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APPENDICES

APPENDIX A.1

DETERMINATION OF RANDOM PACKING EFFECT

Type of packing : 1/2-in. stainless steel raschig-type rings.

a cm.	af cm/s	F_c l/hr.	f p/m.	$F_c + F_d$, liter/hr. 1	2	3
1st random packing						
1	0.37	12.6	22	25.7	25.2	25.6
	0.50	12.6	30	23.5	23.6	23.2
	0.73	12.6	44	22.8	23.2	22.6
	1.43	12.6	85.7	22.2	21.8	22.6
2nd random packing						
1	0.37	12.6	22	25.5	24.8	26.0
	0.50	12.6	30	23.2	22.6	23.8
	0.73	12.6	44	23.1	23.6	22.6
	1.43	12.6	85.7	22.6	22.6	22.6

APPENDIX A.2

FLOODING CHARACTERISTICS

Type of packing : 1/2-in. stainless steel raschig-type rings.

a	f	af	F_c	$F_c + F_d$, liter/hr.		
cm.	p/m	cm/s	l/hr	1	2	3
2	22	0.73	12.6	20.6	19.8	19.0
	30	1.00	12.6	20.2	20.2	20.2
	44	1.47	12.6	22.6	20.2	21.4
	85.7	2.86	12.6	26.0	25.4	24.8
3	22	1.10	12.6	19.6	19.0	19.3
	30	1.50	12.6	19.6	19.0	19.3
	44	2.20	12.6	19.0	19.0	19.0
	85.7	4.29	12.6	24.8	23.4	24.1
4	22	1.47	12.6	17.9	17.9	17.9
	30	2.00	12.6	18.8	17.7	16.6
	44	2.93	12.6	17.9	18.8	18.4
	85.7	5.71	12.6	23.6	22.6	23.1

APPENDIX A.3

FLOODING CHARACTERISTICS

Type of packing : 1/2-in.plastic raschig-type rings.

a	f	af	F_c	$F_c + F_d$, liter/hr.		
cm.	p/m	cm/s	1/hr	1	2	3
2	22	0.73	12.6	20.4	20.2	20.2
	30	1.00	12.6	20.2	20.2	20.6
	44	1.47	12.6	22.4	21.4	21.6
	85.7	2.86	12.6	30.6	27.2	29.3
3	22	1.10	12.6	17.9	20.2	20.2
	30	1.50	12.6	19.0	19.2	20.2
	44	2.20	12.6	20.0	21.4	21.4
	85.7	4.29	12.6	28.4	27.0	27.8
4	22	1.47	12.6	16.6	16.6	17.8
	30	2.00	12.6	17.9	19.0	19.0
	44	2.93	12.6	18.8	19.0	19.0
	85.7	5.71	12.6	26.0	24.9	25.5

APPENDIX A.4

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.plastic raschig-type rings.

Extraction factor 14.22

F_c l/h	F_d l/h	af cm/s	a cm.	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	2.0	0.73	2	22	272.86	95.18	65.11	64.38
					279.20	101.53	63.64	
		1.00		30	266.51	69.81	73.81	71.43
					266.51	82.49	69.05	
		1.47		44	253.82	50.76	80.00	78.75
					253.82	57.11	77.50	
		2.86		85.7	241.13	38.07	84.21	85.70
					247.47	31.73	87.18	
12.6	2.0	1.10	3	22	247.47	57.11	76.92	79.49
					247.47	44.42	82.05	
		1.50		30	241.13	44.42	81.58	80.79
					253.82	50.76	80.00	
		2.20		44	222.09	31.73	85.71	83.58
					241.13	44.72	81.45	
		4.29		85.7	215.75	6.35	97.06	94.59
					241.13	19.04	92.11	
12.6	2.0	1.47	4	22	215.75	25.38	88.24	83.60
					241.13	50.76	78.95	
		2.00		30	215.75	31.73	85.29	83.44
					241.13	44.42	81.58	
		2.93		44	215.75	19.04	91.18	86.38
					241.13	44.42	81.58	
		5.71		85.7	203.06	6.35	96.88	95.66
					228.44	12.69	94.44	

APPENDIX A.5

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.plastic raschig-type rings.

