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## Acceptance Test Procedures

### Purpose:

For testing the efficiency of ammonia scrubber

### Steps in system testing:

1. Check all valve's positioning to be correct.
2. Check the air volumetric flow rate should be at 25.54 m<sup>3</sup>/hr.
3. Check the fresh water feed system shall be at least 0.4 bar. The pressure gauge should be at 1.6 bars.
4. Check the recirculation pump working system of it function properly.
5. Open the "Fresh water feed system", open the air inlet damper and let the system run for 60 min.
6. Check the concentration of ammonia at sampling point 1 (at the standard inlet) and at sampling point 2 (at the outlet gas).

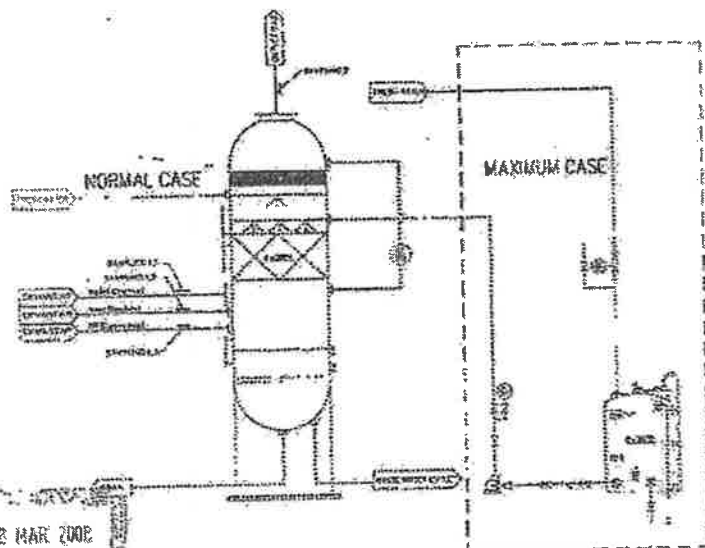
FOR THE DESIGNER'S CONSIDERATION  
 OF DESIGNER'S WORK, THE DESIGNER  
 SHALL NOT BE RESPONSIBLE FOR THE  
 COMPLIANCE WITH THE DESIGNER'S  
 DESIGN.

☒ 1. DESIGNER'S WORK HAS BEEN REVIEWED AND ACCEPTED, WHILE LAY PROCEED

☐ 2. PLEASE REQUEST DOCUMENT AFTER RECEIVING OUR COMMITTEE WORKING PROCEED OR BASE OF DESIGN DOCUMENTS

☐ 3. NOT ACCEPTABLE, WORK MAY NOT PROCEED SEE COMMUNICATION REPORTS

DATE: 12 APR 2008  
 SIGNATURE: [Signature]



Remark: Sampling point should be away from elbow about six times of duct diameter.



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## Performance Testing

No.	Test Description	Design	Test	Remark.
1	Air flow rate (m <sup>3</sup> /hr)	25.54		
2	NH <sub>3</sub> inlet gas concentration			
	- Normal case (mg/m <sup>3</sup> or kg/hr)	191,334 or 4.8		
	- Maximum case (mg/m <sup>3</sup> or kg/hr)	3,134,497 or 111.4		
3	NH <sub>3</sub> outlet gas concentration			
	- Normal case (mg/m <sup>3</sup> or ppm)	16 or 25		
	- Maximum case (mg/m <sup>3</sup> or ppm)	16 or 25		

Remark: This efficiency has designed for normal inlet temperature. It can not work at high temperature because NH<sub>3</sub> can be absorbed by water solution at 60 °C max.

