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APPENDIX A

PHYSICAL AND CHEMICAL PROPERTIES FOR CALCULATION OF HYDROCHLORIC VAPOR ABSORPTION.

A.1 Hydrochloric-Water Gas Mixture Viscosity Estimation

From gas mixture viscosity estimation method by Herning and Zipperer(11), gas mixture viscosity can be estimated by this equation

$$\mu_V = \frac{\sum y_i \mu_i (M_i)^{0.5}}{\sum y_i (M_i)^{0.5}} \qquad \text{(A-1)}$$

Where μ_V = gas mixture viscosity

μ_i = gas component viscosity

M_i = Molecular weight of component i

For hydrochloric - water gas mixture, Eq (A-1) can be written as;

$$\mu_V = \frac{y_{HCl}\mu_{HCl}(M_{HCl})^{0.5} + y_{H2O}\mu_{H2O}(M_{H2O})^{0.5}}{y_{HCl}(M_{HCl})^{0.5} + y_{H2O}(M_{H2O})^{0.5}} \qquad \text{(A-2)}$$

M_{HCl} = 36.5

M_{H2O} = 18

Hydrochloric and water gas absolute viscosity are a function of temperature is concluded in table A.1.

Table A.1 Gas viscosity in packed absorber operating temperature range*

Temperature range (^{o}C)	viscosity ($\mu \times 10^{7}$), (poise)	
	HCl	H_2O
20 - 25	1,425	980
26 - 30	1,450	990
31 - 35	1,500	1,000
36 - 40	1,510	1,025
41 - 45	1,520	1,050
46 - 50	1,540	1,060
51 - 55	1,550	1,070

* From Perry," Chemical Engineers Handbook." ,6nd edition ,1984 ,page 3-250

A.2 Hydrochloric-Water Gas Mixture(in packed absorber of storage tank) Density Estimation

By assumption that hydrochloric - water gas mixture behavior is ideal gas mixture. Gas mixture density can be estimated by following equations;

$$P \quad = \quad p_{HCl} + p_{H2O} \quad = \quad yP + wP \tag{A-3}$$

from ideal gas law $\quad PV = RT$

$$= \frac{RT}{PM}$$

where R = universal gas constant = 0.082 m^3 . atm $kgmol^{-1}$ K^{-1}

V = specific volume of gas mixture (m^3/kgmol)

M = gas molecular weight, for hydrochloric = 36.5, water = 18

T = gas temperature, (K)

$$P = \frac{RT}{MV}$$

$$= \frac{RT}{M}\left(\frac{1}{y_{HCl}P + y_{H_2O}P}\right) \tag{A-4}$$

Gas phase density $\rho_v = \dfrac{1}{V}$

$$\rho = \frac{M}{RT}\left(y_{HCl}P + y_{H_2O}P\right)$$

M = gas mixture molecular weight = $M_{HCl}y = M_{H2O}w$

$$\rho_v = \frac{1}{RT}\left(M_{HCl}y + M_{H_2O}w\right)\left(yP + wP\right) = \frac{P}{RT}\left(M_{HCl}y + M_{H_2O}w\right) \tag{A-5}$$

By assumption that gas pressure is constant along packed tower height, the pressure for gas density estimation is equal atmospheric pressure = 1 atm

2.3.3 Gases Diffusion Coefficients (D_v)

For atmospheric pressures up to about 10 atm, the diffusion coefficient for a binary mixture of gases A and B may be estimated from the Fuller, Schettler, and Giddings relation (5).

$$D_v = 10^{-3} T^{1.75} \frac{\left(\frac{M_A + M_B}{M_A M_B}\right)^{1/2}}{P\left[\left(\sum v\right)_A^{1/3} + \left(\sum v\right)_B^{1/3}\right]^2} \quad \text{(A-6)}$$

where

T is in kelvins, P is in atmosphere, and D_v = is in cm^2/s. M_A and M_B are the molecular weights of gas A and B. To determine Σv the values of the atomic diffusion volumes is shown in table A.2 should be used. These values were determined by a regression analysis of 340 experimental diffusion-coefficient values of 153 binary systems.

