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APPENDIX A

EXPERIMENTAL DATA

Table A.1 Factor Finder and constant for Brookfield Model LV Viscometer

Speed (rpm)	Spindle no.1	Spindle no.2	Spindle no.3	Spindle no.4	K1
0.3	200	1000	4000	20000	0.0628
0.6	100	500	2000	10000	0.1257
1.5	40	200	800	4000	0.3142
3	20	100	400	2000	0.6283
6	10	50	200	1000	1.2566
12	5	25	100	500	2.5133
30	2	10	40	200	6.2832
60	1	5	20	100	12.5664

Table A.2.1 Rheological data for COM of heavy fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
	[2]	[2]	[2]	[3]	[4]	[4]
0.3	0.3	0.5	0.7	0.5	0.2	1.0
0.6	0.4	0.9	1.2	0.7	0.4	2.0
1.5	1.4	2.0	2.5	1.3	0.8	5.0
3	2.8	3.8	4.8	2.4	1.5	9.8
6	5.4	7.5	9.2	4.3	2.8	18.9
12	10.8	14.8	17.6	8.4	5.6	38.2
30	27.0	36.2	43.1	20.5	13.5	94.3
60	53.3	70.7	85.2	40.8	27.6	>100

Value in [ ] is the number of used spindle

Table A.2.2 Rheological data for COM of heavy fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C, coverted to number 2 spindle

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
0.3	0.3	0.5	0.7	2.0	4.0	20.0
0.6	0.4	0.9	1.2	2.8	8.0	40.0
1.5	1.4	2.0	2.5	5.2	16.0	100.0
3	2.8	3.8	4.8	9.6	30.0	196.0
6	5.4	7.5	9.2	17.2	56.0	378.0
12	10.8	14.8	17.6	33.6	112.0	764.0
30	27.0	36.2	43.1	82.0	270.0	1866.0
60	53.3	70.7	85.2	163.2	552.0	-

Table A.2.3 Logarithm of rheological data for COM of heavy fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Log rpm	Log dial reading					
		Weight percent coal in COM					
		0	10	20	30	40	50
0.3	-0.523	-0.523	-0.301	-0.155	0.301	0.602	1.301
0.6	-0.222	-0.398	-0.046	0.079	0.447	0.903	1.602
1.5	0.176	0.146	0.301	0.398	0.716	1.204	2.000
3	0.477	0:447	0.580	0.681	0.982	1.477	2.292
6	0.778	0.732	0.875	0.964	1.236	1.748	2.577
12	1.079	1.033	1.170	1.246	1.526	2.049	2.883
30	1.477	1.431	1.559	1.634	1.914	2.431	3.276
60	1.778	1.727	1.849	1.930	2.213	2.742	-

Table A.3.1 Rheological data for COM of heavy fuel oil and -75 microns Nong Ya Plong coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
	[2]	[2]	[3]	[3]	[4]	[4]
0.3	0.3	0.7	0.5	0.4	1.0	7.5
0.6	0.4	1.0	0.6	0.9	1.2	9.7
1.5	1.4	2.2	1.1	1.8	2.1	16.3
3	2.8	4.4	1.9	3.4	3.0	25.1
6	5.4	8.3	3.4	6.2	4.9	40.3
12	10.8	15.9	6.3	11.7	8.5	77.2
30	27.0	38.1	15.2	27.7	19.1	>100
60	53.3	74.0	29.5	53.6	36.2	>100

Value in [ ] is the number of used spindle

Table A.3.2 Rheological data for COM of heavy fuel oil and -75 microns Nong Ya Plong coal at various coal concentrations (wt%) and 40 °C, converted to number 2 spindle

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
0.3	0.3	0.7	2.0	1.6	20.0	150.0
0.6	0.4	1.0	2.4	3.6	24.0	194.0
1.5	1.4	2.2	4.4	7.2	42.0	326.0
3	2.8	4.4	7.6	13.6	60.0	502.0
6	5.4	8.3	13.6	24.8	98.0	806.0
12	10.8	15.9	25.2	46.6	170.0	1544.0
30	27.0	38.1	60.8	110.8	382.0	-
60	53.3	74.0	118.0	214.4	724.0	-

