.32	
60	FCC SLO -B										0.33	
61	FCC SLO -C										0.33	
62	FCC SLO -D										0.33	
63	FCC SLO -E										0.33	
64	FCC SLO -F										0.33	
65	FCC SLO -G										0.33	
66	LSVR										0.31	

67	Bitumen GV-1										0.32	
68	Bitumen GV-2										0.33	
69	Bitumen GV-3										0.32	
70	Bitumen GV-4										0.33	
71	Bitumen GV-5										0.32	
72	Bitumen GV-6										0.32	
73	VGO [35]	-15.8	62.6	53.1	-20.4	76.9	43.5	15.8	14.1	2.2	0.32	-0.1
74	VGO [35]	40.3	15.7	44.0	11.8	43.4	44.8	10.4	10.2	40.4	0.32	2.8

Table S3 Data for density at 15°C and content of aromatic structures (aromatic, resin, and asphaltene fractions) in 144 vacuum gas oils (taken from ref. 51)

Nr	density at 15°C, g/cm^3	VGO ARO, wt.%	Nr	density at 15°C, g/cm^3	VGO ARO, wt.%	Nr	density at 15°C, g/cm^3	VGO ARO, wt.%	Nr	density at 15°C, g/cm^3	VGO ARO, wt.%	Nr	density at 15°C, g/cm^3	VGO ARO, wt.%	Nr	density at 15°C, g/cm^3	VGO ARO, wt.%
1	0.864	26.3	25	0.900	36.6	49	0.903	47.7	73	0.927	34.0	97	0.964	59.1	121	0.910	30.5
2	0.893	28.2	26	0.895	40.2	50	0.941	52.8	74	0.901	57.6	98	0.978	61.8	122	1.127	99.2
3	0.902	38.2	27	0.878	30.6	51	0.918	48.0	75	0.925	55.0	99	0.864	27.5	123	1.128	99.1
4	0.894	37.1	28	0.866	24.1	52	0.970	49.5	76	0.869	31.7	100	0.893	30.5	124	1.103	97.7
5	0.932	51.9	29	0.924	47.9	53	0.864	9.9	77	0.923	51.6	101	0.902	42.0	125	1.100	94.2
6	0.928	50.0	30	0.915	42.1	54	0.925	53.2	78	0.914	40.7	102	0.894	40.1	126	1.038	89.8
7	0.944	52.6	31	0.919	52.7	55	0.928	54.3	79	0.861	21.5	103	0.932	54.8	127	1.036	85.1
8	0.969	59.7	32	1.089	87.5	56	0.951	65.6	80	0.859	19.6	104	0.928	52.2	128	1.042	84.2
9	1.008	74.7	33	0.861	29.0	57	0.971	71.3	81	0.875	14.2	105	0.944	58.8	129	1.007	80.2
10	0.925	50.7	34	0.913	42.9	58	0.956	64.5	82	0.895	30.8	106	0.969	62.6	130	1.013	77.6
11	0.924	45.4	35	0.921	49.1	59	0.964	70.9	83	0.852	15.8	107	1.008	84.0	131	0.998	76.5
12	0.920	47.3	36	0.879	21.5	60	0.978	77.0	84	0.896	40.0	108	0.911	49.0	132	0.999	74.3
13	0.906	41.0	37	0.918	48.0	61	1.004	79.7	85	0.914	53.6	109	0.895	43.6	133	1.006	78.1
14	0.863	18.6	38	0.938	61.9	62	0.943	64.6	86	0.898	46.8	110	0.865	27.7	134	0.984	70.4
15	0.872	23.2	39	0.918	52.7	63	0.892	49.3	87	0.868	29.4	111	0.869	33.1	135	0.952	65.1
16	0.928	53.9	40	0.902	45.1	64	0.914	51.8	88	0.872	34.8	112	0.936	44.2	136	0.939	61.1
17	0.880	19.6	41	0.872	26.1	65	0.927	52.7	89	0.864	9.3	113	0.942	55.1	137	1.038	77.0
18	0.901	33.0	42	0.879	27.3	66	0.930	53.8	90	0.925	52.3	114	0.932	49.3	138	1.005	70.0
19	0.942	55.1	43	0.886	33.0	67	0.938	55.4	91	0.899	36.1	115	0.911	42.2	139	1.065	96.0
20	0.932	49.3	44	0.891	34.0	68	0.947	64.8	92	0.928	52.3	116	0.899	32.3	140	1.037	92.0
21	0.911	42.2	45	0.896	36.6	69	0.924	47.6	93	0.951	61.8	117	0.906	35.0	141	0.988	73.0
22	0.915	48.5	46	0.903	42.3	70	0.938	49.7	94	0.943	57.5	118	0.932	38.2	142	0.962	60.0
23	0.900	40.0	47	0.937	53.4	71	0.902	39.1	95	0.971	65.6	119	0.957	44.3	143	0.995	69.0
24	0.901	47.0	48	0.930	63.7	72	0.936	52.6	96	0.956	58.4	120	0.930	39.3	144	0.993	64.0

