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APPENDICES

Appendix A Blank Test (Batch System)

Table A1 Concentration of metallic mercury (500 ppb in heavy naphtha) remained as a function of time at 50°C

Time (hr)	Remaining concentration (ppb)			% Error
	Run 1	Run 2	Average	
0	499.13	483.00	491.06	0.00
2	466.13	467.25	466.69	4.96
4	495.00	514.50	504.75	-2.79
6	486.75	467.25	477.00	2.86
8	515.63	441.00	478.31	2.60

Appendix B Appropriate Quantity of Adsorbent (Batch System)

Table B1.1 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on CuS/BEA as a function of time at 50°C

No.	Run 1				Run 2				Average		
	Weight of adsorbent (g)	Initial conc. of Hg (ppb)	Equilibrium conc. of Hg (ppb)	Adsorption capacity (%)	Weight of adsorbent (g)	Initial conc. of Hg (ppb)	Equilibrium conc. of Hg (ppb)	Adsorption capacity (%)	Weight of adsorbent (g)	Adsorption capacity (%)	RSD
1	0.1034	535.90	58.65	89.06	0.1035	533.60	65.55	87.72	0.1035	88.39	0.95
2	0.0506	543.75	86.25	84.14	0.0506	491.25	71.25	85.50	0.0506	84.82	0.96
3	0.0108	468.75	78.75	83.20	0.0110	480.00	90.00	81.25	0.0109	82.23	1.38
4	0.0014	510.00	108.75	78.68	0.0014	499.50	117.00	76.58	0.0014	77.63	1.48

Table B1.2 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on CuS/Al$_2$O$_3$ as a function of time at 50°C

No.	Run 1				Run 2				Average		
	Weight of adsorbent (g)	Initial conc. of Hg (ppb)	Equilibrium conc. of Hg (ppb)	Adsorption capacity (%)	Weight of adsorbent (g)	Initial conc. of Hg (ppb)	Equilibrium conc. of Hg (ppb)	Adsorption capacity (%)	Weight of adsorbent (g)	Adsorption capacity (%)	RSD
1	0.1032	532.50	51.50	90.33	0.1037	543.00	63.00	88.40	0.1035	89.36	1.37
2	0.0503	521.75	79.00	84.86	0.0504	514.00	82.75	83.90	0.0504	84.38	0.68
3	0.0105	547.00	99.75	81.76	0.0107	530.00	98.30	81.45	0.0106	81.61	0.22
4	0.0013	488.00	145.00	70.29	0.0015	478.00	161.50	66.21	0.0014	68.25	2.88

Appendix C Adsorption Kinetic Study (Batch System)

Table C1 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on Beta zeolite (BEA) as a function of time at 50°C

| Time (min) | RUN 1 | | | RUN 2 | | | Average | |
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	566.24	0.00	0.0012	538.35	0.00	0.00	0.00
5	0.0012	504.01	10.99	0.0012	493.28	8.37	9.68	1.85
20	0.0012	493.28	12.89	0.0012	482.55	10.36	11.62	1.78
50	0.0012	487.92	13.83	0.0012	485.77	9.77	11.80	2.88
110	0.0012	482.55	14.78	0.0012	480.41	10.76	12.77	2.84
200	0.0012	485.77	14.21	0.0012	477.19	11.36	12.79	2.02
300	0.0012	484.70	14.40	0.0012	479.33	10.96	12.68	2.43
400	0.0012	481.48	14.97	0.0012	475.04	11.76	13.36	2.27

Table C2 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on CuS on Beta zeolite (CuS/BEA) as a function of time at 50°C

| Time (min) | RUN 1 | | | RUN 2 | | | Average | |
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	443.93	0.00	0.0012	504.01	0.00	0.00	0.00
5	0.0012	305.52	31.18	0.0012	332.34	34.06	32.62	2.04
20	0.0012	242.75	45.32	0.0012	267.96	46.83	46.08	1.07
50	0.0012	202.51	54.38	0.0012	203.58	59.61	56.99	3.69
110	0.0012	119.36	73.11	0.0012	128.48	74.51	73.81	0.99
200	0.0012	34.06	92.33	0.0012	53.37	89.41	90.87	2.06
300	0.0012	12.06	97.28	0.0012	21.18	95.80	96.54	1.05
400	0.0012	9.91	97.77	0.0012	10.45	97.93	97.85	0.11