# ASIAN CHEMICAL & ENGINEERING CO., LTD.

CUSTOMER	: THAI ETHANOLAMINES CO., LTD.
PROJECT NAME	: AMMONIA SCRUBBER PACKAGE
PRODUCTION	: SCRUBBER
SERIAL NUMBER	: A-2014

## A-2014 INSTRUMENT DATA SHEET

### DESIGN CRITERIA / PERFORMANCE

TYPE OF ABSORPTION TOWER	: VERTICAL SCRUBBER, COUNTER-CURRENT FLOW
SUPERFICIAL VELOCITY	: 0.076 m/sec
CONTACTING TIME	: 193.32 sec
LIQUID / GAS RATIO	: 67.53 for Normal Case/ 1406.87 for Max. Case
DESIGN PRESSURE	: 3.5 / FULL VACUUM kg/cm <sup>2</sup> (g)

### CONSTRUCTION

MODEL / BRAND	: SSV 900-3000, ACE
DIAMETER	: 900 mm
HEIGHT	: 7.043 m
SUCTION SIZE	: 50, 50 AND 100 mm
DISCHARGE SIZE	: 200 mm
MATERIAL OF STRUCTURE	: STEEL

### ACCESSORIES

LIFTING	
TYPE	: FALL RING
MATERIAL	: STAINLESS STEEL
SIZE	: 28 mm

### SPRAY NOZZLES

TYPE	: FULL CONE NOZZLE
MATERIAL	: STAINLESS STEEL
SPRAY ANGLE	: 150°
MALE PIPE SIZE	: 1/2"
CAPACITY	: 40 L/min @ 0.7 bar
MODEL / BRAND	: 1/2 HH51-SS 150 (20) SPIRAL JET
MALE PIPE SIZE	: 1/2"
CAPACITY	: 167 L/min @ 0.7 bar
MODEL / BRAND	: 1 HH51-SS 150 (40) SPIRAL JET

D	11/07/2008	CHANGED SERIAL NUMBER	R.W.	J.W.		
C	10/06/2008	RE ISSUE	R.W.	J.W.		REV. SHEET
REV.	DATE	DESCRIPTION	BY	CHKD	D	1 OF 1

# ASIAN CHEMICAL & ENGINEERING CO., LTD.

CUSTOMER	: THAI ETHANOLAMINES CO., LTD.
PROJECT NAME	: AMMONIA SCRUBBER PACKAGE
PRODUCTION	: FRESH WATER TANK
SERIAL NUMBER	: D-2010

## A-2014 INSTRUMENT DATA SHEET

### SPECIFICATION

TYPE	: VERTICAL CYLINDER TANK
CAPACITY	: 18,000 LITER
DIAMETER	: 2,000 mm
HEIGHT	: 2,200 mm
MODEL / BRAND	: SVID 10/2000, ACE

### MATERIAL

CORROSION BARRIER	: ORTHOPHTHALIC RESIN
STRUCTURAL LAYER	: ORTHOPHTHALIC RESIN

D	11/07/2008	CHANGED SERIAL NUMBER	R.W.	J.W.		
C	10/06/2008	RE ISSUE	R.W.	J.W.		REV. SHEET
REV.	DATE	DESCRIPTION	BY	CHKD	D	1 OF 1



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## A-2014 General Description



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## AIR POLLUTION CONTROL SYSTEM A-2014 AMMONIA SCRUBBER PACKAGE

### Introduction

Air pollution has been a significant aspect in Thailand and risky for human being. Contaminants are fumes, toxic gas molecules, particulates, smoke etc. Pollution control system is then needed to treat the contaminant to improve air quality.

The wet scrubber is a gas absorption unit which is used as an air pollutant emission treatment by physical and/or chemical mechanisms. This system is the most effective and inexpensive with high loading concentration and volume of air pollutant.

### Process Description

Gas absorption is where a chemical species (or several species's) in the gas phase is removed by contacting the gas with a liquid phase in which the species is (or the species are) soluble. Mass transfer can occur via two different fundamental mechanisms, chemical species from the gas phase transfer to the liquid phase. It is important to choose a solvent in which the solubility of the gas is high. This will increase the rate of absorption and decrease the amount of solvent required. Sometimes high solubility is caused by a reaction, between the gas and the liquid, but if either the chemical species transferred or the solvent is to be recovered the reaction must be reversible.

