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APPENDICES

APPENDIX A

EUQIPMENT DATA AND STREAM INFORMATION

Table A.1 Equipment data

Unit operation	Properties	Size
Reactor	Volume (ft.^{3})	2458
	Diameter(ft.)	6.80
Ammonia Column (C1)	Diameter(ft.)	2.79
	Reflux drum area (ft.^{2})	578
	Reboiler area (ft.^{2})	753
	Total number Tray	12
	Tray number feed	6
Product Column (C2)	Diameter(ft.)	2.47
	Reflux drum area (ft.^{2})	716
	Reboiler area (ft.^{2})	158
	Total number Tray	22
	Tray number feed	10
DIPA recycle Column (C3)	Diameter(ft.)	4.26
	Reflux drum area (ft.^{2})	906
	Reboiler area (ft.^{2})	479
	Total number Tray	52
	Tray number feed	12
Vaporizer	Area (ft.^{2})	185
	Q (10^6 Btu/hr.)	1.16
Heater (HX1)	Area (ft.^{2})	11.5
	Q (10^6 Btu/hr.)	0.072
Cooler (HX2)	Area (ft.^{2})	532
	Q (10^6 Btu/hr.)	2.03

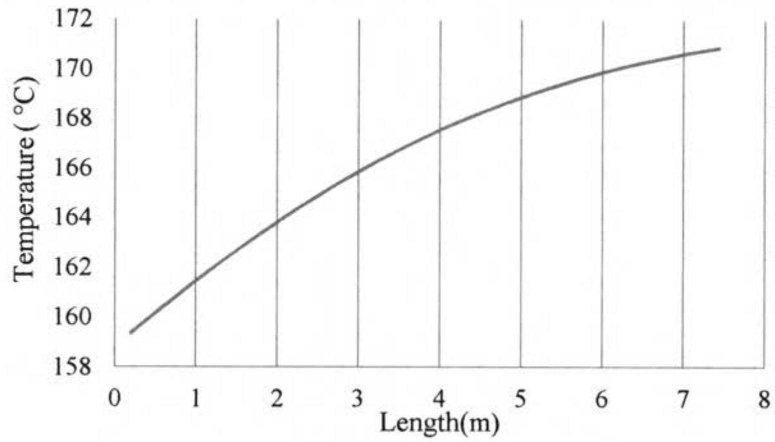
Table A.2 Flow summary for the monoisopropylamine process shown in Figure 4.2

Stream name	IPA fresh feed	NH_3 fresh feed	Total NH_3 flow	Top flow @ Vaporizer	R_{in}	R_{out}	Gas Recycle flow	F1	D1
Temperature (°C)	60	60	60	153.8	158.3	174.3	60	60	60
Pressure (psia)	400	400	400	475	475	450	335	335	300
Vapor fraction	0	0	0	1	1	1	1	0	0
Molar flow (kgmole/hr.)	45.36	45.31	90.76	272.9	272.9	272.9	15.71	202.6	90.76
Composition mole fraction									
Isopropanol	1.000	0.000	0.000	0.169	0.169	0.049	0.001	0.017	0.000
Ammonia	0.000	1.000	0.999	0.538	0.538	0.404	0.458	0.440	0.999
Di-isopropylamine	0.000	0.000	0.000	0.249	0.249	0.235	0.005	0.106	0.000
Water	0.000	0.000	0.000	0.003	0.003	0.122	0.002	0.198	0.000
Hydrogen	0.000	0.000	0.00000	0.039	0.039	0.039	0.516	0.000	0.000

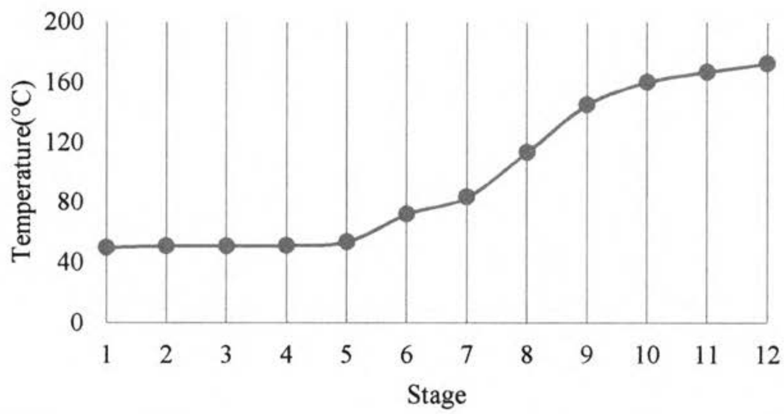
Table A.2 (Continued) Flow summary for the monoisopropylamine process shown in Figure 4.2