Table A.3.3 Logarithm of rheological data for COM of heavy fuel oil and -75 microns Nong Ya Plong coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Log rpm	Log dial reading					
		Weight percent coal in COM					
		0	10	20	30	40	50
0.3	-0.523	-0.523	-0.155	0.301	0.204	1.301	2.176
0.6	-0.222	-0.398	0.000	0.380	0.556	1.380	2.288
1.5	0.176	0.146	0.342	0.643	0.857	1.623	2.513
3	0.477	0.447	0.643	0.881	1.134	1.778	2.701
6	0.778	0.732	0.919	1.134	1.394	1.991	2.906
12	1.079	1.033	1.201	1.401	1.670	2.230	3.189
30	1.477	1.431	1.581	1.784	2.045	2.582	-
60	1.778	1.727	1.869	2.072	2.331	2.860	-

Table A.4.1 Rheological data for COM of heavy fuel oil and -75 microns Mae Moh coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
	[2]	[2]	[3]	[3]	[4]	[4]
0.3	0.3	0.5	0.4	0.4	0.3	0.9
0.6	0.4	1.0	0.6	0.7	0.5	1.7
1.5	1.4	2.6	1.3	1.7	1.1	3.7
3	2.8	5.1	2.6	3.4	2.2	7.2
6	5.4	9.5	4.7	6.2	4.2	14.1
12	10.8	18.3	8.8	12.0	7.9	28.0
30	27.0	43.4	21.0	28.2	18.8	67.4
60	53.3	83.5	40.4	55.2	37.2	>100

Value in [ ] is the number of used spindle

Table A.4.2 Rheological data for COM of heavy fuel oil and -75 microns Mae Moh coal at various coal concentrations (wt%) and 40 °C, converted to number 2 spindle

Speed (rpm)	Dial reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
0.3	0.3	0.5	1.6	1.6	6.0	18.0
0.6	0.4	1.0	2.4	2.8	10.0	34.0
1.5	1.4	2.6	5.2	6.8	22.0	74.0
3	2.8	5.1	10.4	13.6	44.0	144.0
6	5.4	9.5	18.8	24.8	84.0	282.0
12	10.8	18.3	35.2	48.0	158.0	560.0
30	27.0	43.4	84.0	112.8	376.0	1348.0
60	53.3	83.5	161.6	220.8	744.0	-

Table A.4.3 Logarithm of rheological data for COM of heavy fuel oil and -75 microns Mae Moh coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Log rpm	Log dial reading					
		Weight percent coal in COM					
		0	10	20	30	40	50
0.3	-0.523	-0.523	-0.301	0.204	0.204	0.778	1.255
0.6	-0.222	-0.398	0.000	0.380	0.447	1.000	1.531
1.5	0.176	0.146	0.415	0.716	0.833	1.342	1.869
3	0.477	0.447	0.708	1.017	1.134	1.643	2.158
6	0.778	0.732	0.978	1.274	1.394	1.924	2.450
12	1.079	1.033	1.262	1.547	1.681	2.199	2.748
30	1.477	1.431	1.637	1.924	2.052	2.575	3.130
60	1.778	1.727	1.922	2.208	2.344	2.872	-

Table A.5.1 Rheological data for COM of light fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Dial Reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
	[2]	[2]	[2]	[2]	[3]	[4]
0.3	0.1	0.2	0.3	0.7	0.4	0.5
0.6	0.3	0.5	0.6	1.2	0.5	0.7
1.5	0.7	1.2	1.2	2.2	1.3	1.5
3	1.2	2.1	2.2	4.0	2.3	2.8
6	2.3	3.8	4.3	7.8	4.5	5.1
12	4.8	7.2	8.4	15.6	8.6	10.4
30	14.1	18.0	24.0	41.5	22.7	25.3
60	23.7	35.4	42.0	76.0	40.5	50.2

Value in [ ] is the number of used spindle

Table A.5.2 Rheological data for COM of light fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C, converted to number 2 spindle

Speed (rpm)	Dial Reading					
	Weight percent coal in COM					
	0	10	20	30	40	50
0.3	0.1	0.2	0.3	0.7	1.6	10.0
0.6	0.3	0.5	0.6	1.2	2.0	14.0
1.5	0.7	1.2	1.2	2.2	5.2	30.0
3	1.2	2.1	2.2	4.0	9.2	56.0
6	2.3	3.8	4.3	7.8	18.0	102.0
12	4.8	7.2	8.4	15.6	34.4	208.0
30	14.1	18.0	24.0	41.5	90.8	506.0
60	23.7	35.4	42.0	76.0	162.0	1004.0

Table A.5.3 Logarithm of rheological data for COM of light fuel oil and -75 microns Ban Pu coal at various coal concentrations (wt%) and 40 °C