Table C3 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on alumina (Al_2O_3) as a function of time at 50°C

Time (min)	RUN 1			RUN 2			Average	
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	519.03	0.00	0.0012	557.66	0.00	0.00	0.00
5	0.0012	504.01	2.89	0.0012	532.98	4.43	3.66	1.08
20	0.0012	493.28	4.96	0.0012	513.67	7.89	6.42	2.07
50	0.0012	471.82	9.10	0.0012	525.47	5.77	7.43	2.35
110	0.0012	475.04	8.48	0.0012	519.03	6.93	7.70	1.10
200	0.0012	470.75	9.30	0.0012	515.82	7.50	8.40	1.27
300	0.0012	471.82	9.10	0.0012	513.67	7.89	8.49	0.85
400	0.0012	469.68	9.51	0.0012	509.38	8.66	9.08	0.60

Table C4 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on CuS on alumina (CuS/Al_2O_3) as a function of time at 50°C

Time (min)	RUN 1			RUN 2			Average	
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	479.33	0.00	0.0012	538.35	0.00	0.00	0.00
5	0.0012	395.64	17.46	0.0012	438.56	18.54	18.00	0.76
20	0.0012	342.00	28.65	0.0012	364.53	32.29	30.47	2.57
50	0.0012	292.64	38.95	0.0012	303.37	43.65	41.30	3.32
110	0.0012	169.25	64.69	0.0012	182.12	66.17	65.43	1.05
200	0.0012	76.97	83.94	0.0012	83.41	84.51	84.22	0.40
300	0.0012	27.62	94.24	0.0012	40.49	92.48	93.36	1.24
400	0.0012	11.52	97.60	0.0012	32.98	93.87	95.73	2.63

Table C5 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on activated carbon (AC) as a function of time at 50°C

Time (min)	RUN 1			RUN 2			Average	
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	519.03	0.00	0.0012	471.82	0.00	0.00	0.00
5	0.0012	482.55	7.03	0.0012	428.91	9.10	8.06	1.46
20	0.0012	473.97	8.68	0.0012	404.23	14.33	11.50	3.99
50	0.0012	439.64	15.30	0.0012	385.99	18.19	16.75	2.05
110	0.0012	418.18	19.43	0.0012	375.26	20.47	19.95	0.73
200	0.0012	398.86	23.15	0.0012	364.53	22.74	22.95	0.29
300	0.0012	394.57	23.98	0.0012	366.67	22.29	23.13	1.20
400	0.0012	393.50	24.19	0.0012	363.45	22.97	23.58	0.86

Table C6 Amount of metallic mercury (500 ppb in heavy naphtha) adsorbed on CMG273 as a function of time at 50°C

Time (min)	RUN 1			RUN 2			Average	
	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Weight of adsorbent (gram)	Remaining concentration (ppb)	Adsorption capacity (%)	Adsorption capacity (%)	RSD
0	0.0012	566.24	0.00	0.0012	502.96	0.00	0.00	0.00
5	0.0012	521.18	7.96	0.0012	432.46	14.02	10.99	4.28
20	0.0012	387.06	31.64	0.0012	318.37	36.70	34.17	3.57
50	0.0012	263.67	53.44	0.0012	226.37	54.99	54.21	1.10.
110	0.0012	170.32	69.92	0.0012	141.72	71.82	70.87	1.34
200	0.0012	93.07	83.56	0.0012	73.64	85.36	84.46	1.27
300	0.0012	46.93	91.71	0.0012	25.79	94.87	93.29	2.23
400	0.0012	45.86	91.90	0.0012	23.95	95.24	93.57	2.36

Appendix D Adsorption Isotherm Study (Batch System)

Table D1 Adsorption isotherms of metallic mercury in heavy naphtha on CuS/BEA at 50°C

Initial conc. of Hg (ppb)	RUN 1			RUN 2			Average		Fluid phase conc, C (µmole/L)	Solid phase conc, q (µmole/g)
	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)		
890.00	0.0012	265.00	10416.67	0.0013	250.00	9846.15	257.50	10131.41	1.2837	50.5081
717.00	0.0012	210.20	8446.67	0.0012	199.75	8620.83	204.98	8533.75	1.0219	42.5432
463.13	0.0014	75.60	5536.07	0.0014	76.88	5517.86	76.24	5526.96	0.3801	27.5535
337.50	0.0012	55.29	4703.50	0.0012	55.00	4708.33	55.15	4705.92	0.2749	23.4604
210.00	0.0012	27.50	3041.67	0.0012	31.80	2970.00	29.65	3005.83	0.1478	14.9850

