REFERENCES

Adamson, W. (1990) Physical Chemistry of Surfaces. New York: Wiley.

Boonyasuwat, S., Chavadej, S., Malakul, P., and Scahmehorn, J.F. (2003). Anionic and cationic surfactant recovery from water using a multistage foam fractionator. Chemical Engineering Journal, 93, 241-252.

Carleson, T.E. (1989) Surfactant-Based Separation Processes. New York: Marcel Dekker.

Chuyingsakultip, N. (2003) Surfactant Recovery from Aqueous Phase using Multi-stage Foam Fractionation. M.S. Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

Darron, R.C., Supino, S., and Sweeting, K.J. (2004) Development of a Multistage Foam Fractionation Column. Chemical Engineering and Processing , 43, 477-482.

Grieves, R.B. and Wood, R.K. (1964) Continuous Foam Fractionation: The effect of Operating Variables on Separation. American Institute of Chemical Engineers, 10, 456.

Kumpabooth, K. (1996) Surfactant Recovery from Water using Foam Fractionation. M.S. Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

Porter, M.R. (1994) Handbook of Surfactants, 2nd edition, New York: Chapman & Hal.

Rosen, M.J. (1988) Surfactant and Interfacial Phenomena, 2nd edition, New York: Wiley.

Scamehorn, J.F., Christian, S.D., and Ellington, R.T. (1989) Surfactant-Based Separation Processes. NewYork: Marcel Dekker.

Scamehorn, J.F. and Harwell, J.H. (1992) Surfactant-based Separation Processes. New York: Marcel Dekker.

Sebba, F. (1987) Foam and Biliquid Foam-Aphrons New York: Wiley.

Thrapiwattananon, N., Scahmehon, J.F., Osuwan, S., and Harwell, J.H. (1996) Surfactant Recovery from Water Using Foam Fractionation. Separation Science Technology, 31, 1259.

Triroj, M. (2005) Recovery of Mixed Surfactant form Water Using Multi-stage Foam Fractionation. M.S. Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

APPENDIX

Experimental Data

Table A1 The results of steady-state experiment under operational condition [CPC] = 0.225 mM; feed flow rate = 50 ml/min; air flow rate = 80 L/min; foam height = 60 cm and number of tray = 5

Time (hr)	Concentration (μM)					
	Effluent	Tray 1	Tray 2	Tray 3	Tray 4	Tray 5
1	30.24	36.67	37.86	49.76	72.62	119.52
2	26.43	29.52	35.24	46.67	72.86	116.67
3	27.62	30.24	37.14	48.57	72.38	118.10
4	26.67	29.29	33.33	50.24	76.90	121.43
5	26.19	30.48	36.67	53.10	81.43	130.24
6	26.23	31.27	35.75	54.44	82.38	130.28
7	25.24	28.81	38.10	50.95	84.05	132.86

Table A2 The results of Operational zone under operational condition [surfactant] = 0.225 mM; foam height = 60 cm and feed tray number 5

Air Flow Rate (LPM)	Maximum Feed Flow Rate (ml/min)				Minimum Feed Flow Rate (ml/min)			
	Water	CPC	1 : 1	$OPEO_{10}$	Water	CPC	1 : 1	$OPEO_{10}$
50	180	300	310	320	40	40	40	40
60	200	350	360	370	25	25	25	25
70	210	370	380	390	25	25	25	25
80	230	380	400	400	25	25	25	25
90	220	350	360	370	25	25	25	25
100	220	330	350	350	25	25	25	25
110	220	310	310	310	25	25	25	25

Table A3 The experimental data of foam ability and foam stability of surfactants

Surfactant concentration (μM)	CPC		Mixed 1:1		$OPEO_{10}$	
	Foam ability	Foam stability	Foam ability	Foam stability	Foam ability	Foam stability
50	0.512	13	0.827	15	0.457	5
100	0.937	20	0.976	40	0.724	8
150	0.945	35	1.079	52	0.756	15
200	1.024	42	1.134	63	0.772	14
225	1.087	54	1.157	69	0.827	17

Table A4 Data of Dynamic surface tension of pure CPC system

CPC	
Surface Age (ms)	Surface Tension (mN/m)
10.2	73.5
12.7	73.3
14.9	73.2
19.2	72.9
23.3	72.9
28.8	72.8
36.6	72.6
45.2	72.4
58.3	72.1
73.8	71.9
93.3	71.6
116	71.5
147.7	71.1
181.7	70.9
226.3	70.6
284.2	70.3
357.9	70
461.1	69.7
603.7	69.3
739.9	69
978.5	68.6
1194.3	68.3
1491.6	68
1941.3	67.6
2490	67.3
3348.6	66.8
3557.6	66.7
5330.7	66.1
5995.5	65.9
6949.5	65.7
8433	65.4
11460.4	64.9