Table S4 Comparison between measured and predicted by the empirical correlations refractive index of VGO from different origin

RI (measured)	RI (eq.30)	RI (eq.31)	RI (Fig.1b)	RI (eq.17)	RI (eq.13)	Abs. dev. (eq.30)	Abs. dev. (eq.31)	Abs. dev. (Fig.1b)	Abs. dev. (eq.17)	Abs. dev. (eq.13)
1.4747	1.4723	1.4738	1.4764	1.4788	1.4712	0.0024	0.0016	0.0026	0.0023	0.0075
1.5130	1.5073	1.5213	1.5150	1.5166	1.5092	0.0057	0.0140	0.0062	0.0015	0.0074
1.4967	1.4976	1.5007	1.4983	1.5025	1.4891	0.0009	0.0031	0.0024	0.0042	0.0134
1.5153	1.5134	1.5238	1.5170	1.5204	1.5094	0.0019	0.0103	0.0067	0.0033	0.0109
1.5323	1.5260	1.5414	1.5314	1.5344	1.5269	0.0063	0.0154	0.0100	0.0029	0.0074
1.5269	1.5140	1.5351	1.5263	1.5262	1.5249	0.0129	0.0211	0.0088	0.0001	0.0013
1.5397	1.5336	1.5571	1.5442	1.5452	1.5461	0.0061	0.0235	0.0129	0.0011	0.0009
1.5324	1.5355	1.5454	1.5347	1.5404	1.5287	0.0031	0.0100	0.0107	0.0058	0.0117
1.5370	1.5347	1.5516	1.5397	1.5430	1.5372	0.0023	0.0169	0.0119	0.0033	0.0058
1.5393	1.5331	1.5621	1.5482	1.5475	1.5548	0.0062	0.0290	0.0139	0.0007	0.0073
1.4786	1.4802	1.4736	1.4763	1.4821	1.4688	0.0016	0.0066	0.0027	0.0058	0.0133
1.4936	1.4950	1.4963	1.4948	1.4992	1.4855	0.0014	0.0014	0.0016	0.0045	0.0138
1.5013	1.4993	1.5031	1.5003	1.5044	1.4911	0.0020	0.0038	0.0028	0.0041	0.0133
1.4990	1.4977	1.4967	1.4951	1.5007	1.4852	0.0013	0.0010	0.0017	0.0056	0.0154
1.5171	1.5226	1.5262	1.5190	1.5256	1.5096	0.0055	0.0035	0.0072	0.0066	0.0160
1.5154	1.5210	1.5237	1.5170	1.5237	1.5073	0.0056	0.0026	0.0067	0.0068	0.0164
1.5297	1.5370	1.5357	1.5268	1.5368	1.5187	0.0073	0.0012	0.0089	0.0100	0.0182
1.5588	1.5524	1.5552	1.5426	1.5530	1.5385	0.0064	0.0028	0.0126	0.0104	0.0145
1.5695	1.5752	1.5855	1.5673	1.5776	1.5739	0.0057	0.0103	0.0182	0.0104	0.0038
Average absolute deviation						0.0044	0.0094	0.0078	0.0047	0.0104

Table S5 Comparison between measured and predicted by the empirical correlations hydrogen content in VGO from different origin