Speed (rpm)	Log rpm	Log dial Reading					
		Weight percent coal in COM					
		0	10	20	30	40	50
0.3	-0.523	-1.000	-0.699	-0.523	-0.155	0.204	1.000
0.6	-0.222	-0.523	-0.301	-0.222	0.079	0.301	1.146
1.5	0.176	-0.155	0.079	0.079	0.342	0.716	1.477
3	0.477	0.079	0.322	0.342	0.602	0.964	1.748
6	0.778	0.362	0.580	0.633	0.892	1.255	2.009
12	1.079	0.681	0.857	0.924	1.193	1.537	2.318
30	1.477	1.149	1.255	1.380	1.618	1.958	2.704
60	1.778	1.375	1.549	1.623	1.881	2.210	3.002

Table A.6 Effect of weight percent coal on yield stress at 40 °C

COM		Weight percent coal in COM					
		0	10	20	30	40	50
Ban Pu coal+Fuel oil							
HFO	STI	0.987	1.062	1.094	1.170	1.085	1.015
	ln(Ty)	0.801	2.486	2.808	3.695	3.960	5.007
LFO	STI	0.989	1.054	1.065	1.108	1.094	1.117
	ln(Ty)	1.586	2.011	2.204	2.829	4.048	5.135
Mae Moh+Fuel oil							
HFO	STI	0.987	1.039	1.125	1.069	1.087	1.065
	ln(Ty)	0.801	3.285	4.161	4.198	5.265	5.790
Nong Ya Plong coal+Fuel oil							
HFO	STI	0.987	1.104	1.240	1.102	1.427	1.570
	ln(Ty)	0.801	3.088	4.026	4.426	6.671	8.335

STI is defined as shear thinning index
Ty is defined as yield stress in unit dynes/cm^2

Table A.7 Effect of temperature on viscosity for COM of -75 microns Ban Pu coal and heavy fuel oil at various coal concentrations (wt%), speed 30 rpm and 40 °C

Weight percent coal in COM	Dial reading				
	Temperature (C)				
	40	50	60	70	80
0	27(2)	12.6(2)	30.2(1)	18.3(1)	12.5(1)
10	36.2(2)	17(2)	9.6(2)	25.5(1)	17(1)
20	43.1(2)	21.4(2)	13.5(2)	35(1)	22.2(1)
30	20.5(3)	36.2(2)	19.9(2)	13.9(2)	38.2(1)
40	13.5(4)	33.4(3)	15.9(3)	42(2)	25.9(2)
50	94.3(4)	38.7(4)	23.5(4)	11.2(4)	39.1(3)

Value in ( ) is number of used spindle

Table A.8 Effect of oil type on viscosity for COM of -75 microns Ban Pu coal and fuel oil at various coal concentrations (wt%), speed 30 rpm and 40 °C

Weight percent coal in COM	Dial reading	
	Type of oil	
	LFO	HFO
0	14.1(2)	27(2)
10	18(2)	36.2(2)
20	24(2)	43.1(2)
30	41.5(2)	20.5(3)
40	22.7(2)	13.5(4)
50	25.3(2)	94.3(4)

Value in ( ) is number of used spindle

Table A.9 Effect of particle size distribution on viscosity for COM of Ban Pu coal and heavy fuel oil at various coal concentrations (wt%), speed 30 rpm and 40 °C

Weight percent coal in COM	Dial reading		
	Particle size distribution(microns)		
	-75	75-90	90-106
10	36.2(2)	32.4(2)	26.8(2)
20	43.1(2)	42.9(2)	39.2(2)
30	20.5(3)	17.2(3)	14.1(3)
40	13.5(3)	45(3)	32.3(3)
50	94.3(4)	43.8(4)	18.8(4)

Value in ( ) is number of used spindle

Table A.10 Effect of weight percent coal on sedimentation ratio for COM of -75 microns Ban Pu coal and fuel oil with 3 wt% additives at 50 °C