Table A5 Data of Dynamic surface tension of pure $OPEO_{10}$ system

OPEO10	
Surface Age (ms)	Surface Tension (mN/m)
10.2	74.6
11.5	74.6
14.3	74.5
18.4	74.1
22.7	74.2
28.5	74.1
37.6	73.9
45.2	73.6
58.1	73.3
74.6	73
92.3	72.4
117.2	71.9
143	71.3
187.4	70.6
226.7	70.2
285.5	69
357.2	67.3
451.8	65.7
594	64.1
714.9	63
955.5	60.7
1124.5	59.5
1406.9	57.9
1810.4	56.2
2294.8	54.5
3026.6	52.5
4114.4	50.4
4383.9	50
5446.9	48.5
7796.5	46.1
8780	45.5
10164.6	44.6

Table A6 Data of dynamic surface tension of mixed-surfactant system

Mixed 1:1	
Surface Age (ms)	Surface Tension (mN/m)
10	74.2
12.9	74
14.8	73.7
18.7	73.5
23.2	73.4
28.6	73.4
37	73.2
45.4	73.1
58.2	72.8
74	72.5
92	72.1
116.4	71.9
143.6	71.7
180	71.2
226.4	70.7
285.2	70
358.3	69.6
456.8	68.8
604.5	67.8
713.5	67
965	65.4
1146.2	64.3
1472.4	62.8
1886.3	61.1
2412.6	59.4
3180.9	57.6
4235	55.5
4512.9	55
5527.9	53.5
7289.9	51.8
8198.2	51
14614.6	47.6

Table A7 The experimental data of the CPC concentration profile of the effect of feed position

	Concentration (μM)				
	Feed Position				
	1	2	3	4	5
Feed	223.454	224.441	225.336	225.601	225.793
Tray#1	51.446	22.594	10.687	12.996	14.035
Tray#2	47.195	52.605	17.165	15.636	14.724
Tray#3	45.189	45.012	56.084	27.704	15.678
Tray#4	46.610	45.196	46.618	57.857	24.656
Tray#5	50.748	49.671	46.990	54.590	60.961
Effluent	53.605	23.407	12.282	13.996	14.458

Table A8 The experimental data of the $OPEO_{10}$ concentration profile of the effect of feed position

	Concentration (μM)				
	Feed Position				
	1	2	3	4	5
Feed	225.054	225.465	222.785	227.515	225.251
Tray#1	28.304	10.600	9.082	7.682	5.256
Tray#2	14.980	32.176	8.205	11.228	4.269
Tray#3	15.655	17.794	32.042	13.912	6.447
Tray#4	15.623	13.844	19.416	35.345	10.846
Tray#5	19.060	19.240	23.850	31.387	36.023
Effluent	24.725	12.738	11.714	10.449	6.198

Table A9 The experimental data of the CPC concentration profile of the effect of reflux position

	Concentration (μM)					
	Reflux Position					
	No reflux	1	2	3	4	5
Feed	225.336	221.884	222.238	223.379	221.801	223.770
Tray#1	10.687	7.371	8.769	9.901	11.344	10.124
Tray#2	17.165	10.333	15.740	18.055	20.331	20.000
Tray#3	56.084	48.679	50.533	48.363	48.023	54.745
Tray#4	46.618	41.246	42.999	42.096	41.030	47.111
Tray#5	46.990	42.059	44.573	42.110	41.191	45.899
Effluent	12.282	8.791	9.685	11.138	11.400	10.772

Table A10 The experimental data of the $OPEO_{10}$ concentration profile of the effect of reflux position

	Concentration (μM)					
	Reflux Position					
	No reflux	1	2	3	4	5
Feed	225.251	221.844	224.811	227.124	225.200	225.439
Tray#1	5.256	4.439	4.462	5.449	4.192	6.363
Tray#2	4.269	5.645	5.222	6.571	6.271	5.766
Tray#3	6.447	5.352	3.743	6.070	5.106	7.722
Tray#4	10.846	10.525	8.424	9.946	12.884	12.171
Tray#5	36.023	32.261	33.582	30.921	32.157	32.983
Effluent	6.198	5.908	6.292	6.966	7.212	8.041

Table A11 The experimental data of the CPC concentration profile of the effect of reflux ratio