Table A.2 Atomic Diffusion Volumes for Use in Estimating D_v by the Method of Fuller, Schettler , and Giddings*

Atomic and structural diffusion-volume increments ,v			
C	16.5	(Cl)	19.5
H	1.98	(S)	17.0
O	5.48	Aromatic ring	-20.2
(N)	5.69	Heterocyclic ring	-20.2

Diffusion Volumes for simple molecules Σv

H_2	7.07		
D_2	6.70	CO_2	26.9
He	2.88	N_2O	35.9
N_2	17.9	NH_3	14.9
O_2	16.6	H_2O	12.7
Air	20.1	(CCl_2F_2)	114.8

Ar	16.1	(SF_6)	69.7
Kr	22.8	(Cl_2)	37.7
(Xe)	37.9	(Br_2)	67.2
CO	18.9	(SO_2)	41.1

*Parentheses indicate that the value listed in based on only a few data points.

In this work is assumed that pressure pressure is average pressure along packed absorber is equal atmosphere pressure.

A.3.1 Diffusion Coefficient of Hydrochloric in Water Vapor ($D_{HCl-H2O}$)

Diffusion coefficient of hydrochloric in water vapor or water in hydrochloric vapor can be calculated by substitute related required value into equation (A-6).

$$D_{HCl-H2O} = 10^{-3}T^{1.75}\frac{\left(\frac{36.5+18}{36.5x18}\right)^{1/2}}{P\left[(21.48)^{1/3}+(12.7)^{1/3}\right]^2} \quad cm^2/s$$

$$= 1.101747733x10^{-5}\frac{T^{1.75}}{P} \quad cm^2/s$$

$$= 1.101747733x10^{-9}\frac{T^{1.75}}{P} \quad m^2/s \qquad \text{(A-7)}$$

Where T = Average gas phase temperature in packed tower

= (inlet gas temperature + outlet gas temperature)/2

P = Packed tower pressure assumed that equal atmosphere pressure = 1 atm

*Data from Perry Chemical Engineers Handbook, 6nd edition, 1984, page 3-285

A.4 Hydrochloric Acid Vapor Pressure Estimation

Gas phase vapor pressure in hydrochloric acid storage tank is the sum of hydrochloric vapor pressure and water vapor pressure which can be calculated by correlated equations (5).

$$\log_{10} p_{HCl} = A + (B/T) \quad \text{(A-8)}$$

and

$$\log_{10} p_{H2O} = A + (B/T)$$

$$P = p_{HCl} + p_{H2O} \quad \text{(A-9)}$$

A,B are constant of individual acid concentration, T is temperature (273.16 + acid temperature (°C), p_{HCl} is partial pressure of hydrochloric over aqueous solution of hydrochloric (mmHg), p_{H2O} is partial pressure of water over aqueous solution of hydrochloric (mmHg) and P is vapor pressure of solution

Table A.3 A,B, constant or equation (A-10)*

For hydrochloric vapor

%HCl	A	B
2	11.6037	4736
4	11.0000	4471
6	11.2144	4202
8	11.0406	4042
10	10.9311	3908
12	10.7900	3765
14	10.6954	3636
16	10.6251	3516
18	10.4957	3376
20	10.3833	3245
22	10.3172	3125
24	10.3165	2999
26	10.1303	2870
28	10.0115	2732
30	9.8763	2593
32	9.7523	2457
34	9.6061	2316
36	9.5262	2229
38	9.4670	2094
40	9.2156	1939
42	8.9925	1800
44	8.8621	1681

For water vapor

%HCl	A	B
6	8.99156	2282
10	8.99664	2295
14	3.97075	2300
16	8.98014	2323
20	8.92877	2334
22	9.02208	2363
24	8.96022	2356
26	9.01511	2390
28	8.97611	2395
30	9.80117	2422
32	9.03317	2433
34	9.07143	2487
36	9.11815	2626
38	9.20283	2579
40	9.33923	2647
42	9.44953	2709

*From Perry Chemical Engineers Handbook 6nd edition 1984 page 3-64,

A.5 Gas Phase Heat Capacity.

Gas phase is mixture of hydrochloric vapor and water vapor, gas phase heat capacity can be estimated by assumption that gas mixture properties is ideal gas.

Heat capacity at constant pressure of pure hydrochloric (5) gas is related with temperature as is described by equation.

$$Cp_G = 6.70 + 0.00084\ T \text{ (kcal/kg-mol K)} \qquad \text{(A-10)}$$

and heat capacity at constant of pure water (5) gas is related with temperature as is described by equation.

$$Cp_G = 8.22 + 0.00015\ T + 0.00000134\ T^2 \text{ (kcal/kg-mol K)} \qquad \text{(A-11)}$$

For ideal hydrochloric - water gas mixture heat capacity is

$$Cp_G = y(6.7+0.000084\ T) + w(8.22+0.00015\ t + 0.00000134\ T^2) \text{ (kcal/kg-mol K)} \qquad \text{(A-12)}$$

A.6 Water Surface Tension

Water surface tension which is required as one variable in mass transfer coefficient estimation equation (2-45) is a function of water temperature (5) as is described by equation 2-62.

$$\sigma = 0.1232\ (1-0.00146T) \quad \text{(N/m)} \qquad \text{(A-13)}$$

where T = Liquid temperature ($^{\circ}$K)

σ = Surface tension of water (N/m)

A.7 Hydrochloric Acid Specific Heat Capacity.