Hydrogen, wt.% measured	RI (Fig. 1d)	H (Goosens; eq.22)	H (COP; eq.24)	H (Dhulesia; eq.16)	Abs. dev. (Fig.1d)	Abs. dev. (eq.22)	Abs. dev. (eq.24)	Abs. dev. (eq.16)
13.7	13.6	14.2	13.59	13.81	0.10	0.50	0.11	0.11
12.3	12.1	12.9	12.15	12.60	0.17	0.58	0.15	0.30
12.8	12.8	12.9	12.66	14.11	0.05	0.08	0.14	1.31
12.1	12.0	12.4	11.98	12.36	0.06	0.31	0.12	0.26
11.5	11.4	12.0	11.46	11.90	0.11	0.51	0.04	0.40
11.8	11.6	12.8	11.81	12.24	0.21	1.04	0.01	0.44
11.1	11.1	12.0	11.07	11.74	0.00	0.91	0.03	0.64
11.2	11.4	11.3	11.20	11.48	0.18	0.10	0.00	0.28
11.2	11.2	11.7	11.13	11.62	0.01	0.47	0.07	0.42
11.1	11.1	12.2	11.01	11.96	0.02	1.15	0.09	0.86
13.4	13.4	13.3	13.42	13.30	0.05	0.07	0.02	0.10
12.8	12.9	12.9	12.78	12.83	0.07	0.13	0.02	0.03
12.6	12.6	12.8	12.58	12.49	0.02	0.22	0.02	0.11
12.7	12.7	12.7	12.71	12.85	0.04	0.04	0.01	0.15
11.8	12.0	11.6	11.75	11.73	0.17	0.20	0.05	0.07
11.8	12.0	11.6	11.82	11.77	0.23	0.17	0.02	0.03
11.3	11.5	10.6	11.31	11.06	0.19	0.69	0.01	0.24
10.7	10.4	10.1	10.70	10.09	0.33	0.60	0.00	0.61
9.8	10.0	9.5	9.77	9.80	0.16	0.31	0.03	0.00
Average absolute deviation, wt.%					0.11	0.43	0.05	0.34

Table S6 Comparison between measured and predicted by the empirical correlations aromatic carbon content in VGO from different origin

C_A wt.% measured	C_A (Fig.1c)	C_A (Dhulesia; eq.15)	C_A (COP; eq.23)	C_A (eq.33).	C_A (eq.32).	Abs. dev. (eq.Fig.1c)	Abs. dev. (eq.15)	Abs. dev. (eq.23)	Abs. dev. (eq.33)	Abs. dev. (eq.32)
4.4	3.8	1.6	4.3	3.9	4.5	0.6	2.8	0.1	0.5	0.1
17.6	20.6	9.3	16.7	18.8	17.8	3.0	8.3	0.9	1.2	0.2
14.6	14.6	11.8	15.1	15.8	15.4	0.0	2.8	0.5	1.2	0.8
20.2	23.0	14.6	20.3	22.3	21.7	2.8	5.6	0.1	2.1	1.5
24.7	30.2	16.6	24.6	27.6	27.4	5.5	8.1	0.1	2.9	2.7
20.9	26.6	6.8	17.8	20.8	20.6	5.7	14.1	3.1	0.1	0.3
25.4	34.9	12.1	25.9	29.9	28.8	9.5	13.3	0.5	4.5	3.4
30.1	33.7	24.8	30.2	33.0	33.1	3.6	5.3	0.1	2.9	3.0
28.8	33.7	18.9	28.1	31.5	30.6	4.9	9.9	0.7	2.7	1.8
24.4	34.9	6.4	24.2	28.8	25.5	10.5	18.0	0.2	4.4	1.1
9.9	7.4	9.8	9.9	9.0	10.5	2.5	0.1	0.0	0.9	0.6
14.4	14.6	12.0	14.4	14.9	15.7	0.2	2.4	0.0	0.5	1.3
15.7	17.0	12.4	15.7	16.6	17.5	1.3	3.3	0.0	0.9	1.8
16.3	15.8	14.6	16.3	16.6	17.6	0.5	1.7	0.0	0.3	1.3
26.2	26.6	22.8	26.2	27.8	27.6	0.4	3.4	0.0	1.6	1.4
25.7	26.6	22.8	25.7	27.2	27.7	0.9	2.9	0.0	1.5	2.0
33.8	32.6	32.9	33.8	35.5	34.8	1.2	0.9	0.0	1.7	1.0
39.6	39.7	38.2	39.6	42.3	41.2	0.1	1.4	0.0	2.7	1.6
47.8	50.5	43.0	47.8	52.1	50.4	2.7	4.8	0.0	4.3	2.6
27.0		27.8	30.0	32.0			0.8	3.0	5.0	
24.0		24.6	26.8	28.5			0.6	2.8	4.5	
20.0		16.6	19.6	20.6			3.4	0.4	0.6	
82.0	85.1	75.4	77.2	84.4	84.1	3.1	6.6	4.8	2.4	2.1
79.0	85.4	75.6	74.6	82.1	83.4	6.4	3.4	4.4	3.1	4.4
76.0	77.9	81.2	70.9	77.4	77.2	1.9	5.2	5.1	1.4	1.2