		Weight percent coal in COM				
		10	20	25	30	40
Light fuel oil						
COM (no additive)	Density(g/cc)	1.1206	1.1207	1.1312	1.1261	-
	Spv(cc/g)	0.8924	0.8923	0.8840	0.8880	-
	wt%	47.3843	47.4092	49.4739	48.4789	-
COM + Triton X-400	Density(g/cc)	1.0602	1.0668	1.0735	1.0884	-
	Spv(cc/g)	0.9432	0.9374	0.9315	0.9188	-
	wt%	34.7475	36.1903	37.6580	40.8172	-
COM + Ethomeen C-20	Density(g/cc)	1.0201	1.0389	1.0471	1.1153	-
	Spv(cc/g)	0.9803	0.9626	0.9550	0.8966	-
	wt%	25.5187	29.9216	31.8122	46.3396	-
Heavy fuel oil						
COM (no additive)	Density(g/cc)	1.1356	1.1270	-	1.1423	1.1473
	Spv(cc/g)	0.8806	0.8873	-	0.8754	0.8716
	wt%	50.0807	48.3584	-	51.4175	52.3943
COM + Triton X-400	Density(g/cc)	1.0514	1.0527	-	1.0599	1.1127
	Spv(cc/g)	0.9511	0.9499	-	0.9435	0.8987
	wt%	31.9573	32.2658	-	33.9111	45.4278

Table A.11 Effect of weight percent additive on sedimentation ratio for COM of -75 microns Ban Pu coal and fuel oil at 25 wt% coal for light fuel oil, 30 wt% coal for heavy fuel oil, various additives at 50 °C

Component		Weight percent additive in COM				
		0.25	0.5	1	2	3
Light fuel oil						
COM (no additive)	Density(g/cc)	-	1.1312	1.1312	1.1312	1.1312
	Spv(cc/g)	-	0.8840	0.8840	0.8840	0.8040
	wt%	-	49.4739	49.4739	49.4739	49.4739
COM + Triton X-400	Density(g/cc)	-	1.1127	1.0929	1.0477	1.0471
	Spv(cc/g)	-	0.8907	0.9150	0.9545	0.9550
	wt%	-	43.7525	40.9167	38.5286	37.6580
COM + Ethomeen C-20	Density(g/cc)	-	1.1025	1.0889	1.0776	1.0735
	Spv(cc/g)	-	0.9070	0.9184	0.9280	0.9315
	wt%	-	45.8172	41.7624	31.9366	31.8122
Heavy fuel oil						
COM (no additive)	Density(g/cc)	1.1423	1.1423	1.1423	1.1423	-
	Spv(cc/g)	0.8754	0.8754	0.8754	0.8754	-
	wt%	51.4183	51.4183	51.4183	51.4183	-
COM + Triton X-400	Density(g/cc)	1.0945	1.0688	1.0543	1.0527	-
	Spv(cc/g)	0.9137	0.9356	0.9485	0.9499	-
	wt%	41.5717	35.9419	32.6257	32.2650	-

Table A.12 Effect of additives (stabilizing agents) on sedimentation ratio for COM of -75 microns Ban Pu coal in light fuel oil at 25 wt% coal with 2 wt% additives at 50 ^{o}C .

Component	Density (g/cc)			Specific volume (cc/g)			wt% coal		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
COM	0.9634	0.9934	1.1312	1.0379	1.0066	0.8840	11.1803	18.9719	49.4739
COM + Anionic stabilizers									
COM + Span 60	0.9475	0.9674	1.1009	1.0554	1.0337	0.9083	6.8348	12.2354	43.4172
COM + Span 40	0.9505	0.9712	1.1209	1.0521	1.0297	0.8921	7.6635	13.2415	47.4489
COM + Arlacel 83	0.9468	0.9636	1.1208	1.0562	1.0378	0.8922	6.6407	11.2214	47.4291
COM + Arlacel 20	0.9568	0.9700	1.1303	1.0452	1.0309	0.8847	9.3867	12.9247	49.2946
COM + Cationic stabilizers									
COM + Ethomeen C-20	0.9475	1.0215	1.0389	1.0554	0.9790	0.9626	6.8348	25.8539	29.9325
COM + Ethomeen C-15	0.9898	0.9901	1.0629	1.0103	1.0100	0.9408	18.0547	18.1308	35.3390
COM + Triton X-400	0.9656	0.9941	1.0735	1.0356	1.0059	0.9315	11.7624	19.1418	37.6499
COM + Nonionic stabilizers									
COM + Brij 78	0.9624	0.9971	1.0745	1.0391	1.0029	0.9307	10.8995	19.8947	37.8656
COM + Brij 76	0.9481	0.9629	1.0915	1.0547	1.0385	0.9162	7.0010	11.0337	41.4713
COM + Brij 56	0.9640	0.9861	1.0832	1.0373	1.0141	0.9232	11.3285	17.1117	39.7250
COM + Tween 40	0.9656	0.9886	1.0882	1.0356	1.0115	0.9189	11.7561	17.7496	40.7802
COM + Tween 20	0.9429	0.9875	1.0883	1.0606	1.0127	0.9189	5.5540	17.4693	40.8012
COM + Surfonic N-95	0.9482	0.9970	1.0883	1.0546	1.0030	0.9189	7.0287	19.8696	40.8012
COM + Igepal CO-610	0.9457	0.9841	1.0895	1.0574	1.0162	0.9179	6.3351	16.5990	41.0529