Absorption of odorant like AMMONIA is a mass transfer process, where the odorant designed scrubbing system will have a capacity of treating 35.54 CMH. This system designed on one stage operation consisting of vertical packing tower which has main equipment, recirculation pump, exhaust fan and instrument. In this case, the waste gas (AMMONIA) will be absorbed by fresh water in packed tower.

Ammonium hydroxide is a weak base that is partially ionized in water according to the equilibrium:



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The efficiency of mass transfer depends on the following factor.

- have a plenty of surface area contact
- well mix between gas and liquid
- appropriated contact time
- gas/liquid is more soluble in liquid

A common apparatus used in gas absorption is the packed tower. However, the device consists of the following detail.

#### 1. Packed Tower (Wet Scrubber)

It is a vertical column, equipped with a gas inlet and distributing space at the bottom; a liquid inlet and distributor at the top; gas and liquid outlets at the top and bottom called counter-current flow, respectively; and a supported mass of inert solid shapes, called tower packing. The packing support is typically a screen, corrugated to give it strength, with a large open area so that flooding does not occur at the support.

#### 2. Spray nozzles

This device is a common apparatus used in wet scrubber. A liquid inlet is distributed over the top of the packing by spray nozzles. The kind of this spray is Full Cone as shown in figure 1 which liquid inlet is circularly distributed in tower. It is also easy to take off for cleaning.



Figure 1 Full Cone Spray Nozzle



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#### 3. Packing

It is a major part in packed towers, which are commonly used in gas absorption. The packing are used to establish an intimate contact between vapors and liquid used to wash the objectionable components. ACE designation is used stainless steel Pall Ring 38 mm. as shown in Figure 2. The advantage is low pressure drop, corrosion resistance, larger specific area means larger area available for contact between gas and liquid and therefore more efficient absorption operating.



Figure 2 Stainless Steel Pall Ring 38 mm.

#### 4. Pump

The fresh liquid is distributed over the top of packing and contacted with waste gas. This liquid is enriched in solute as it flows down the tower and then drain the liquid out (Figure 3).

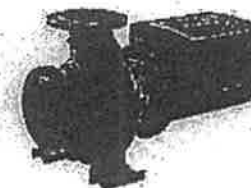
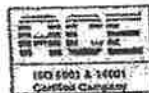


Figure 3 Pump



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## A-2014 Technical Data

- Design Basis
- Design Calculation for Ammonia Scrubber

## ASIAN CHEMICALS & ENGINEERING

AMMONIA SCRUBBER PACKAGE  
 (DIVATION OPTION)

PAGE NO.	DE 12	REV. 0
CUSTOMER	THAI ETHANOLAMINES CO., LTD	
PROJECT CODE	AETP 07090442	
PROJECT NAME	AMMONIA SCRUBBER PACKAGE	
PREPARED BY	RWEEFAORN	
CHECKED BY	S.FREECHIA	
APPROVED BY	J.WORADECH	
ISSUED DATE	27	FEBRUARY 2008

### DESIGN BASIS

ABSORPTION SCRUBBER FOR AMMONIA SCRUBBER (A-2014) (NORMAL CASE)

☞ TOTAL AIR CAPACITY FOR PEAK FLOW	: 33.54 CMH @ Temperature 60 °C
☞ INLET CONDITION	
- PRESSURE	: ATMOSPHERE
- OPERATING TEMPERATURE	: 60 °C FOR NORMAL (MAX 145 °C)
- INLET GAS POLLUTANT	: NH <sub>3</sub> and N <sub>2</sub>
- NH <sub>3</sub> INLET GAS CONCENTRATION	: 191.334 mg/m <sup>3</sup> (6.80 kph)
☞ TYPE OF ABSORPTION TOWER	: VERTICAL SCRUBBER, COUNTER-CURRENT FLOW
☞ SUPERFICIAL VELOCITY	: 0.016 m/sec
☞ CONTACTING TIME	: 193.32 sec
☞ LIQUID/GAS RATIO	: 67.50 m <sup>3</sup> /m <sup>3</sup>
☞ SCRUBBING LIQUID	: WATER
☞ PACKING TYPE	: FALL RING 35 mm
☞ PACKING HEIGHT	: 3,000 mm
☞ EXPECTED PRESSURE ACROSS VESSEL	: < 0 mbar
☞ NH <sub>3</sub> OUTLET GAS CONCENTRATION	: 25 ppm (16 mg/m <sup>3</sup> @ Temperature 40 °C)