Due to data of specific heat capacity for hydrochloric acid is not available for all acid concentration as are shown in Table A.4. Specific heat capacity for each concentration of hydrochloric acid is estimated by assumption that specific heat capacity was a function of concentration.

Table A.4 specific heat of hydrochloric acid*

Mole	Specific heat, cal./g. °C.				
%HCl	0 °C	10 °C	20 °C	40 °C	60 °C
0.0	1.00				
9.09	0.72	0.72	0.74	0.75	0.78
16.7	0.61	0.605	0.631	0.645	0.67
20.0	0.58	0.575	0.591	0.615	0.638
25.9	0.55	....	....	....	....

Figure (A.1) is a graph which plotted from data in table A.5 at average value at temperature 30 °C for correctly prediction for relation of acid concentration and specific heat.

Result from graph are described by equation

$$c_{P,L} = 0.0007x^2 - 0.0342x + 0.9991 \quad \text{(cal./g.C)}$$

$$= (0.0007x^2 - 0.0342x + 0.9991) \,.\, (4.18) \,.\, (18) \quad \text{(KJ/kmol k)} \quad \text{(A-15)}$$

where

$c_{P,L}$ = Specific heat capacity (cal./g.C)

*Data from Perry Chemical Engineers Handbook, 6nd edition, 1984, page 3-145

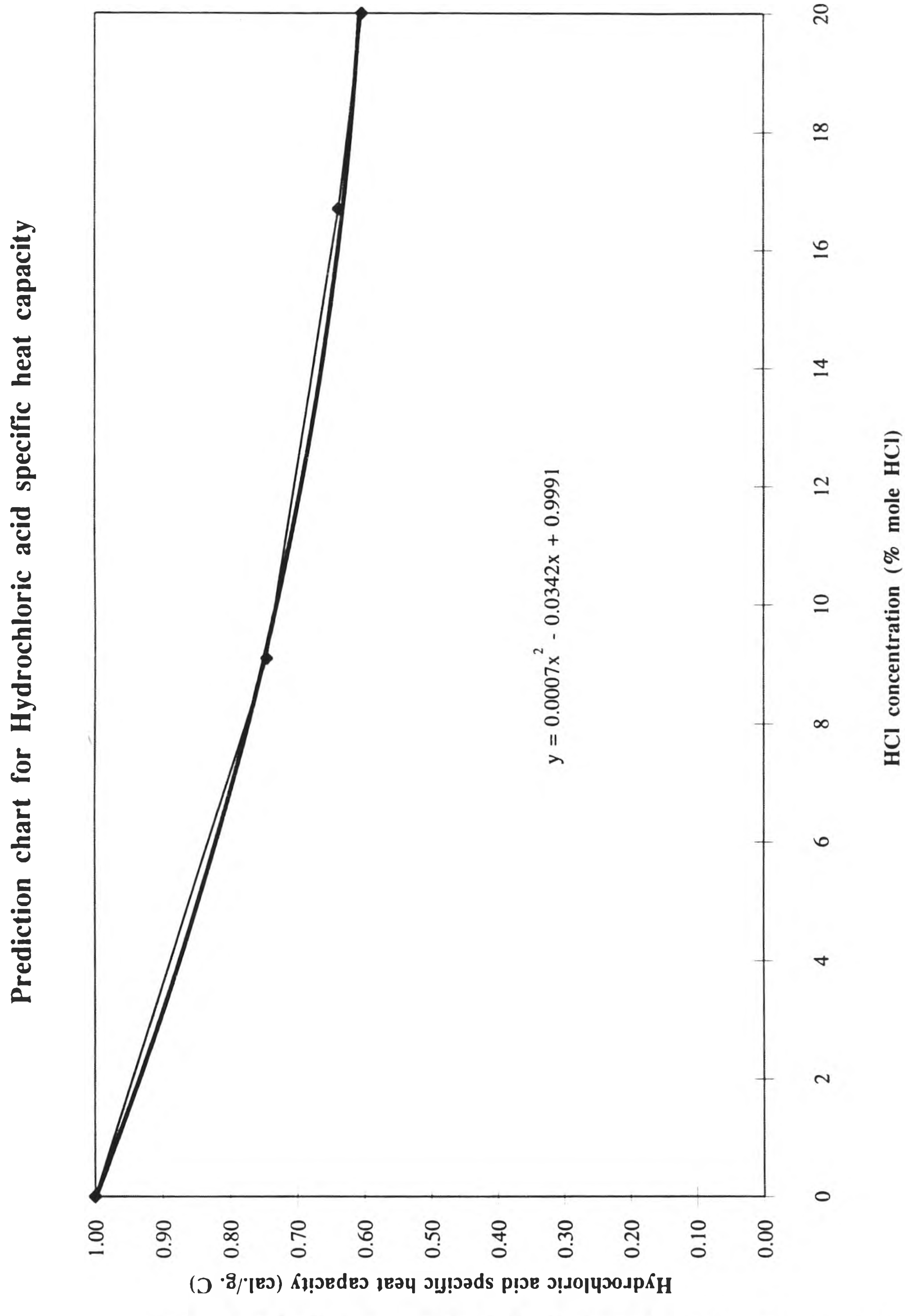


Figure A.1 Prediction chart for hydrochloric acid specific heat capacity.