Stream name	Vent flow	B1	F2	B2	D2	F3	D3	B3
Temperature (°C)	60	179.8	173.7	124.5	62.5	102.8	43.4	97.1
Pressure (psia)	300	358	318	77	30	37	5	10.25
Vapor fraction	1	0	0	0	0	0.1206	0	0.0000
Molar flow (kgmole/hr.)	3.72	109.32	109.32	61.51	45.30	61.51	17.92	45.40
Composition mole fraction								
Isopropanol	0.000	0.030	0.030	0.044	0.000	0.044	0.012	0.000
Ammonia	0.950	0.001	0.001	0.000	0.001	0.000	0.000	0.000
Mono-isopropylamine	0.000	0.426	0.426	0.170	0.999	0.170	0.003	0.000
Di-isopropylamine	0.000	0.189	0.189	0.274	0.000	0.274	0.974	0.001
Water	0.000	0.353	0.353	0.512	0.000	0.512	0.010	0.999
Hydrogen	0.050	0.000	0.000	0.0000	0.000	0.000	0.000	0.000

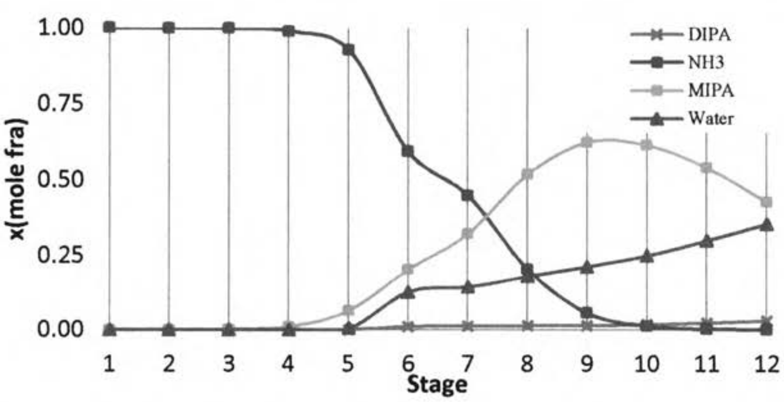
Table A.3 Show the temperature profile and composition profile