REMARK: 1. Absorption has designed for normal inlet temp. it can not work at high temp. because NH<sub>3</sub> can be absorbed by Water solution at 60 °C max. But all selected equipments and instruments can be used at temp. 145 °C



ASIAN CHEMICALS & ENGINEERING	PAGE NO.	DS22	REV. 0
	CUSTOMER	THAI ETHANOLAMINES CO., LTD.	
	PROJECT CODE	AETP 0700662	
	PROJECT NAME	AMMONIA SCRUBBER PACKAGE	
	PREPARED BY	R. WEERAPORN	
AMMONIA SCRUBBER PACKAGE (DIVISION OPTION)	CHECKED BY	S. PRECHA	
	APPROVED BY	J. WORADECH	
	ISSUED DATE	27	FEBRUARY 2008

DESIGN BASIS	
ABSORPTION SCRUBBER FOR AMMONIA SCRUBBER (A-201) (MAXIMUM CASE)	
☛ TOTAL AIR CAPACITY FOR PEAK FLOW	: 35.54 CMH @ Temperature 60°C
☛ INLET CONDITION	
- PRESSURE	: ATMOSPHERE
- OPERATING TEMPERATURE	: 60°C FOR NORMAL (MAX 145°C)
- INLET GAS POLLUTANT	: NH <sub>3</sub> and H <sub>2</sub>
- MAX. NH <sub>3</sub> INLET GAS CONCENTRATION	: 3,134.697 mg/m <sup>3</sup> (111.4 kg/h)
☛ TYPE OF ABSORPTION TOWER	: VERTICAL SCRUBBER COUNTER-CURRENT FLOW
☛ SUPERFICIAL VELOCITY	: 0.016 m/sec
☛ CONTACTING TIME	: 193.32 sec
☛ LIQUID/GAS RATIO	: 1406.87 l/m <sup>3</sup>
☛ SCRUBBING LIQUID	: WATER
☛ PACKING TYPE	: PALL RING 38 mm.
☛ PACKING HEIGHT	: 3,000 mm.
☛ EXPECTED PRESSURE ACROSS VESSEL	: < 3 mbar
☛ NH <sub>3</sub> OUTLET GAS CONCENTRATION	: 25 ppm (16 mg/m <sup>3</sup> @ Temperature 60°C)
REMARK: 1. Absorption has designed for normal inlet temp. It can not work at high temp because NH <sub>3</sub> can be absorbed by Water Solution at 60°C max. But all selected equipments and instruments can be used at temp. 145°C	

CHINWU/DRAWING/APC/AETP0700662/REV.0/D0/A/1099044/2008.DOC

FM-TCH-DBA-01-R00



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# CALCULATION OF INLET GAS CONCENTRATION FOR AMMONIA SCRUBBER PACKAGE (A-201)

## Previous Data from Customer

Total Gas Mass Flow Rate (NH <sub>3</sub> + N <sub>2</sub> )	=	382	kg/h
Design Temperature	=	60	°C
∴ NH <sub>3</sub> inlet	=	381.4	kg/h
	=	$\left( 381.4 \frac{\text{kg}}{\text{hr}} \right) \left( \frac{1}{348} \frac{\text{hr}}{\text{min}} \right) \left( \frac{10^6 \text{ mg}}{1 \text{ kg}} \right)$	
	=	449,769	mg/m <sup>3</sup>

## Present Data from Customer (Max. case)

Total Gas Mass Flow Rate (NH <sub>3</sub> + N <sub>2</sub> )	=	112.0	kg/h
Design Temperature	=	60	°C
∴ NH <sub>3</sub> inlet	=	111.4	kg/h
	=	$\left( 111.4 \frac{\text{kg}}{\text{hr}} \right) \left( \frac{1}{35.54} \frac{\text{hr}}{\text{min}} \right) \left( \frac{10^6 \text{ mg}}{1 \text{ kg}} \right)$	
	=	3,134,697	mg/m <sup>3</sup>