A.8 Specific Heat of Hydrochloric Dilution in Water.

Heat effect from hydrochloric vapor dilution in water can be calculated by equation (2-18) which use heat of dilution; λ_A data (5). For hydrochloric dilution in water

$$\lambda_A = 7.96 \text{ kcal/g mol} = 75{,}194.928 \text{ kJ/kg mol}$$

A.9 Specific Heat of Water Vaporization.

Specific heat of water vaporization for calculate heat effect of water vaporized to gas phase is assumed constant along packed column by using data at water temperature = 30 °C(5).

specific heat of vaporization (λ_w)	=	9,729	(cal/mol)
	=	40,733.372	(kJ/kg mol)

A.10 Specific Heat of Hydrochloric Vaporization.

Specific heat of hydrochloric vaporization for calculate heat effect of hydrochloric vaporized to gas phase was specific heat of vaporization (λy) = 3860 (cal/mol)

= 16161.05 (kj/kgmol)

A.11 Specific Water Heat Capacity.

Specific water heat capacity is assumed that constant along packed column at water temperature = 30 ^{o}C (5).

specific water heat of vaporization (λ_w)	=	4.18	(kJ/kg K)
	=	75.24	(kJ/kg mol K)

A.12 Water Viscosity.

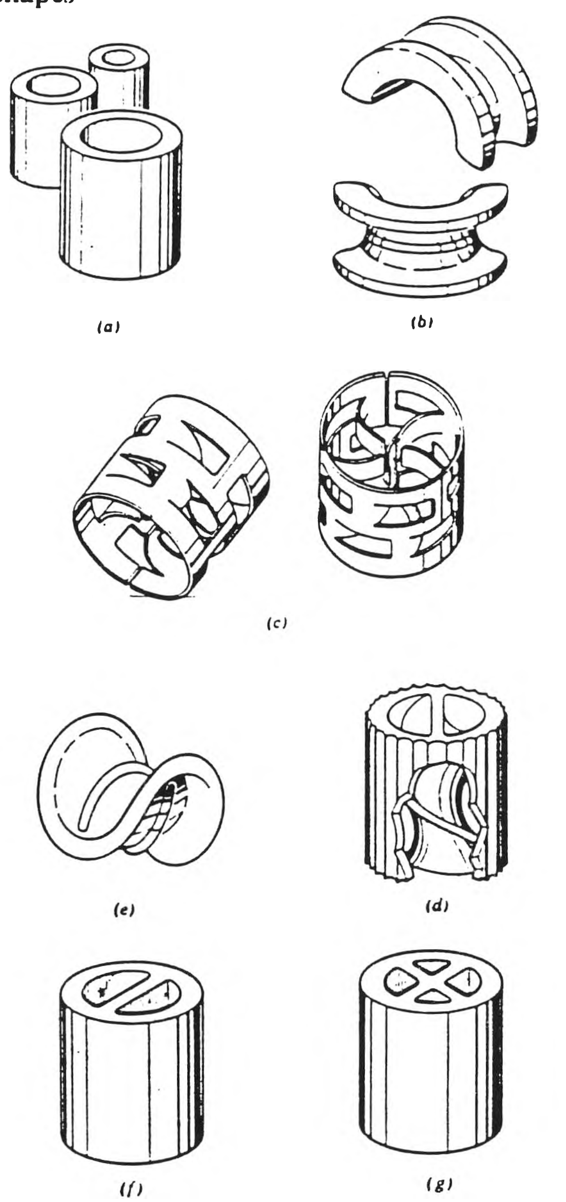
Water viscosity data required for equation (2-46) is assumed that constant at