Table D2 Adsorption isotherms of metallic mercury in heavy naphtha on CuS/Al$_2$O$_3$ at 50°C

Initial conc. of Hg (ppb)	RUN 1			RUN 2			Average		Fluid phase conc, C (µmole/L)	Solid phase conc, q (µmole/g)
	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (µg/g of adsorbent)		
705.00	0.0012	121.00	9733.33	0.0013	128.25	8873.08	124.63	9303.21	0.6213	46.3792
635.63	0.0012	112.50	8718.75	0.0012	117.50	8635.42	115.00	8677.08	0.5733	43.2578
535.00	0.0012	80.63	7572.92	0.0012	77.50	7625.00	79.06	7598.96	0.3941	37.8830
326.25	0.0012	32.78	4891.17	0.0012	31.70	4909.17	32.24	4900.17	0.1607	24.4288
225.00	0.0012	24.25	3345.83	0.0012	17.95	3450.83	21.10	3398.33	0.1052	16.9417

Table D3 Adsorption isotherms of metallic mercury in heavy naphtha on CMG273 at 50°C

| Initial conc. of Hg (ppb) | RUN 1 | | | RUN 2 | | | Average | | Fluid phase conc, C (μmole/L) | Solid phase conc, q (μmole/g) |
	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (μg/g of adsorbent)	Weight of adsorbent (gram)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (μg/g of adsorbent)	Equlibrium. conc. of Hg (ppb)	Amount of adsorbed Hg (μg/g of adsorbent)		
747.50	0.0012	142.88	10077.00	0.0012	137.50	10166.67	140.19	10121.83	0.6989	50.4603
652.50	0.0012	118.90	8893.33	0.0012	113.50	8983.33	116.20	8938.33	0.5793	44.5602
491.25	0.0012	65.00	7104.17	0.0012	71.25	7000.00	68.13	7052.08	0.3396	35.1567
325.00	0.0012	33.40	4860.00	0.0012	35.50	4825.00	34.45	4842.50	0.1717	24.1413
192.50	0.0012	24.38	2802.08	0.0012	15.00	2958.33	19.69	2880.21	0.0981	14.3587

Appendix E Pilot Plant Testing (Continuous System)

Table E1 Adsorption and desorption of 1000 ppb metallic mercury in heavy naphtha on CuS/BEA

Adsorption Phase
Feed stock : ATC heavy naphtha (110 SN 7) spiked with Hg° (1228 ppb)
Adsorbent : CuS/BEA 0.29 g (0.5 ml of adsorbent:2ml of SiC)
Temperature : 50°C
Pressure : 7 bar
Feed flow : 2 ml/min
Duration time : 30 hr

Total Time (h)	Feed Weight (g)	Sample Weight (g)	Outlet Conc. (ppb)	Total Hg (µg)	C/Co
Feed 1 (t=00 h)	2146		1244.36	3518.76	
Feed 2 (t=24.47 h)	504		1212.17	805.02	
1	89	18.7	2.44	0.06	0.002
3	270	29	2.55	0.10	0.002
5	450	33.79	2.65	0.12	0.002
7	628	37.92	5.12	0.26	0.004
11.37	1010	41.1	102.01	5.52	0.083
14.12	1256	52.2	315.17	21.68	0.257
18.12	1601	41	603.80	32.62	0.492
22.12	1949	45.9	731.48	44.24	0.596
24	2109	44.02	946.07	54.88	0.770
26.28	2311	44.02	1006.16	58.36	0.819
28	2468	44.88	935.34	55.31	0.762
30	2650	44.33	1014.74	59.27	0.826
Slop (Total at t=30 h)		2141	329.12	928.51	
	Total	2617.86		1260.94	

Desorption Phase
Feed stock : Xylene
Temperature : 50°C
Pressure : 7 bar
Feed flow : 2 ml/min
Duration time : 31 hr