## Present Data from Customer (Normal Case)

Total Gas Mass Flow Rate (NH <sub>3</sub> + N <sub>2</sub> )	=	6.30	kg/h
Design Temperature	=	60	°C
∴ NH <sub>3</sub> inlet	=	6.30	kg/h
	=	$\left( 6.30 \frac{\text{kg}}{\text{hr}} \right) \left( \frac{1}{35.54} \frac{\text{hr}}{\text{min}} \right) \left( \frac{10^6 \text{ mg}}{1 \text{ kg}} \right)$	
	=	191,333.7	mg/m <sup>3</sup>



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### CALCULATION OF PRESSURE DROP IN PACK COLUMN

#### 1. Ammonia Scrubber Package (A-2014) (Maximum Case)

- Scrubber area	=	$3.144 \times (0.9 \times 0.9)$	m <sup>2</sup>
	=	0.636	m <sup>2</sup>
	=	112	kg/hr
- Mixing gas mass flow rate	=	112 kg/hr	
Mixing gas mass velocity (G)	=	$\frac{112 \text{ kg/hr}}{0.636 \text{ m}^2}$	kg/m <sup>2</sup> hr
	=	176.10	kg/m <sup>2</sup> hr
- Liquid flow rate (Dissolution approx. = 1,000 kg/m <sup>3</sup> )	=	50	m <sup>3</sup> /hr
Liquid mass velocity (L)	=	$\frac{50 \text{ m}^3/\text{hr} \times 1,000 \text{ kg/m}^3}{0.636 \text{ m}^2}$	kg/m <sup>2</sup> hr
	=	78,616.35	kg/m <sup>2</sup> hr

From: G = 176.10 kg/m <sup>2</sup> hr	=	0.0100189	lb/ft <sup>2</sup> s
L = 78,616.35 kg/m <sup>2</sup> hr	=	4.47275	lb/ft <sup>2</sup> s
$\rho_{\text{mix}} = 3.159 \text{ kg/m}^3$	=	0.196648	lb/ft <sup>3</sup>
$\rho_{\text{water}} = 1,000 \text{ kg/m}^3$	=	62.42797	lb/ft <sup>3</sup>

$$\frac{L}{G} \sqrt{\frac{\rho_{\text{air}}}{\rho_{\text{water}}}} = \frac{4.473}{0.010} \sqrt{\frac{0.197}{62.43}} = 25.13$$

From

$C_s$	= The capacity factor
$u_s$	= Superficial Velocity (ft/s)
$\nu$	= The Viscosity

$$\text{Use } u_s = 0.0156 \text{ m/s} = 0.0512 \text{ ft/s}$$

$$C_s = 0.0512 \sqrt{\frac{0.197}{62.43 - 0.157}} = 0.0029$$

$$\text{For Pall Ring 38 mm., } F_p = 28 \text{ (For Stainless Steel)}$$

$$C_s F_p^{0.75} \sqrt{\nu} = 0.0029 \times 28^{0.75} \times 1^{0.75} = 0.0152$$

For these conditions predicted the pressure drop is about 0.05 in<sub>2</sub>O/ft of packed height

Packing length	=	3.0 m	=	9.842 ft
∴ Pressure drop of packing	=	$0.05 \times 9.842$	=	0.492 in <sub>2</sub> O
	=	12.50		mmHg
Pressure from mist eliminator and vessel	=	10		mmHg
Total pressure across vessel	=	22.50		mmHg
	=	2.21		mbar



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#### 2. Ammonia Scrubber Package (A-2014) (Normal Case)