Table A.13 Effect of additives(stabilizing agents) on sedimentation ratio for COM of coal in heavy fuel oil at 30 wt% coal with 1 wt% additives, various coal types, coal sizes at 50 °C.

Component	Density (g/cc)			Specific volume (cc/g)			wt% coal		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
-75 microns Ban Pu coal									
COM (no additive)	1.0241	1.0347	1.1423	0.9764	0.9664	0.8754	25.4456	28.0182	51.4175
COM + Ethomeen C-20	1.0192	1.0113	1.0231	0.9812	0.9888	0.9774	24.2294	22.2591	25.1909
COM + Ethomeen C-15	0.9964	1.0020	1.0504	1.0036	0.9980	0.9520	18.4578	19.8997	31.7213
COM + Triton X-400	0.9849	1.0197	1.0527	1.0153	0.9807	0.9499	15.4454	24.3531	32.2560
-75 microns Nong Ya Plong coal									
COM (no additive)	1.0010	1.0062	1.1308	0.9990	0.9938	0.8843	18.3348	19.6654	47.8893
COM + Ethomeen C-20	1.0169	1.0183	1.0152	0.9834	0.9820	0.9850	22.3606	22.7091	21.9362
COM + Ethomeen C-15	1.0167	1.0169	1.0178	0.9836	0.9834	0.9825	22.3107	22.3606	22.5847
COM + Triton X-400	1.0158	1.0241	1.0221	0.9844	0.9765	0.9784	22.0861	24.1425	23.6500
-75 microns Mae Moh coal									
COM (no additive)	0.9898	0.9986	1.0912	1.0103	1.0014	0.9164	22.7177	26.0030	57.3608
COM + Ethomeen C-20	1.0001	1.0037	1.0119	0.9999	0.9963	0.9882	26.5572	27.8806	30.8598
COM + Ethomeen C-15	0.9904	0.9967	1.0279	1.0097	1.0033	0.9729	22.9435	25.2986	36.5361
COM + Triton X-400	0.9935	0.9999	1.0307	1.0065	1.0001	0.9702	24.1061	26.4834	37.5113
106-150 microns Ban Pu coal									
COM (no additive)	0.9441	0.9503	1.1276	1.0592	1.0523	0.8868	4.1656	5.9421	48.4768
COM + Ethomeen C-20	0.9390	0.9463	1.1157	1.0650	1.0567	0.8963	2.6867	4.7986	46.0452
COM + Triton X-400	0.9387	0.9737	1.1208	1.0653	1.0270	0.8922	2.5992	12.4431	47.0936

APPENDIX B

SAMPLE OF CALCULATION

1. Calculation of weight percent coal in COM

In this work, coal concentration in COM varies 10-50 wt% based on total COM weight.

Example. COM composed of -75 microns Ban Pu coal and HFO.
at 10 wt% coal; The ratio of coal to fuel oil is 1 : 9
where the amount of used coal (W) ;

$$W = \frac{\text{ratio of coal in COM} * \text{weight of fuel oil}}{\text{ratio of fuel oil in COM}}$$

so, at 250 g of HFO ; $W = \frac{1 * 250}{9} = 27.78$ g

2. Calculation of shear stress, T

For Brookfield LV Model viscometer :

Calibration Spring Torque = 673.7 dyne-cm (Full scale)

and T, dynes/cm^2 $= \frac{5 * \text{Spring Torque} * \text{dial reading}}{100}$

$= \frac{5 * 673.7 * \text{dial reading}}{100}$

Example. COM composed of -75 microns Ban Pu coal and HFO at 0.3 rpm and dial reading = 0.5

$$T = \frac{5 * 673.7 * 0.5}{100} = 16.84 \text{ dynes/cm}^2$$

3. Calculation of shear rate, r

Sikdar, S. K., and Fernando Ore (24) give equations to calculate shear rate

$$r\ ,\ 1/s = K1 * STI$$

where STI is shear thinning index and equal to the slope of the plot of the log(rpm) against the log of Brookfield dial reading.