	Concentration (μM)				
	Reflux Ratio				
	No reflux	0.25	0.5	0.75	1
Feed	225.336	222.603	221.884	222.158	223.114
Tray#1	10.687	8.988	7.371	10.053	12.927
Tray#2	17.165	12.015	10.333	14.108	16.303
Tray#3	56.084	49.515	48.679	52.676	56.592
Tray#4	46.618	43.960	41.246	45.162	47.476
Tray#5	46.990	45.315	42.059	46.396	48.410
Effluent	12.282	10.444	8.791	11.270	14.969

Table A12 The experimental data of the $OPEO_{10}$ concentration profile of the effect of reflux ratio

	Concentration (μM)				
	Reflux Ratio				
	No reflux	0.25	0.5	0.75	1
Feed	225.2508	223.0296	221.8442	222.1432	223.1232
Tray#1	5.256446	4.9906	4.439	3.0308	3.5102
Tray#2	4.26938	5.253	5.6454	4.3734	3.9522
Tray#3	6.447306	4.5278	5.3516	3.9678	2.7426
Tray#4	10.84561	7.9344	10.5252	6.5958	6.364
Tray#5	36.02345	31.5472	32.2612	29.9338	29.7916
Effluent	6.19843	6.9098	5.9078	5.2144	5.024

Table A13 The %surfactant recovery of two single-surfactant systems and the mixed-surfactant system on the effect of feed position

System		%Surfactant recovery				
		Feed Position				
		1	2	3	4	5
Pure	CPC	87.340	94.423	97.627	94.937	94.561
Pure	OPEO10	89.743	94.743	95.043	95.700	97.565
Mixed	CPC	87.749	94.214	91.627	93.292	93.657
	OPEO10	97.340	100	100	100	100

Table A14 The enrichment ratio of two single-surfactant systems and the mixed-surfactant system on the effect of feed position

System		Enrichment ratio				
		Feed Position				
		1	2	3	4	5
Pure	CPC	2.193	1.860	1.977	4.602	6.044
Pure	OPEO10	160.677	138.659	141.884	141.261	139.702
Mixed	CPC	1.290	1.577	13.361	23.261	81.172
	OPEO10	1.216	1.559	15.737	28.213	105.001

Table A15 The %surfactant recovery of two single-surfactant systems and the mixed-surfactant system on the effect of reflux position

System		%Surfactant recovery					
		Reflux Position					
		No reflux	1	2	3	4	5
Pure	CPC	97.627	96.599	96.076	95.807	95.559	95.327
Pure	OPEO10	97.565	96.383	96.055	95.852	95.715	94.876
Mixed	CPC	93.657	87.028	87.005	87.972	88.080	88.456
	OPEO10	100	100	100	100	100	100

Table A16 The enrichment ratio of two single-surfactant systems and the mixed-surfactant system on the effect of reflux position

System		Enrichment ratio					
		Reflux Position					
		No reflux	1	2	3	4	5
Pure	CPC	1.977	1.743	1.782	1.678	1.711	1.876
Pure	OPEO10	139.702	138.839	135.708	135.834	138.896	134.485
Mixed	CPC	81.172	65.678	64.056	66.286	63.691	64.557
	OPEO10	105	75.587	76.342	75.481	74.995	74.505

Table A17 The %surfactant recovery of two single-surfactant systems and the mixed-surfactant system on the effect of reflux ratio

System		%Surfactant recovery				
		Reflux Ratio				
		No reflux	0.25	0.5	0.75	1
Pure	CPC	97.627	96.756	96.600	93.785	90.975
Pure	OPEO10	97.565	96.532	96.383	96.287	95.902
Mixed	CPC	93.657	89.791	87.028	85.550	80.788
	OPEO10	100	100	100	100	100

Table A18 The enrichment ratio of two single-surfactant systems and the mixed-surfactant system on the effect of reflux ratio

System		Enrichment ratio				
		Reflux Ratio				
		No reflux	0.25	0.5	0.75	1
Pure	CPC	1.977	1.859	1.743	1.950	1.994
Pure	OPEO10	139.702	137.826	138.839	142.759	141.792
Mixed	CPC	81.172	63.579	65.678	57.916	69.176
	OPEO10	105.001	74.180	75.587	76.439	79.713

CURRICULUM VITAE

Name: Mr. Racharith Sripituk

Date of Birth: November 11, 1981

Nationality: Thai

University Education:

2000-2004 Bachelor Degree of Chemical Engineering, Faculty of Engineering, Mahidol University, Nakhonphatom, Thailand.