- Scrubber area	=	$3.144 \times (0.9 \times 0.9)$	m <sup>2</sup>
	=	0.636	m <sup>2</sup>
- Mixing gas mass flow rate	=	6.80	kg/hr
Mixing gas mass velocity (G)	=	$\frac{6.80 \text{ kg/hr}}{0.636 \text{ m}^2}$	kg/m <sup>2</sup> hr
	=	10.69	kg/m <sup>2</sup> hr
- Liquid flow rate (Dissolution approx. = 1,000 kg/m <sup>3</sup> )	=	2.4	m <sup>3</sup> /hr
Liquid mass velocity (L)	=	$\frac{2.4 \text{ m}^3/\text{hr} \times 1,000 \text{ kg/m}^3}{0.636 \text{ m}^2}$	kg/m <sup>2</sup> hr
	=	3,775.59	kg/m <sup>2</sup> hr

From: G = 10.69 kg/m <sup>2</sup> hr	=	0.00060819	lb/ft <sup>2</sup> s
L = 3,775.59 kg/m <sup>2</sup> hr	=	0.214692	lb/ft <sup>2</sup> s
$\rho_{\text{mix}} = 0.191 \text{ kg/m}^3$	=	0.0119425	lb/ft <sup>3</sup>
$\rho_{\text{water}} = 1,000 \text{ kg/m}^3$	=	62.42797	lb/ft <sup>3</sup>

$$\frac{L}{G} \sqrt{\frac{\rho_{\text{air}}}{\rho_{\text{water}}}} = \frac{0.2147}{0.00061} \sqrt{\frac{0.012}{62.43}} = 4.5797$$

From

$C_s$	= The capacity factor
$u_s$	= Superficial Velocity (ft/s)
$\nu$	= The Viscosity

$$\text{Use } u_s = 0.0156 \text{ m/s} = 0.0512 \text{ ft/s}$$

$$C_s = 0.0512 \sqrt{\frac{0.012}{62.43 - 0.012}} = 0.00071$$

$$\text{For Pall Ring 38 mm., } F_p = 28 \text{ (For Stainless Steel)}$$

$$C_s F_p^{0.75} \sqrt{\nu} = 0.00071 \times 28^{0.75} \times 1^{0.75} = 0.00376$$

For these conditions predicted the pressure drop is about 0.05 in<sub>2</sub>O/ft of packed height

Packing length	=	3.0 m	=	9.842 ft
∴ Pressure drop of packing	=	$0.05 \times 9.842$	=	0.492 in <sub>2</sub> O
	=	12.50		mmHg
Pressure from mist eliminator and vessel	=	10		mmHg
Total pressure across vessel	=	22.50		mmHg
	=	2.21		mbar



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### Calculation of Bottom Liquid Flowrate

#### For Annular Scrubber (A-2010)

From  $H_p = \frac{v^2}{2g}$  \*\*\* (1)  
 $v^2 = 2H_p g$  \*\*\* (2)  
 Given  $H_p =$  Height of Sump  
 $= 0.74 \text{ m (740 mm)}$   
 $v =$  Velocity (m/s)  
 $g =$  Acceleration due to gravity.  
 $= 9.81 \text{ m/s}^2$

#### Substituted in equation (2)

$v^2 = 2 \times 9.81 \times$   
 $= 2 \times 9.81 \times (0.74 \text{ m})$   
 $= 14.53 \frac{\text{m}^2}{\text{s}^2}$   
 $v = 3.81 \frac{\text{m}}{\text{s}}$

When the diameter of drain piping is 150 mm (0.15 m)

From (1)  $= VA$   
 and  $A = \frac{\pi d^2}{4}$   
 $= \frac{\pi (0.15)^2}{4}$   
 $= 0.0177 \text{ m}^2$   
 $Q = VA$   
 $= (3.81 \frac{\text{m}}{\text{s}}) (0.0177 \text{ m}^2)$   
 $= 0.067 \frac{\text{m}^3}{\text{s}}$   
 $= (0.067 \frac{\text{m}^3}{\text{s}}) \left( \frac{1000 \text{ L}}{1 \text{ m}^3} \right) \left( \frac{60 \text{ s}}{1 \text{ min}} \right)$   
 $= 4020 \frac{\text{L}}{\text{min}}$