$$\mu_L = 1\ cP = 0.001 \text{ (kg/ms)}$$

APPENDIX B

Properties of packings

Common packing shapes



(*a*) Rashig rings. (*b*) Intalox saddle. (*c*) Pall rings. (*d*) Cyclohelix spiral ring. (*e*) Berl saddle. (*f*) Lessing ring. (*g*) Cross-partition ring.

Figure B.1 Common packing shapes. (From Alan S. Foust, "Principles of unit operation", second edition, John Wiley & Sons Inc, 1979, page 386)

Table B.1 Critical surface tension of packing materials

	σ_c, dynes/cm
Carbon	65
Ceramic	61
Glass	73
Paraffin	20
Polyethylene	33
Polyvinyl chloride	40
Steel	75

*Data from Alan S. Foust, "Principles of unit operation", 2nd edition, John Wiley & Sons Inc, 1979, page 399.

Table B.2 Physical Characteristics of Dry Commercial Packings. (Data to be used for guide purpose only. Manufacturers should be contacted for exact data.)

Packing	Size (inches)	Specific Surface (a_v) (m^2/m^3)
Ceramic Raschig rings		
	0.25	787
	0.5	364
	1	190
	2	92
Berl saddles		
	0.25	899
	0.5	466
	1	249
	2	105
Pall rings (polypropylene)		
	0.625	341
	1	207
	1.5	128
	2	102
	3.5	92
Cyclohelix and single spiral		
	3.25	131
	4	105
	6	69
Heilex (polypropylene)		
	2	98
	3	75
Intalox saddle (polypropylene)		
	1	207
	2	108
	3	92
Tellerettes		
(1/13/16 in. OD x 3/4 in. H)	1	180
(2-3/4 in. OD x 1 in. H)	2	125
(3-3/4 in. OD x 1-1/2 in. H)	3	98

APPENDIX C.

PROGRAM USING GUIDE

Program using guide.

Computer program for design packed absorber for hydrochloric vapor is DOS platform program, file name was PACKED.EXE, user can be used program by following steps;

1. Set operating system in DOS mode (C:\ prompt).
2. Change directory to A:\ directory.
3. Insert diskette which consists program PACKED.EXE into disk drive A.
4. Type PACKED at A:\ prompt to execute program.
5. Program PACKED is executed, monitor display two title menu to describe program name and program owner as are shown in Figure C.1 and C.2
6. Monitor display main menu for choose one from five selections as is shown in Figure C.3.
7. Choose selection in main menu by use Up and Down arrow button and press Enter button to select required item.
8. Monitor display program required input data which consist packed absorber data, storage tank data, inlet water data, packing data, solar radiation, absorptivity, size of storage tank and another required data which are depend on type of selection as diameter of absorber in case of packed absorber design with fixed diameter.

Related input data as properties of packings are available in Appendix B. All required data are shown in following row which has input type cell to fill data into program as are shown in Figures C.4 to C.8

9. Fill each data by press Tab button after type data into each cell.
10. After all required input data are entered to program as shown in Figure C.9. Printer (dot metrix type) is connected with computer port and press Enter button to calculate and show and press Enter again to print calculation results. After result is printed program will return to main menu.
11. Press Esc button to exit program.

```
PACKED ABSORBER FOR HYDROCHLORIC ACID STORAGE TANK
                 Pinit reargmuang
                  (Wait a minute)
```

Figure C.1 Menu of program name

PRODUCTION SECTION
SIAM OCCIDENTAL ELECTROCHEMICAL CO.,LTD.
403 Bangpu Industrial Estate
Ampheo Muang, Samutprakan 10280.
Tel.(662)323-9980
(Wait a minute)

Figure C.2 Menu of program owner

```
Siam Occidental Electrochemical Co., Ltd.



                    PLEASE SELECT YOUR SELECTION.
A) Packed absorber design(sizing).
B) Packed absorber design(sizing) with specified water flow rate.
C) Packed absorber design(sizing) with specified absorber diameter.
D) Packed absorber simulation(without inlet gas data).
E) Packed absorber simulation(with inlet gas data).



 [Up, Dn Arrow] moves field., [Enter] selects item., [Esc] exits.
```