77.0	77.0	77.6	70.9	77.2	76.6	0.0	0.6	6.1	0.2	0.4
60.0	57.9	51.8	53.5	58.1	58.0	2.1	8.2	6.5	1.9	2.0
57.0	57.4	48.7	51.8	56.5	57.0	0.4	8.3	5.2	0.5	0.0
59.0	59.1	45.0	51.0	56.0	57.7	0.1	14.0	8.0	3.0	1.3
51.0	48.6	34.5	40.8	44.9	46.9	2.4	16.5	10.2	6.1	4.1
52.0	50.3	38.1	43.4	47.5	49.1	1.7	13.9	8.6	4.5	2.9
49.0	45.7	36.7	40.7	44.3	45.3	3.3	12.3	8.3	4.7	3.7
48.0	46.1	36.1	40.5	44.2	45.4	1.9	11.9	7.5	3.8	2.6
50.0	48.3	37.6	42.2	46.2	47.5	1.7	12.4	7.8	3.8	2.5
45.0	41.5	30.8	35.8	39.1	40.6	3.5	14.2	9.2	5.9	4.4
30.0	31.7	17.2	24.1	26.8	29.4	1.7	12.8	5.9	3.2	0.6
37.0	27.8	15.2	21.4	23.6	25.9	9.2	21.8	15.6	13.4	11.1
62.0	59.5					2.5				
58.0	50.4					7.6				
69.0	74.4					5.4				
67.0	67.6					0.6				
57.0	48.9					8.1				
55.0	43.0					12.0				
61.0	55.5					5.5				
59.0	54.1					4.9				
18.0	18.2					0.2				
	Average absolute deviation, wt.%					3.3	7.5	3.4	2.8	2.1

Table S7 Comparison between measured and predicted by the empirical correlations saturates content in VGO from different origin

Designation	Measured VGO saturates content, wt.%	Estimated as 100-eq.39 VGO sat. content, wt.%	Estimated by eq.40 VGO sat. content, wt.%	Abs. dev. (eq.39)	Abs. dev. (eq.40)
	90.1	77.0	88.0	13.1	2.1
	46.8	50.4	46.4	3.6	0.4
	61	61.4	65.9	0.4	4.9
	45.7	49.1	45.5	3.4	0.2
	34.4	40.6	36.6	6.2	2.2
	35.4	43.6	39.1	8.2	3.7
	28.7	33.8	29.9	5.1	1.2
	35.5	38.8	35.5	3.3	0.0
	29.1	36.1	32.4	7.0	3.3
	23	31.8	27.8	8.8	4.8
	73.7	77.2	82.1	3.5	8.4
	71.7	63.8	62.7	7.9	9.0
	61.9	60.0	57.5	1.9	4.4
	62.9	63.6	61.6	0.7	1.3
	48.2	47.9	45.0	0.3	3.2
	50	49.1	46.3	0.9	3.7
	47.4	43.3	40.6	4.1	6.8
	40.3	34.6	31.5	5.7	8.8
	25.3	23.1	20.5	2.2	4.8
DQ-VGO (Nr.40 from Table S1)	83.0	107.9	100.0	24.9	17.0

	60.8	56.6	53.3	4.3	7.5
	0.8	4.6	3.3	3.8	2.5
	0.9	4.5	3.0	3.6	2.1
	2.3	7.8	6.2	5.5	3.9
	5.8	8.2	6.7	2.4	0.9
	10.2	19.5	17.2	9.3	7.0
	14.9	19.8	17.4	4.9	2.5
	15.8	18.6	16.1	2.8	0.3
	19.8	26.6	23.6	6.8	3.8
	22.4	25.3	22.4	2.9	0.0
	23.5	29.1	26.1	5.6	2.6
	25.7	28.7	25.8	3.0	0.1
	21.9	26.8	23.9	4.9	2.0
	29.6	32.8	29.6	3.2	0.0
	34.9	42.6	38.9	7.7	4.0
	38.9	46.9	43.4	8.0	4.5
FCC SLO (Nr.57 from Table S1)	38.1	22.1	19.4	16.0	18.7
Average absolute deviation				5.6	4.1