$$C_s R_p^{0.5} \approx 0.05$$

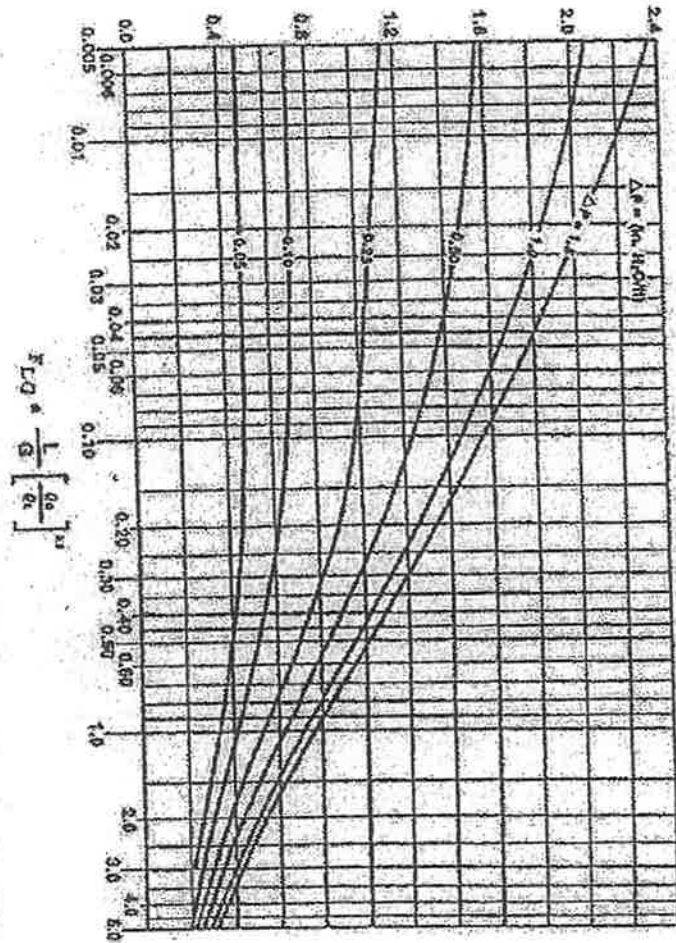


FIG. 14-4-8. Generalized pressure drop correlation of Ishai & Leva, as modified by Soudki. To convert inlet  $H_2O$  to mm  $H_2O$ , multiply by 9.806. From *Process Heat Design and Applications* by Ralph E. Soudki, Jr., copyright © 1994 by Gulf Publishing Co., Houston, Texas. Used with permission. All rights reserved.