Extraction factor 7.11

F_c l/h	F_d l/h	af cm/s	a cm	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	1.0	0.73	2	22	234.80	114.2	51.35	51.35
					234.80	114.2	51.35	
		1.00		30	234.80	107.9	54.05	54.05
					234.80	107.9	54.05	
		1.47		44	234.80	76.2	67.57	67.57
					234.80	76.2	67.57	
		2.86		85.7	234.80	69.8	70.27	73.24
					234.80	76.2	76.20	
12.6	1.0	1.10	3	22	241.10	88.8	63.17	63.01
					222.10	82.5	62.85	
		1.50		30	260.20	88.8	65.87	66.72
					234.80	76.1	67.57	
		2.20		44	272.90	76.2	72.10	73.38
					225.30	57.1	74.65	
		4.29		85.7	272.90	50.8	81.40	82.37
					228.40	38.1	83.33	
12.6	1.0	1.47	4	22	215.80	69.8	67.65	69.04
					225.3	66.6	70.43	
		2.00		30	231.60	57.1	75.43	76.86
					234.80	50.7	78.38	
		2.93		44	228.40	44.4	80.56	80.56
					228.40	44.4	80.56	
		5.71		85.7	228.40	38.1	83.33	84.72
					228.40	31.73	86.11	

APPENDIX A.6

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.plastic raschig-type rimgs.

Extraction factor 3.56

F_c 1/h	F_d 1/h	af cm/s	a cm	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	0.5	0.73	2	22	342.66	203.06	40.74	42.11
					291.89	164.98	43.48	
		1.00		30	342.66	171.33	50.00	54.17
					304.58	126.91	58.33	
		1.47		44	342.66	177.67	48.15	52.08
					317.28	139.60	56.00	
		2.86		85.7	336.31	171.33	49.06	49.53
					317.28	158.64	50.00	
12.6	0.5	1.10	3	22	342.66	177.67	48.15	48.12
					329.97	171.33	48.08	
		1.50		30	336.31	164.98	50.94	49.51
					329.97	171.33	48.08	
		2.20		44	336.31	171.33	49.06	48.57
					329.97	171.33	48.08	
		4.29		85.7	323.63	158.64	50.98	54.49
					317.28	133.26	58.00	
12.6	0.5	1.47	4	22	323.62	171.33	47.06	51.53
					317.28	139.60	56.00	
		2.00		30	323.62	164.98	49.02	50.51
					317.28	152.29	52.00	
		2.93		44	304.58	164.98	45.83	47.92
					317.28	158.64	50.00	
		5.71		85.7	310.93	126.91	59.18	56.77
					291.89	133.26	54.35	

APPENDIX A.7

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.stainless steel raschig-type rings.

Extraction factor 14.22

F_c l/h	F_d l/h	af cm/s	a cm	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	2.0	0.73	2	22	158.64	88.84	44.00	48.39
					228.44	107.87	52.78	
		1.00		30	152.29	76.15	50.00	49.29
					222.09	114.22	48.57	
		1.47		44	145,95	44.42	69.56	65.67
					215.75	82.49	61.77	
		2.86		85.7	139.60	38.07	72.73	69.70
					209.40	69.80	66.67	
12.6	2.0	1.10	3	22	139.60	50.76	63.64	64.64
					203.06	69.80	65.63	
		1.50		30	133.26	57.11	57.14	56.70
					203.06	88.84	56.25	
		2.20		44	126.91	38.07	70.00	66.82
					209.40	76.15	63.64	
		4.29		85.7	114.22	25.38	77.78	74.83
					203.06	57.11	71.88	
12.6	2.0	1.47	4	22	114.22	44.42	61.11	58.68
					203.06	88.84	56.25	
		2.00		30	95.18	31.73	66.67	62.37
					196.71	82.49	58.06	
		2.93		44	95.18	25.38	73.33	74.67
					158.64	38.07	76.00	
		5.71		85.7	76.15	12.69	83.33	80.95
					177.67	38.07	78.57	

APPENDIX A.8

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.stainless steel raschig-type rings.

