بسم الله الرحمن الرحيم

Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Mechatronics Engineering

Graduation Project

"Design and Building of an Absorption Process for Reducing Environmental Impacts of Fiber Baking Process"

Project Team

Rami Shawamreh **Merihan Da'do'**

Tareq Hashlamon

Rami Sarahnih **Rana Turman**

Project Supervisor

Dr. Maher Al-Jabari

Hebron-Palestine
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(PPU)

DEPARTMENT HEAD AND SUPERVISOR SIGNATURE

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According to the project supervisor and according to the agreement of the Testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of (B.Eng) the bachelor's degree.

Department Head Signature Supervisor Signature

Name: ___________ Name: _______________

Hebron-Palestine
2009

Dedication

To our parents who gave us their moral supports and sustained encouragement.

To our supervisor Dr. Maher Al-jabary, whose guidance and support made this work possible. His sustained encouragement, intuitive wisdom, and resolute leadership were instrumental in completing this work.

To Palestine polytechnic university, especially to our college and department.

To the whole team in mechanical engineering department.

To Feras, Ali and Wa'el Shawamreh, Ahmad Hashlamoon, Mera Da'do', Ryad Al-Shareef, Baher Al-fallah, and Fadel Nieroukh.

To our friends in college of engineering and technology.

Especially to Gaza martyrs, and its children who bear injustice and aggression.

We dedicate this humble work

Project Team

Acknowledgement

Special thanks to our advisor Dr. Maher Al-Jabari who helped us when we needed his support strongly.

Thanks to Mr. Roubin Joulani, the Maneger of Jelanco company, who paved the way to make this project possible.

Thanks to Eng. Majdi Zalloum for helping us in the project's scientific background.

Thanks to the Dean of the engineering college, Dr. Mohammad Ghazi Al-Qawasmi, as well as to the mechanical department's head, Dr. Zohdi Salhab, and the college council members, and to the Dean of the scientific research Dr. Imad Al-Khateeb, and Dr. Ramzi Qwasmi for supports,

Special thanks to Eng. A'ref Al-Herbawi and Eng. Mohannad Nassar for such encouragement and help, also to Eng. Ghadah Tbakhi, , Eng. Kholoud Al-Jabari, and Eng. Khalid Tmaizi.

Thanks and grateful for "*PPUISC*" for the effort and encouragement also to the "*REERU*" which made this work possible, which are located at PPU.

Thanks to all teachers and doctors in mechanical engineering department.

Thanks to our friends in college of engineering and technology who have encouraged us to achieve this work.

Thanks to all who helped us and hadn't been mentioned here.

Project Team

Abstract

Reducing the environmental impact of manufacturing cut-off wheels in local industry; is the aim of this project. This aim is met through developing a new technique to solve the air pollution problem depending on the absorption technique.

The project focus is to design, build and establish an absorption packed tower with a control/monitoring system. This was accomplished after performing a process performance evaluation for existing gas treatment process in Eagleflex Company. This report summarizes the industrial and scientific backgrounds of this project and presents the design and building works. Also, recommendations for improving the operating system in the company are made.

Field visits to the company, for the purpose of process analyses and real data measurements of gas concentrations, lead to performance evaluation (qualitative and quantitative evaluation). This showed that there are various types of polluting gases released from the process furnaces, including NH_3, VOC and HCN. The existing treatment process, based on wetting exhaust gases by simple water downward flow in a cylindrical vessel with water circulation system removed some of the gases with different removal efficiencies. However, measurement results showed that a stripping process (pollutant release from water to gas stream) occurs after water saturation. This paved the way to improve the existing treatment process, and give the basic data for designing, building and monitoring a new absorption process to increase the efficiency.

The preliminary performance evaluation had established a consolidate methodology for the new process design. Absorption packed tower of 40 cm diameter, and a 2 m height was built with full accessories.

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Chapter One

General Background and Project Concept

- Project Background.
- Project Scope.
- Project Goals and Objectives.
- Project Choice Justification.
- Project Implementation Plan.
- Budget.

Chapter 1

General Introduction

1.1 Project Background

Air pollution problem is one of the most important problems overall the world, and occurs when the air contains gases, dust, fume or odor in harmful amounts. Human activities release substances into the air, some of which can cause problems for human, plants, and animals, such as Noxious gases, chemical vapor, toxic compounds, and other gases such as H_2S, NH_3, and SO_2 in addition to particles. These pollutants can cause smog, the green house effect, and the acid rain.

One of the famous industrial operations is the manufacturing of cut-off wheels (fibers baking) that are used in stones and iron bars cutting processes, and consists of chemical compounds and bonding material as the main components of fiber composition. The formed wheels (fibers) are baked in ovens for specified period of time and under specified temperature ranges. The process releases various gases such as NH_3, SO_2, VOCs, and HCN, whose concentrations were measured and mentioned in chapter four. These gases cause the air pollution problem that is reflected in bad smell and shortness of breath.