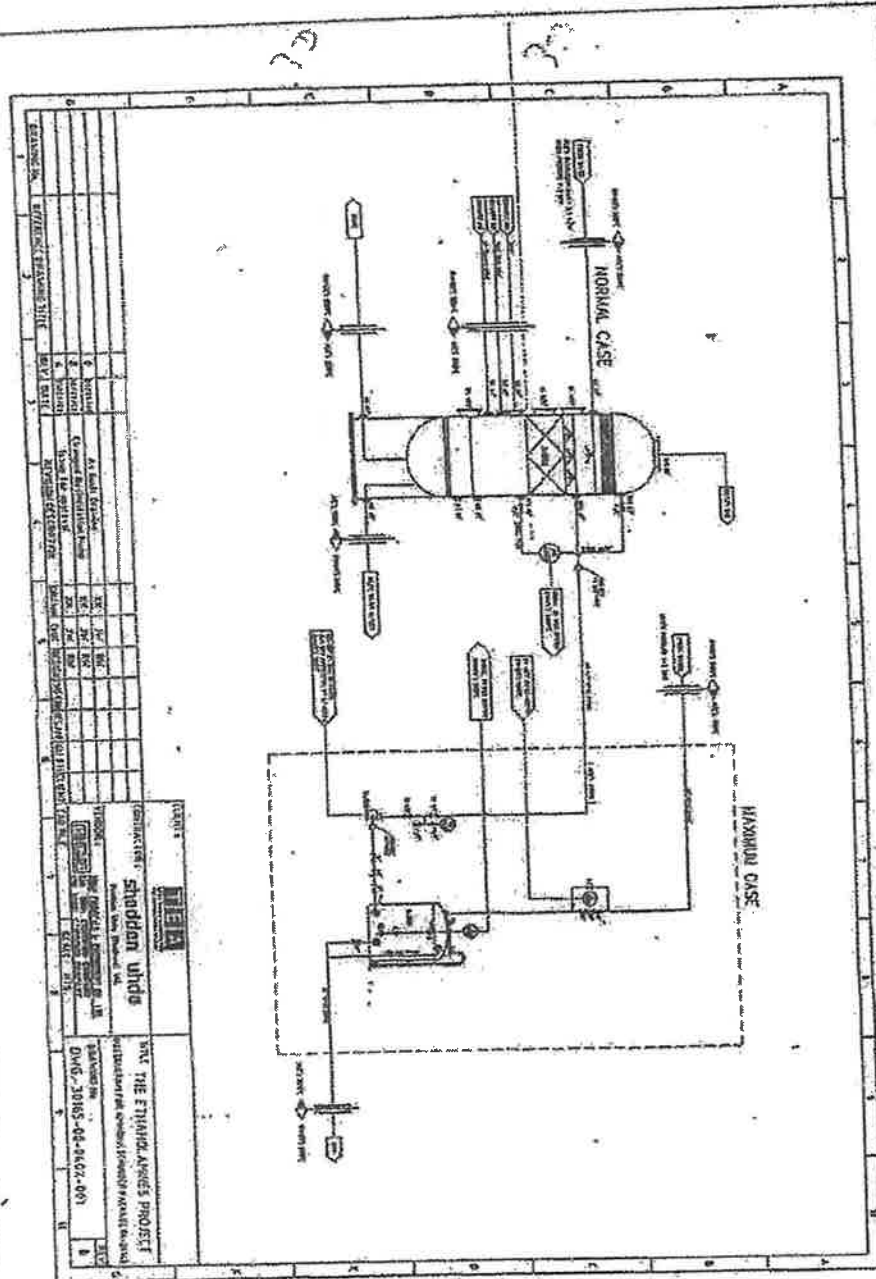




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## A-2014 Operation Manual / Specification





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## A-2014 Operation Manual of Air Pollution Control System

### Pre-start up checking

Before start up and using the dirty air scrubber, the general condition of the system have to be checked as follows:

- 1) Check the water level inside the fresh water tank, whether it is filled or not.
- 2) Check the circulation pump condition if it is ready for operation.
- 3) Check the rotational direction of circulation pump if it is in the correct direction following the sign besides the pump.
- 4) Check the normally "open - close" valve position as follows:
  - Suction, discharge valves of circulation pump normally open.
  - Pressure gauge valve normally open.
  - Drain valve and waste water outlet valve normally open.
- 5) Check the packing condition if there are scales attached; turn on the pump to clean the packing media first.

### System start up

Follow the specified steps:

- 1) Turn on the fresh water inlet valve to scrubber

### System shut down

Follow the specified steps:

- 1) Turn off the fresh water inlet valve to scrubber



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### Automatic control system of water filling into fresh water tank

If the water in the fresh water tank is lower than the "L" or low level, the solenoid valve will be turned on to fill the water to the fresh water tank until the water level is at "H" or high level. Then the solenoid valve will be turned off.

### Automatic control system of circulation pump

When NH<sub>3</sub> inlet gas concentration increased to set point value (Maximum Case) and water in the fresh water tank is higher than the "L" or low level, the circulation pump will be turned on.

And then, if the water level in the fresh water tank is at Low / Low; the circulation pump will be shut down automatically for preventing the circulation pump to "Run Dry" and be damaged.

Finally, if NH<sub>3</sub> inlet gas concentration is decreasing to less than the set point value, the circulation pump will be shut down automatically.