$$STI = \frac{d\ \ln(rpm)}{d\ \ln(\text{dial reading})}$$

$$K1 = 3.1416 * rpm/15$$

Example. 10 wt% COM composed of -75 microns Ban Pu coal and HFO at 0.3 , 0.6 rpm , dial reading = 0.5, 0.9 ,respectively.

$$STI = \frac{\ln 0.6 - \ln 0.3}{\ln 0.9 - \ln 0.5} = 1.18$$

$$K1 = 3.1416 * 0.3/15 = 0.0628$$

at 0.3 rpm $r = 0.0628 * 1.18 = 0.0741$ 1/s

4. Calculation of viscosity

For Brookfield LV Model viscometer

viscosity (centipoise) = dial reading * factor

Example. COM composed of -75 microns Ban Pu coal and HFO at 40 °C

10 wt% coal use #2 spindle at 30 rpm

so, viscosity = 36.2 * 10 = 362 cp

5. Calculation of density and specific volume

Density is measured from pycnometer

$$\text{Density ,g/cc} = \frac{\text{Weight of sample in pycnometer}}{\text{pycnometer volume}}$$

$$\text{pycnometer volume} = \frac{\text{Weight of water in pycnometer}}{\text{Density of water}}$$

Specific volume, cc/g = 1/ density

Example. COM composed of -75 microns Ban Pu coal and HFO at 10 wt% coal weight of sample in pycnometer = 9.4732 g

10 ml of pycnometer volume = 9.8556 cc

Density = 9.4732 / 9.8556 = 0.9612 g/cc

Specific volume = 1 / 0.9612 = 1.0404 cc/g

6. Calculation of weight percent coal at bottom of sedimentation column

The equations for converted specific volume to wt% coal are shown in Table 4.13.

Example. COM composed of -75 microns Ban Pu coal and HFO at 10 wt% specific volume = 0.8924 cc/g

$$Spv = -0.00389(\text{wt\% coal}) + 1.075414$$

$$\text{so,} \quad \text{wt\% coal} = \frac{0.8924 - 1.075414}{-0.00389} = 47.05$$

7. Calculation of weight percent additive used for sedimentation

Example. Given total weight of COM = 300 g

at 3 wt% additive

so, amount of used additive = 300 * 0.03 = 9 g

8. Calculation of sedimentation ratio, SR

$$SR = \frac{\text{wt\% coal from bottom sampling (with additive)}}{\text{wt\% coal from bottom sampling (with no additive)}}$$

Example. COM composed of -75 microns Ban Pu coal and LFO at 25 wt% coal and 50 °C.

wt% coal from bottom for COM = 49.47

wt% coal from bottom for COM with Ethomeen C-20 = 29.93

SR = 29.93 / 49.47 = 0.61

APPENDIX C

FUEL OIL

Table C.1 Properties of light fuel oil

ESSO LIGHT FUEL OIL ESSO STANFUEL (FO NO. 1)			
	Specification		Typical
	Min	Max	Inspection
Gravity, API @ 15 C	-	-	22.7
Gravity, Specific @ 15.6/15.6 C	-	0.985	0.9176
Flash Point, C (PMCC)	66	-	over 70
Pour Point, C	-	24	24 max
Sulphur, mass%	-	3.0	1.29
Viscosity @ 50 C, cSt	7	80	80 max
Ash, mass%	-	0.07	0.01
Carbon Residue, mass%	-	-	3.08
Water and Sediment, vol%	-	1.0	0.1
Sediment by Extraction, mass%	-	0.15	0.010
Color, ASTM	8.0	-	over 8.0
Gross Heat of Combustion, cal/g	10,000	-	10,542

Remark : The typical inspection value shown here are representative of current production. All may vary within the modest range.

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Table C.2 Properties of heavy fuel oil

ESSO HEAVY FUEL OIL

(FO NO. 6)

	Specification		Typical
	Min	Max	Inspection
Gravity, API @ 15 C	-	-	19.0
Gravity, Specific @ 15.6/15.6 C	-	0.995	0.9402
Flash Point, C (PMCC)	66	-	over 70
Pour Point, C	-	30	30 max
Sulphur, mass%	-	3.5	1.98
Viscosity @ 50 C, cSt	-	280	280 max
Ash, mass%	-	0.10	0.02
Carbon Residue, mass%	-	-	5.20
Water and Sediment, vol%	-	1.50	0.5
Sediment by Extraction, mass%	-	0.25	0.015
Gross Heat of Combustion, cal/g	9,900	-	10,311

Remark : The typical inspection value shown here are representative of current production. All may vary within the modest range.