Figure C.3 Menu of main program menu

```
                  Siam Occidental Electrochemical Co., Ltd.

                 Packed Absorber for HCl acid storage tank
                               Custom Name :
                          Storge tank Type :
                   Storge tank Volume (m3) :
               Total tank surface area(m2) :
                     Storage tank material :
                      Type of tank surface :
          Absorptivity for solar radiation :
           Absorptivity for tank radiation :
       HCl acid concentration(% by wt.) :
                 HCl acid temperature (C) :
                              Packing type :
                     Packing size (inches) :
                          Packing material :
    Packing surface tension(dyne/cm) :
      Packing specific surface (m2/m3) :
            Inlet water temperature (C) :
                    Limit liquid outlet pH :
             Surrounding temperature (C) :
           Solar radiation to tank (W/m2) :

        [Tab] moves field., [Enter] show results., [Esc] exits.
```

Figure C.4 Menu of packed absorber design program case A

```
                Siam Occidental Electrochemical Co., Ltd.

               Packed Absorber for HCl acid storage tank
                       Custom Name :
              Storge tank Volume (m3) :
          Total tank surface area(m2) :
                 Type of tank surface :
   Absorptivity for solar radiation :
    Absorptivity for tank radiation :
   HCl acid concentration(% by wt.) :
           HCl acid temperature (C) :
                         Packing type :
                Packing size (inches) :
                     Packing material :
   Packing surface tension(dyne/cm) :
   Packing specific surface (m2/m3) :
         Inlet water temperature (C) :
         Inlet water flowrate (m3/h) :
         Surrounding temperature (C) :
     Solar radiation to tank (W/m2)  :


     [Tab] moves field., [Enter] show results., [Esc] exits.
```

Figure C.5 Menu of packed absorber design program case B

```
                 Siam Occidental Electrochemical Co., Ltd.

                Packed Absorber for HCl acid storage tank
                                Custom Name :
                     Storge tank Volume (m3) :
                 Total tank surface area(m2) :
                       Storage tank material :
                        Type of tank surface :
              Absorptivity for solar radiation :
               Absorptivity for tank radiation :
              HCl acid concentration(% by wt.) :
                   HCl acid temperature (C) :
                                Packing type :
                       Packing size (inches) :
                            Packing material :
            Packing surface tension(dyne/cm) :
            Packing specific surface (m2/m3) :
                 Inlet water temperature (C) :
                       Limit liquid outlet pH :
                 Surrounding temperature (C) :
               Solar radiation to tank (W/m2) :
                 Packed column diameter (m) :

          [Tab] moves field., [Enter] show results., [Esc] exits.
```

Figure C.6 Menu of packed absorber design program case C

```
             Siam Occidental Electrochemical Co., Ltd.

              Packed Absorber for HCl acid storage tank
            Packed absorber name :
        Packed column height (m) :
      Packed column diameter (m) :
         Storge tank Volume (m3) :
     Total tank surface area(m2) :
            Type of tank surface :
Absorptivity for solar radiation :
 Absorptivity for tank radiation :
HCl acid concentration(% by wt.) :
        HCl acid temperature (C) :
                    Packing type :
           Packing size (inches) :
                Packing material :
Packing surface tension(dyne/cm) :
Packing specific surface (m2/m3) :
      Inlet water temperature (C) :
      Inlet water flowrate (m3/h) :
      Surrounding temperature (C) :
  Solar radiation to tank (W/m2)  :

       [Tab] moves field., [Enter] show results., [Esc] exits.
```

Figure C.7 Menu of packed absorber design program case D

Siam Occidental Electrochemical Co., Ltd.

Packed Absorber for HCl acid storage tank

Packed absorber name
Packed column height (m)
Packed column diameter (m)
Inlet gas phase flowrate (Nm3/hr)
Inlet gas phase temperature (C)
Inlet gas phase density (kg/m3)
Inlet gas phase viscosity (kg/m s)
Inlet gas HCl mole fraction
Inlet gas H2O mole fraction
Packing type
Packing size(inches)
Packing material
Packing surface tention(dyne/cm)
Packing specific surface(m2/m3)
Inlet water temperature (C)
Inlet water flow rate(m3/hr)

[Tab] moves field., [Enter] show results., [Esc] exits.