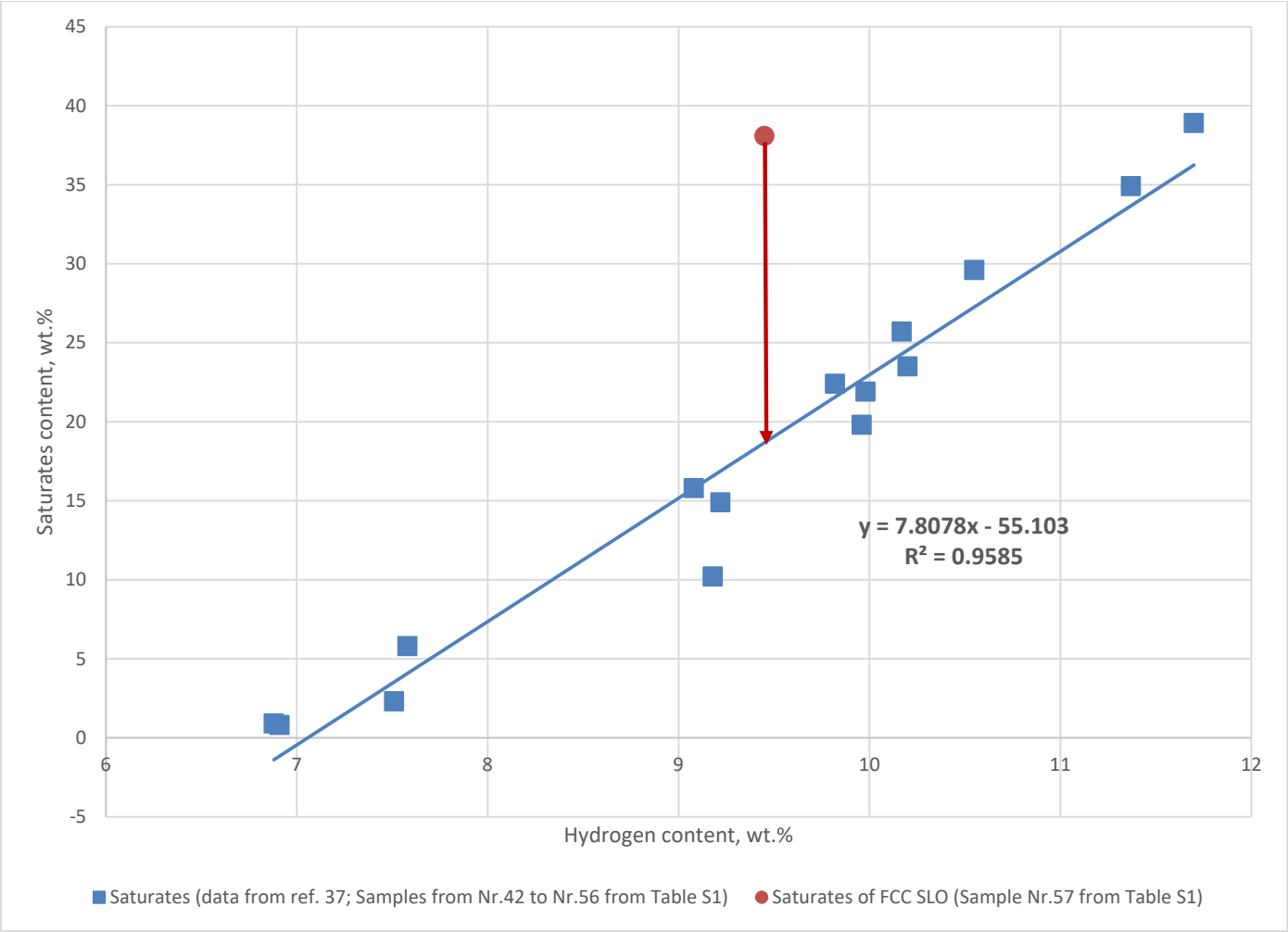

Figure S1 Relation of fluid catalytic cracking slurry oil hydrogen content to saturates content

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