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APPENDIX D

ANALYTICAL METHODS

1. Moisture in the analysis sample of coal. ASTM D 3173

Procedure

- Heat the empty capsules for 15 to 30 min. and weigh.
- Put the sample approximately 1 g. into the capsule, close and weigh.
- Place the capsules in an oven (at 104 to 110 °C) for 1 h.
- Cool in a desiccator and weigh.

Calculation

Moisture in analysis sample, % = [(A-B)/A] * 100

where :

A = grams of sample used

B = grams of sample after heating

2. Ash in the analysis sample of coal. ASTM D 3174

Procedure

- Weigh the sample approximately 1 g. to a weighed crucible and cover quickly.
- Place the crucible in a cold furnace and heat gradually until the temperature reaches 450 to 500 °C in 1 h.
- Continue the ashing at 700 to 750 °C for 2 h.
- Place the crucible, cool and weigh.

Calculation

Ash in analysis sample, % = [(A-B)/C] * 100

Where :

A = weight of crucible, cover and ash residue, g.

B = weight of empty crucible and cover, g.

C = weight of analysis sample used, g.

3. Volatile matter in the analysis sample of coal. ASTM D 3175

Procedure

- Weigh 1 g. of the sample in a weighed nickle crucible, close with a cover.
- Heat it at 600 ± 50 °C in 6 min., then heat at 950 ± 20 °C in 6 min.
- Remove the crucible from the furnace, cool and weigh.

Calculation

Volatile matter in analysis sample, % = [(A-B)/A] * 100 - D

Where :

A = weight of sample used, g.

B = weight of sample after heating, g.

D = moisture, %

4. Fixed carbon in the analysis sample of coal.

Calculation

Fixed carbon in analysis sample, % = 100 - (moisture, %) - (Ash, %) - (volatile, %)

5. Pour point of petroleum oils. ASTM D 97

Procedure

- Pour the oil into the test jar to the level mark.
- Close the test jar tightly by the cork and adjust the position of the cork and the thermometer so the cork fits tightly.
- The thermometer bulb is immersed below the surface of the oil 3 mm.
- Insert the test jar in the jacket.

- Maintain the temperature of the cooling bath at 30 to 35 °F (-1 to +2 °C)
- If the oil in the test jar does not flow when the jar is tilted, hold the test jar in a horizontal for 5.0 s, record the temperature.

6. <u>Sulfur in petroleum product.</u> ASTM D 129

Procedure

- Cut a piece of firing wire 100 mm. in length.
- Arrange the coil above and to one side of the sample cup.
- Place about 5 ml.of Na_2CO_3 (50 g/l) in the bomb.
- Weigh the sample about 0.3 to 0.4 g.
- Place the sample cup in position and arrange the coil.
- Admit oxygen slowly until a pressure is reached 27-29 atm.
- Immerse the bomb in a cold distilled-water bath and close the circuit to ignite the sample.
- Release the pressure at a slow, uniform rate.
- Rinse the bomb, the oil cup with distilled water, add 10 ml.of saturated bromine water to the washing.
- Adjust the heat to maintain slow boiling and add 10 ml. of a $BaCl_2$ solution (85g/l), stir the solution during the addition.
- Place it to cool for 1 h. before filtering with an ashless, quantitative filter paper.
- Transfer the paper and precipitate to weighed crucible and ignite at a bright red heat until the residue is white color, cool and weigh.

Calculation

Sulfur, weight percent = (P - B)13.73/W

where : P = gram of $BaSO_4$ obtain from sample

B = gram of $BaSO_4$ obtain from blank

W = gram of sample used

7. Gross calorific value of coal and oil by the adiabatic bomb calorimeter. ASTM D 2015

7.1 Determine the energy equivalent of the calorimeter.

Procedure

- Weigh the pellets of benzoic acid to the nearest 0.0001 g. in the sample holder.
- Add 1.0 ml of water to the bomb.
- Connect a 10 cm. of ignition wire to contact with the sample.
- Charge bomb with oxygen to a consistent pressure between 20 - 30 atm.
- Fill the calorimeter vessel (bucket) with 2000 ml of 25 °C water.
- Allow 5 min for attainment of equilibrium. Record the initial temperature and ignite the charge.
- Read temperature at 1 min intervals until the same temperature and record this as the final temperature.
- Wash the interior of the bomb with distilled water, and titrate the washing with standard Sodium Carbonate solution (0.0709 N)
- Measure the combined pieces of unburned ignition wire.