Total Time (h)	Feed Weight (g)	Sample Weight (g)	Outlet Conc. (ppb)	Total Hg (μg)
Feed 1 (t=0 h)	824		116.28	50.24
Feed 2 (t=7.58 h)	1967		13.96	119.93
Feed 3 (t=26.72 h)	2430		29.10	148.16
1	139	53.3	465.53	28.48
3	343	52.3	268.64	16.13
5	550	52.03	194.22	11.60
6.25	681	51.91	154.88	9.23
9.00	931	51.86	147.06	8.76
13.00	1343	51.95	100.23	5.98
15.42	1592	45.59	83.77	4.38
19.67	2027	44.98	83.45	4.31
24.00	2478	51.27	72.56	4.27
26.00	2689	52.48	69.20	4.17
31.00	3254	52.17	57.48	3.44
Slop 1 (Total at t=7.58 h)		518.2	274.62	163.37
Slop 2 (Total at t=31 h)		2055	30.71	72.45
	Total	3133.04		336.57

Mass Balance

Total Hg 'ENTER' in Adsorption Phase = 4323.79   μg
Total Hg 'ENTER' in Desorption Phase = 318.33   μg
Total Hg 'OUT' from Adsorption Phase = 1260.94   μg
Total Hg 'OUT' from Desorption Phase = 336.57   μg
Total Hg accumulated on Solid Phase = 3044.61   μg
Mercury concentration in solid phase = 0.30   %

Table E2 Adsorption and desorption of 1000 ppb metallic mercury in heavy naphtha on CuS/Al$_2$O$_3$

Adsorption Phase

Feed stock :   ATC heavy naphtha (110 SN 7) spiked with Hg° (822 ppb)
Adsorbent :   CuS/Al$_2$O$_3$ 0.23 g (0.5 ml of adsorbent:2ml of SiC)
Temperature : 50°C
Pressure :   7 bar
Feed flow :   2 ml/min
Duration time : 30 hr

Total Time (h)	Feed Weight (g)	Sample Weight (g)	Outlet Conc. (ppb)	Total Hg (µg)	C/Co
Feed 1 (t=00 h)	2686		822.15	2909.85	
1	94	45.02	1.47	0.09	0.002
3	280	45.50	1.26	0.08	0.002
5	454	44.50	31.30	1.84	0.038
7	632	45.31	91.07	5.44	0.111
9	816	44.92	138.79	8.21	0.169
13.25	1189	41.14	223.97	12.14	0.272
16.07	1442	37.18	264.74	12.97	0.322
20.22	1815	38.09	323.76	16.25	0.394
23.47	2106	46.69	351.65	21.63	0.428
26.5	2378	45.11	404.23	24.03	0.492
28.5	2553	45.21	395.64	23.57	0.481
30	2686	45.30	411.74	24.58	0.501
Slop (Total at t=30 h)		2097.9	240.06	663.63	
	Total	2621.87		814.45	

Desorption Phase

Feed stock :   Xylene
Temperature : 50°C
Pressure :   7 bar
Feed flow :   2 ml/min
Duration time : 25.5 hr

Total Time (h)	Feed Weight (g)	Sample Weight (g)	Outlet Conc. (ppb)	Total Hg (μg)
Feed 1 (t=0 h)	2623		22.34	67.28
1	104	51.66	180.12	10.68
2.5	254	51.25	48.79	2.87
6.5	678	44.17	24.22	1.23
9.77	1003	41.06	21.00	0.99
13.17	1357	40.85	23.04	1.08
17.50	1804	48.84	17.68	0.99
21.50	2216	47.46	14.89	0.81
25.50	2623	47.82	13.06	0.72
Slop (Total at t=25.5 h)		2238.1	25.29	64.99
	Total	2611.21		84.36

Mass Balance

Total Hg 'ENTER' in Adsorption Phase	=	3801.35	μg
Total Hg 'ENTER' in Desorption Phase	=	79.73	μg
Total Hg 'OUT' from Adsorption Phase	=	2073.66	μg
Total Hg 'OUT' from Desorption Phase	=	58.56	μg
Total Hg accumulated on Solid Phase	=	1748.86	μg
Mercury concentration in solid phase	=	0.17	%

CURRICULUM VITAE

Name: Mr. Rattakit Kitsanguan

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Nationality: Thai

University Education:

2002-2005   Bachelor of Science in Chemical Engineering (2nd honor), Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand

Working Experience:

2004   Position: Student Trainee in the Position of Process Control

Company name: Thai Oil Public Company Limited.