Figure C.8 Menu of packed absorber design program case E

```
                Siam Occidental Electrochemical Co., Ltd.

               Packed Absorber for HCl acid storage tank
                          Custom Name : Siam Oxy
              Storge tank Volume (m3) : 6
          Total tank surface area(m2) : 16
                Storage tank material : PVC/FRP
                 Type of tank surface : White paint
     Absorptivity for solar radiation : 0.1
      Absorptivity for tank radiation : 0.9
    HCl acid concentration(% by wt.) : 35
            HCl acid temperature (C) : 43.3
                        Packing type : Pall rings
               Packing size (inches) : 0.625
                    Packing material : Polypropylene
    Packing surface tension(dyne/cm) : 33
    Packing specific surface (m2/m3) : 341
          Inlet water temperature (C) : 30
               Limit liquid outlet pH : 1.5
          Surrounding temperature (C) : 35
        Solar radiation to tank (W/m2) : 800
            Packed column diameter (m) : 0.204

         [Tab] moves field., [Enter] show results., [Esc] exits.
```

Figure C.9 Menu of example of program input data

APPENDIX D

PROGRAM SIMULATED RESULTS

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed Absorber for Hydrochloric acid Storage tank

Input data

Customer Name	: Siam Oxy
Tank material	: PVC/FRP
Tank volume (m3)	: 6
Total tank surface area(m2)	: 16
Type of tank surface	: White paint
Absorptivity for solar radiation	: 0.1
Absorptivity for tank radiation	: 0.9
HCl acid concentration (percent by wt.)	: 35
HCl acid temperature (C)	: 43.3
Packing type	: Pall rings
Packing material	: Polypropylene
Packing size(inches)	: 0.625
Packing surface tension(dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet water temperature (C)	: 30
Surrounding temperature (C)	: 35
Solar radiation to tank (W/m2)	: 800
Packed column diameter (m)	: 0.204

Calculation result

Packed column height (m)	: 1.48
Inlet Water flow rate (m3/h)	: 2.64
Outlet Water pH	: 1.50
HCl in outlet water (percent by wt.)	: 0.11536
HCl in outlet gas (mg/Nm3)	: 0.15367
Outlet Water temperature (C)	: 30.25

Figure D.1 Result of design program at limited pH = 1.5

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed Absorber for Hydrochloric acid Storage tank

Input data

Customer Name	:	Siam Oxy
Tank material	:	PVC/FRP
Tank volume (m3)	:	6
Total tank surface area(m2)	:	16
Type of tank surface	:	White paint
Absorptivity for solar radiation	:	0.1
Absorptivity for tank radiation	:	0.9
HCl acid concentration (percent by wt.)	:	35
HCl acid temperature (C)	:	43.3
Packing type	:	Pall rings
Packing material	:	Polypropylene
Packing size(inches)	:	0.625
Packing surface tension(dynes/cm)	:	33
Packing specific surface (m2/m3)	:	341
Inlet water temperature (C)	:	30
Surrounding temperature (C)	:	35
Solar radiation to tank (W/m2)	:	800
Packed column diameter (m)	:	0.204

Calculation result

Packed column height (m)	:	0.81
Inlet Water flow rate (m3/h)	:	8.35
Outlet Water pH	:	2.00
HCl in outlet water (percent by wt.)	:	0.03649
HCl in outlet gas (mg/Nm3)	:	2.41046
Outlet Water temperature (C)	:	29.93

Figure D.2 Result of design program at limited pH = 2.0

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.035
Inlet Water temperature (C)	: 35

Calculation results	
Outlet Water pH	: 0.26
HCl in outlet water(percent by wt.)	: 2.02
Outlet water temperature (C)	: 42.96
HCl in outlet gas (mg/Nm3)	: 2438.54

Figure D.3 Simulation results by input data from Table 4.5

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.07
Inlet Water temperature (C)	: 35

Calculation results	
Outlet Water pH	: 0.56
HCl in outlet water(percent by wt.)	: 1.02
Outlet water temperature (C)	: 38.89
HCl in outlet gas (mg/Nm3)	: 89.64

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.089
Inlet Water temperature (C)	: 35

Calculation results	
Outlet Water pH	: 0.66
HCl in outlet water(percent by wt.)	: 0.80
Outlet water temperature (C)	: 38.01
HCl in outlet gas (mg/Nm3)	: 22.24

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.125
Inlet Water temperature (C)	: 35
Calculation results	
Outlet Water pH	: 0.81
HCl in outlet water(percent by wt.)	: 0.57
Outlet water temperature (C)	: 37.08
HCl in outlet gas (mg/Nm3)	: 2.38