7.2 Determine the gross calorific value of coal.

Procedure

- Weigh approximately 1 g. of coal sample into the sample holder.
- Make each determination in accordance with the procedure described in 7.1 (2 through 9)

7.3 Determine the sulfur content of coal. ASTM D 3177

Procedure

- Collect the washing solution after titrate with sodium carbonate solution boil it and filtering with a filter paper no.1.
- Add Bromine solution 1.0 ml and HCl (1:9) 10 ml
- Boiling it slowly and add 10 ml of a $BaCl_2$ solution (100g/l), stir the solution during the addition.
- Stand it to cool for 2 hr. and filtering with an ashless filter paper.
- Put the paper and precipitate to weighed crucible and ignite at 925 °C for 3 h.
- Place it to cool in desiccator and weigh.

Calculation

Energy eqivalent :

$$E = [H(g) + e_1 + e_2] / t \quad \text{--------(1)}$$

Gross Calorific Value :

$$Q = [t(E) - e_1 - e_2 - e_3] / g \quad \text{--------(2)}$$

Sulfur content :

$$\%S = 13.738 (A - B)/ g \quad \text{-------(3)}$$

where ; E = calorimeter energy equivalent , cal/ °C

H = heat of combustion of benzoic acid , 2404 cal/g

Q = gross calorific value

t = corrected temperature rise

e_1 = correction for the heat of formation of HNO_3 , cal

= (0.0709 N) (ml Na_2CO_3)

e_2 = correction for the heat of combustion of ignition wire, cal

= (2.3) x (length of used ignition wire)

e_3 = correction of difference between heat of formation H_2SO_4 , cal

= 14 x (% sulfur)

g = gram of sample

A = gram of $BaSO_4$ obtain from sample

B = gram of $BaSO_4$ obtain from blank

B = gram of $BaSO_4$ obtain from blank.

C = gram of sample.

9. Brookfield viscometer operation.

Procedure

- Attach spindle to lower shaft. It is best to lift the shaft slightly while it is held firmly with one hand while screwing the spindle on with the other.
- Insert spindle in the test material until the fluid's level is at the immersion groove cut in the spindle's shaft.
- Level the Viscometer.
- Depress the clutch and turn on the Viscometer's motor: following the procedure of having the clutch depressed at this point will prevent unnecessary wear. Release the clutch and allow the dial to rotate until the pointer stabilizes at a fixed position on the dial.
- Depress the clutch and read dial .
- The interpretation of results are used these equations:

viscosity in centipoise(mPa.s) = dial reading*faction finder

shear stress(dynes/cm^2) = 5 * 673.7 * dial reading/100

for LV model ;Spring torque = 673.7 dyne-cm (full scale)

shear rate (1/s) = K1*STI

where : K1 = 3.1416 * rpm/15

STI = d ln(rpm)/d ln(dial reading)

8. Total Sulfur in the analysis sample of coal. ASTM D 3177 (Eschka Method)

Procedure

- Weigh approximately 1 g. of coal sample and 3 g. of Eschka mixture in crucible, mix throughly and cover with 1 g. of Eschka mixture.
- Place the crucible in a cold muffle and gradually raise the temperature to 825 °C in 1 h. maintain this temperature for 2 h.
- Take the crucible from a furnace and digest the sample in crucible with 100 ml of hot water for 1/2 h. into 250-ml beaker, stirring occasionally.
- Filter and wash the insoluble matter.
- Treat the filtrate with HCl (1:9) to slightly acid and just neutral to methyl orange with $NaCO_3$ solution, then add 1 ml of HCl (1:9).
- Boil again and add slowly 10 ml of $BaCl_2$ (10%), stirring occasionally.
- Allow to stand for at least 2 h. or overnight.
- Filter through an ashless filter paper and wash with hot water until an $AgNO_3$ solution shows no precipitate with a drop of the filtrate.
- Place the wet filter containing the precipitate in a weighed crucible.
- Burn it with flame, then put into the furnace (at 925 °C) for 3 h., cool in desiccator and weigh.
- Blank correction by running a blank exactly as described above, using the same amount of all reagents that were employed in the regular determination.

Calculation

Total Sulfur content, % = (A-B)*13.738/C

where ; A = gram of $BaSO_4$ obtain from sample.

VITA

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