(a) Temperature profile in the reactor

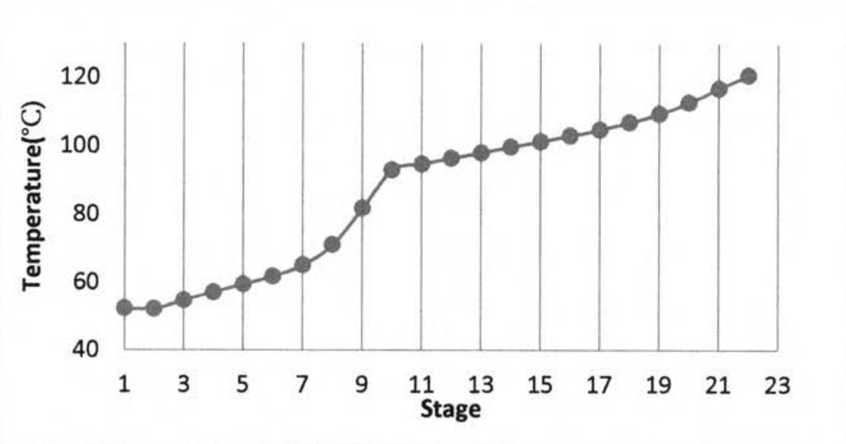


(b)Temperature profile in the C1

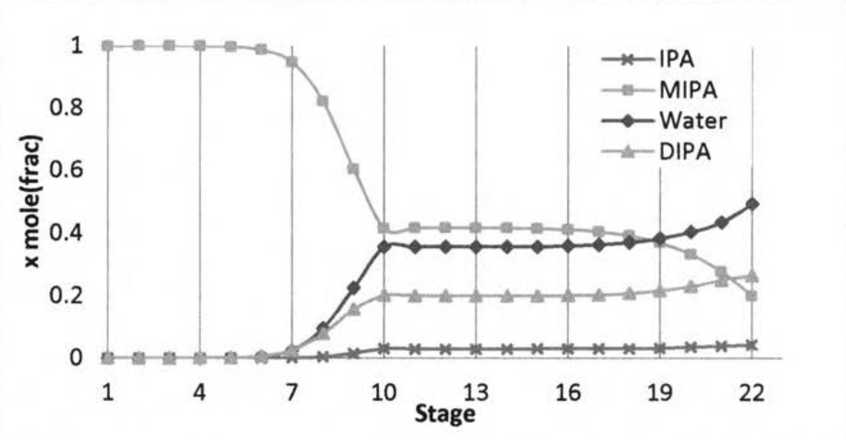


(c) Composition profile in the C1

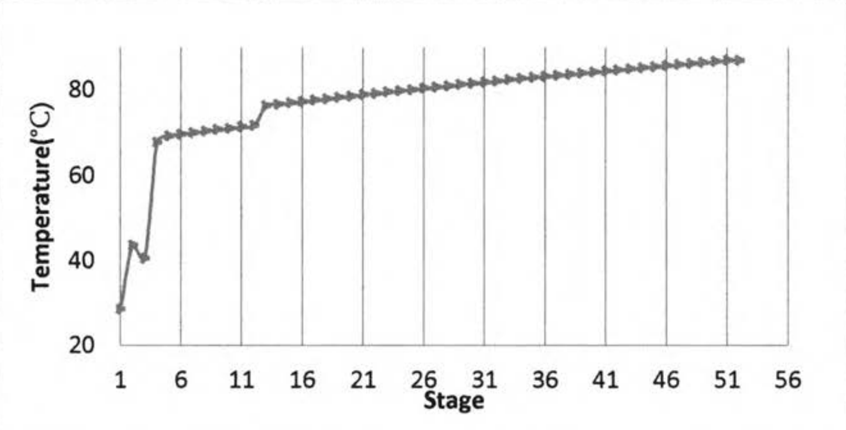
Table A.3 (continuous) Show the temperature profile and composition profile



(d) Temperature profile in the C2



(e) Composition profile in the C2



(f) Temperature profile in the C3

APPENDIX B

TUNING PARAMETER OF CONTROL STRUCTURES

The relay-feedback testing is a simple method to find the dynamic parameters. The results of the test are the ultimate gain and the ultimate frequency. This information is sufficient to calculate tuning parameters of controllers as shown in Table B.1.

Table B.1 Tyreus-Luyben rule Controller type Tuning parameters

Controller type	Tuning parameters		
	Kc	τi	τd
PI	0.31Kcu	2.2Pu	-
PID	0.45Kcu	2.2Pu	Pu/6.3

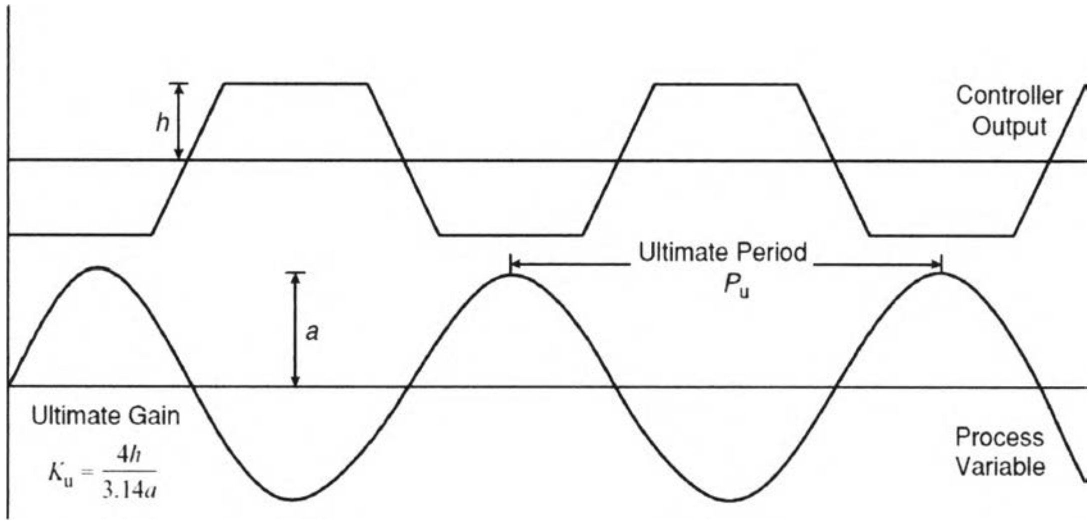


Figure B.1 Show Tuning parametuers.

Table B.1 Type of controllers and tuning parameters of Base case

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Total ammonia feed	FC	Ammonia /IPA ratio flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
IPA fresh feed	FC	Flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
Vaporizer	LC	Level	Duty flow rate	P	Direct	2	-	-
Heater (HX1)	TC	Temperature outlet	Heat duty	PID	Reverse	14.5	1.58	0.351
Cooler (HX2)	TC	Temperature outlet	Heat duty	PID	Reverse	1.90	2.56	0.570
Flash tank	PC	Pressure	Compressor work	PI	Reverse	0.2254	17.3	-
	TC	Level	Bottom flow rate	P	Direct		-	-
Ammonia column (C1)	TC	Temperature average (tray 7,8,9)	Reboiler duty	PID	Reverse	1.80	9.20	2.40
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	17.1	0.519	-

Table B.1 (continue) Type of controllers and tuning parameters of Base case

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Product column (C2)	TC	Temperature tray 9	Reboiler duty	PID	Reverse	1.08	8.95	1.99
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	6.24	0.194	-
DIPA recycle column (C1)	TC	Temperature tray 5	Reboiler duty	PID	Reverse	4.94	11.4	0.253
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	4.30	0.095	-