Extraction factor 7.11

F_c 1/h	F_d 1/h	af cm/s	a cm	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	1.0	0.73	2	22	260.2	142.8	45.00	44.58
					203.1	114.2	43.75	
		1.00		30	253.8	133.3	47.50	49.56
					196.7	95.2	51.61	
		1.47		44	241.1	126.9	47.37	48.68
					203.1	101.5	50.00	
		2.86		85.7	244.3	88.8	63.64	61.82
					190.4	76.2	60.00	
12.6	1.0	1.10	3	22	241.1	120.6	50.00	49.14
					184.0	95.2	48.28	
		1.50		30	228.4	107.9	52.78	53.18
					177.7	[illegible]2.5	53.57	
		2.20		44	212.6	104.7	50.75	52.16
					177.7	82.5	53.57	
		4.29		85.7	209.4	82.5	60.61	62.71
					171.3	60.3	64.81	
12.6	1.0	1.47	4	22	209.4	92.0	56.06	56.88
					164.9	69.8	57.69	
		2.00		30	203.1	82.5	59.38	59.69
					158.6	63.5	60.00	
		2.93		44	196.7	82.5	58.06	59.43
					152.3	59.6	60.80	
		5.71		85.7	196.7	63.5	67.74	68.66
					146.0	44.4	69.57	

APPENDIX A.9

EFFICIENCY DETERMINATION

Type of packing : 1/2-in.stainless steel raschig-type rings

Extraction factor 3.56

F_c l/h	F_d l/h	af cm/s	a cm	f p/m	Y_{in} mg/l	Y_{out} mg/l	Eff. %	Eff. %aver.
12.6	0.5	0.73	2	22	368.00	266.50	27.58	26.56
					298.24	222.09	25.53	
		1.00		30	349.00	241.13	30.90	29.58
					291.89	209.40	28.26	
		1.47		44	355.00	215.75	39.28	34.42
					279.20	196.71	29.55	
		2.86		85.7	329.97	215.75	34.62	33.22
					279.20	190.37	31.82	
12.6	0.5	1.10	3	22	317.28	209.40	34.00	30.64
					279.20	203.06	27.27	
		1.50		30	310.93	215.75	30.61	30.42
					272.86	190.37	30.23	
		2.20		44	298.24	190.37	36.17	34.75
					266.51	177.67	33.33	
		4.29		85.7	285.55	158.64	44.44	42.95
					260.17	152.29	41.46	
12.6	0.5	1.47	4	22	279.20	177.67	36.36	31.61
					260.17	190.37	26.85	
		2.00		30	266.51	190.37	28.57	26.79
					253.82	190.37	25.00	
		2.93		44	260.17	177.67	31.71	30.86
					253.82	177.67	30.00	
		5.71		85.7	209.40	152.29	27.27	24.16
					241.13	190.37	21.05	

APPENDIX B

PROPERTIES OF CHEMICALS USED

The physical properties of chemicals used in water-iodine-carbon tetrachloride system are as follows:[32]

	Water	Carbon tetrachloride
Density, gm/cm^3	1.00	1.590
Viscosity, 20°C, cp	1.00	0.95
Refractive index @20°C	1.333	1.46
Surface tension (@20°C, dyne/cm.)	72.8	26.66
Interfacial tension (@20°C, dyne/cm.)	-	45.0
Solubility@20°C by weight	0.010(in CCl_4)	0.080(in H_2O)
Distribution Coefficient of I_2 for 20°C ± 2°C	89.6	

APPENDIX C

PREPARATION OF CHEMICALS USED

Preparation of the iodine solution

Preparation of an approximately 270 mg/l .
Weigh about 150 gm . of pure KI into a 2 liter beaker and dissolve in 1 liter of water. Add 40 gm . of pure I_2(flake) and stir occasionally until solution is complete. Dilute in 250 liter of water in a stainless steel storage tank.