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.143
Inlet Water temperature (C)	: 35

Calculation results	
Outlet Water pH	: 0.86
HCl in outlet water(percent by wt.)	: 0.50
Outlet water temperature (C)	: 36.79
HCl in outlet gas (mg/Nm3)	: 0.89

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.218
Inlet Water temperature (C)	: 35
Calculation results	
Outlet Water pH	: 1.05
HCl in outlet water(percent by wt.)	: 0.33
Outlet water temperature (C)	: 36.10
HCl in outlet gas (mg/Nm3)	: 0.03

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.324
Inlet Water temperature (C)	: 35
Calculation results	
Outlet Water pH	: 1.22
HCl in outlet water(percent by wt.)	: 0.22
Outlet water temperature (C)	: 35.67
HCl in outlet gas (mg/Nm3)	: 0.00

Figure D.3 Simulation results by input data from Table 4.5 (continue)

Siam Occidental Electrochemical Co., Ltd.
Production Section
Description

Packed absorber for hydrochloric acid storage tank.

Input data	
Packed absorber Name	: 40AP01
Inlet gas phase flow rate (Nm3/h)	: 0.474
Inlet gas phase temperature (C)	: 35
Inlet gas phase density (kg/m3)	: 1.39
Inlet gas phase viscosity (kg/m s)	: 0.000149
Inlet gas HCl mole fraction	: 0.925
Inlet gas H2O mole fraction	: 0.075
Packed column height	: 1.5
Packed column diameter	: 0.204
Packing type	: pall rings
Packing size(inches)	: 0.625
Packing material	: PP
Packing surface tension (dynes/cm)	: 33
Packing specific surface (m2/m3)	: 341
Inlet Water flow rate (m3/h)	: 0.502
Inlet Water temperature (C)	: 35
Calculation results	
Outlet Water pH	: 1.41
HCl in outlet water(percent by wt.)	: 0.14
Outlet water temperature (C)	: 35.35
HCl in outlet gas (mg/Nm3)	: 0.00

Figure D.3 Simulation results by input data from Table 4.5 (continue)

APPENDIX E

SOLAR RADIATION DATA OF
METEOROLOGICAL DEPARTMENT

Table E.1 Conclusion of Radiation Balance Q and Total Radiation Data(sun and sky) T,10^2 MJ/m^2

MARCH	09-10	10-11	11-12	12-13	13-14	14-15	
1993	251	309	317	322	282	212	
1994	240	265	293	293	242	179	
1995	239	298	297	274	251	204	
1996	272	322	357	350	303	236	
1997	248	315	343	330	280	206	
AVERAGE	250	301.8	321.4	313.8	271.6	207.4	277.667

APRIL	09-10	10-11	11-12	12-13	13-14	14-15	
1993	257	303	326	315	272	200	
1994	296	343	361	346	293	223	
1995	239	278	289	283	265	211	
1996	194	247	295	308	299	260	
1997	287	342	358	324	267	207	
AVERAGE	254.6	302.6	325.8	315.2	279.2	220.2	282.933

Table E.2 Conversion of Radiation Balance Q and Total Radiation Data from Table D.1 (sun and sky) T,W/m^2

MARCH	09-10	10-11	11-12	12-13	13-14	14-15	
1993	697.222	858.333	880.556	894.444	783.333	588.889	
1994	666.667	736.111	813.889	813.889	672.222	497.222	
1995	663.889	827.778	825.000	761.111	697.222	566.667	
1996	755.556	894.444	991.667	972.222	841.667	655.556	
1997	688.889	875.000	952.778	916.667	777.778	572.222	
AVERAGE	694.444	838.333	892.778	871.667	754.444	576.111	771.296

APRIL	09-10	10-11	11-12	12-13	13-14	14-15	
1993	713.889	841.667	905.556	875.000	755.556	555.556	
1994	822.222	952.778	1002.778	961.111	813.889	619.444	
1995	663.889	772.222	802.778	786.111	736.111	586.111	
1996	538.889	686.111	819.444	855.556	830.556	722.222	
1997	797.222	950.000	994.444	900.000	741.667	575.000	
AVERAGE	707.222	840.556	905.000	875.556	775.556	611.667	785.926

BIOGRAPHY

Mr. Pinit reargmuang was born in Khon Kaen at 13 February 1971. He is a production engineer in Siam occidental electrochemical co.,Ltd. He received B.E. in Chemical engineering from Khon Kaen university in 1993. He was chemical engineering student of graduated school in Chulalongkorn university since 1994.