Table B.2 Type of controllers and tuning parameters of CS1

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Total ammonia feed	FC	Ammonia /IPA ratio flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
IPA fresh feed	FC	Flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
Vaporizer	LC	Level	Duty flow rate	P	Direct	2	-	-
Heater (HX1)	TC	Temperature outlet	Heat duty	PID	Reverse	14.0	1.70	0.379
Cooler (HX2)	TC	Temperature outlet	Heat duty	PID	Reverse	1.36	3.12	0.693
Flash tank	PC	Pressure	Compressor work	PI	Reverse	1.12	3.02	-
	TC	Level	Bottom flow rate	P	Direct	2		
Ammonia column (C1)	TC	Temperature average (tray 7,8,9)	Reboiler duty	PID	Reverse	1.5	7.42	1.65
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	2	10	-

Table B.2 (continue) Type of controllers and tuning parameters of CS1

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Product column (C2)	TC	Temperature tray 9 (set point from CC MIPA)	Reboiler duty	PID	Reverse	1.32	13.8	0.125
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	2	10	-
DIPA recycle column (C3)	TC	Temperature tray 5	Reboiler duty	PID	Reverse	2.37	8.93	0.023
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	4.30	0.095	-

Table B.3 Type of controllers and tuning parameters of CS2

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Total ammonia feed	FC	Ammonia /IPA ratio flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
IPA fresh feed	FC	Flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
Vaporizer	LC	Level	Duty flow rate	P	Direct	2	-	-
Heater (HX1)	TC	Temperature outlet	Heat duty	PID	Reverse	14.2	1.52	0.382
Cooler (HX2)	TC	Temperature outlet	Heat duty	PID	Reverse	1.20	3.37	0.749
Flash tank	PC	Pressure	Compressor work	PI	Reverse	2	10	-
	TC	Level	Bottom flow rate	P	Direct	2	-	-
Ammonia column (C1)	TC	Temperature average (tray 7,8,9)	Reboiler duty	PID	Reverse	1.47	8.20	4.65
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	2	10	-

Table B.3 (continue) Type of controllers and tuning parameters of CS2

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Product column (C2)	TC	Temperature tray 9	Reboiler duty	PID	Reverse	1.32	13.8	0.125
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	2	10	-
DIPA recycle column (C3)	TC	Temperature tray 5	Reboiler duty	PID	Reverse	2.37	8.93	0.023
	CC	Composition DIPA	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	4.30	0.095	-

Table B.4 Type of controllers and tuning parameters of CS3

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_i	τ_d
Total ammonia feed	FC	Ammonia /IPA ratio flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
IPA fresh feed	FC	Flow rate	Feed flow rate	PI	Reverse	0.5	0.3	-
Vaporizer	LC	Level	Duty flow rate	P	Direct	2	-	-
Heater (HX1)	TC	Temperature outlet	Heat duty	PID	Reverse	9.61	2.24	0.499
Cooler (HX2)	TC	Temperature outlet	Heat duty	PID	Reverse	1.80	3.887	0.197
Flash tank	PC	Pressure	Compressor work	PI	Reverse	2	10	-
	TC	Level	Bottom flow rate	P	Direct	2	-	-
Ammonia column (C1)	TC	Temperature average (tray 7,8,9)	Reboiler duty	PID	Reverse	1.53	7.37	1.64
	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	2	10	-

Table B.4 (continue) Type of controllers and tuning parameters of CS3

Equipment	Controller	Controlled Variable	Manipulate Variable	Type	Action	Tuning parameters		
						K_c	τ_I	τ_d
Product column	TC	Temperature tray 9	Reboiler duty	PID	Reverse	1.32	13.2	0.856
(C2)	FC	Reflux/feed ratio	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	6.96	0.191	-
DIPA recycle	TC	Temperature tray 5	Reboiler duty	PID	Reverse	4.94	11.4	0.469
column (C3)	CC	Composition DIPA	Reflux flow rate	PI	Reverse	0.5	0.3	-
	LC	Reboiler level	Bottom flow rate	P	Direct	2	-	-
	LC	Reflux drum level	Distillate floe rate	P	Direct	2	-	-
	PC	Top column	Condenser duty	PI	Reverse	4.30	0.095	-
Heat exchanger By-pass	FC	Temperature outlet	By-pass flow rate	PI	Direct	0.008	0.25	

VITAE

Miss Chanisa Chumna was born in Nakhon Si Thammarat, Thailand on September 18, 1987. She received the Bachelor Degree of Science, field of Chemical and process engineering from Walailak University in 2009. After that she entered the Graduate School of Chulalongkron University to pursue the Master of Engineering in Chemical Engineering and completed in 2012.