Preparation of 0.1N Sodium thiosulfate

Heat 1 liter of distilled water to boil in a beaker covered with a watch glass. Boil for at least 5 minutes. Cool, add about 25 gm . of $Na_2S_2O_3.5H_2O$ and 0.1 gm . of Na_2CO_3. Stir until solution is complete, then transfer to a clear glass stoppered bottle. Store in the dark.

APPENDIX D

HYDROPHOBIC PROPERTIES OF THE PACKINGS

It was considered necessary to measure both the contact angles made by a solvent droplet on materials used in this work, in a water environment and also that made by a water droplet in a solvent environment.

Samples of the surfaces investigated were made 1-in. long and 1-in. wide for glass, 1-in. long and 1/2-in. wide for stainless steel and 1 1/2-in. long and 1/2-in. in diameter for plastic, contained in a 100 ml. beaker. These contact angles were measured by taking photographs and making observations.

The results of thosemeasurements are given in the table below. It is seen that plastic is more hydrophobic than stainless steel. The negative sign for $\cos\theta_1 - \cos\theta_2$ indicates that the surface is of a hydrophilic nature, being preferentially wetted by the water phase, whereas a positive value of $\cos\theta_1 - \cos\theta_2$ indicates that the surface is preferentially wetted by the solvent phase(hydrophobic nature).

	Water receding (θ_1, degrees)	Water advancing (θ_2, degrees)	$\cos\theta_1 - \cos\theta_2$
Glass......	136	20	-1.659
Plastic.....	14	150	1.836
Stainless steel..	32	129	1.477

APPENDIX E

NOMENCLATURE

a : Amplitude of pulsation (cm)

E_i : Axial dispersion coefficient for phase i

F_i : Volumetric flow rate of phase i (l/h)

HTU : Height of the transfer unit (ft)

L : Length of column (ft)

NTU : Number of transfer unit

V_i : Superficial velocity of phase i (cm/h)

V_k : Characteristic velocity ($\frac{V_d}{\phi} + \frac{V_c}{1-\phi} = V_k(1-\phi)$)

Y : Concentration of iodine in continuous phase (mg/l)

d : d_{43}, drop diameter, mean drop diameter,

$$\sum_i n_i d^4 / \sum_i n_i d_i^3$$

f : Frequency of pulsation (pulse/min)

m : Slope of equilibrium distribution curve

k : Mass transfer coefficient

y : Concentration phase y (gm/cm^3)

$\mathcal{E}$: Extraction factor (mF_d/F_c)

ϕ : Fraction dispersed phase hold-up

<u>Subscripts</u>

c : Continuous phase

d : Dispersed phase

f : Flooding

t : Toluene

w : Water

ow : Overall based on water phase

AUTOBIOGRAPHY

Wattana Opanonomata was born on February 15, 1956 in Nakorn Pathom, Thailand. He attended Prapathom Witayalai High School in Nakorn Pathom and graduated in 1973. He received his Bachelor of Science Degree in Chemical Engineering from Chulalongkorn University, Thailand, in April, 1977. Following the graduation, he worked at The Siam Kraft Paper Industry. At the same time he continued his Master's study at the same university. In June of 1978, the second year of his Master's study, he received the professor Dr. Boonrawd Binson Fellowship to study for a Master's Degree in Chemical Engineering at Chulalongkorn University. He was granted the degree in October of 1979. Now he works at Thailand Institute of Scientific and Technological Research in the Industrial Research Division, Bangkok, Thailand.