Eagleflex Company is a well known local company in Hebron city which manufactures cut-off wheels (fibers). A study of the resulting exhausted gases needs to be done for treating the problem and reducing the emissions of pollutant gases.

In recent years, Eagleflex identified the problem and installed a hand-made device for gas absorption based on what is called it "the waterfall"; it is a wet scrubber in a metal box with water circulation. Pollutant gases stream enters inside and impinges the waterfall. This removes a percentage of pollutant gases by absorption, and the treated gas leaves the scrubber into atmosphere. No design calculations were made before installing the device and it is not build and operated according to absorption engineering concepts.

This project includes a review of the industrial operation for making cut-off wheels (cutting fibers), evaluation of existing pollutant removal system in Eagleflex Company, and a suggested controlled design for improving the system efficiency. In addition, designing and building a new gas absorption process in packed bed has been done within the project, for better gas removal efficiency; this illustrates the importance of the project as it tackles a problem in local factory by applying engineering principles.

1.2 Project Scope

The scope of the project is to reduce environmental impacts of a local industry by improving its existing gas treatment process and suggesting a new process. This includes the following main topics:

- Literature review of the industrial operation for manufacturing cut-off wheels focusing in types of gases released, and also a field study for understanding the operation of making them in Eagleflex Company which manufactures the wheels.
- Reviewing the scientific background of the air pollution problem and its treatment by using absorption method.
- Literature study of environmental impacts of air pollutants such as NH_3, HCN, VOCs, and other gases. This includes highlighting and their environmental impact over human beings, animals, and plants.
- Quantitative and qualitative study of air pollutants that are released as a result of baking cut-off wheels (fibers) in Eagleflex Company.
- An evaluation of the existing treatment process for pollutant removal in Eagleflex Company.
- A suggested packed tower design and building in order to improve the efficiency of pollutant removal process.
- Recommendations for developing the existing industrial operation such as installing monitoring and control systems to control the existing pollutant removal system and the suggested design. In addition, improving the operational procedures as well as making potential equipment modifications.

1.3 Project Goals and Objectives

The overall aim of the project is reducing the environmental impacts of air pollution that results from manufacturing cut-off wheels in local industry by gas absorption and integrated controlled system.

1.3.1 General Goals

- Attempting to reduce environmental impacts in Eagleflex company by handling the air pollution problem.
- Applying the mechanical engineering principles and the concepts of Mechatronics engineering on the various process components and systems.
- Improving operation in a local industry and serving the society in order to improve the quality of life.
- Creating bridges between engineering education and local industry.

1.3.2 Specific Objectives

1) Evaluation of the existing treatment system for pollutant removal in Eagleflex Company by:

- Qualitative study of pollutant gases and their environment impacts.

- Quantitative study of pollutant gases such as determining the percentage removal of pollutants.

2) Suggesting process improvements for developing the existing pollutant removal system and the industrial operation in Eagleflex company such as:

- Installing relief valves into ovens to provide fresh air when gas outlet opens in order to allow gas to leave the oven and to provide slightly cooling for fibers, rather than opening the oven gas door currently, which pollutes the production site.
- Installing monitoring system by installing gas sensors in different places in the factory, where workers exist in order to operate ventilation system if the concentration of gases exceeds definite limits.
- Other suggestions to be identified during process evaluation.

3) Designing and building a packed tower in order to improve the efficiency of pollutant removal system. This includes determining packing height, tower diameter, distributor design, pump and fan power calculations … etc.

4) Implementing the packed tower.

5) Developing control and monitoring system, this includes:

- Installing sensors to control gas flow and water flow.
- Installing sensors to monitor the concentrations of gases at both the inlet and the outlet of packed tower, and the existing treatment process for better operation.
- Programming the chosen control system.

1.4 Project Choice Justification

1) The air pollution problem needs to be resolved and treated in local factories such as Eagleflex factory, and this can be done by the ability of local engineers; this will serve the local society.
2) Projects that are integrated with industry like this project can develop the practical aspects for engineering students.
3) Such a project provides the opportunity to apply what have been studied in five years in the engineering college.
4) The availability of obtaining funds from Industry Synergy Center (ISC) for purchasing the required project components.

1.5 Project Implementation Plan

This project intends to sustain a high level of scientific value, however, the project has got tasks, goals and objectives, in addition to the time table, thus when they are achieved; and then the project has accomplished that level.

1.5.1 Main Tasks and Activities

The main tasks and activities that have been scheduled were as follows:

- Field visits to Eagleflex factory in order to:
    1) Measure the concentrations of pollutants, and for estimating gas flow rate and density.
    2) Understand the industrial operation of making cut-off wheels (fibers), and for treating pollutant gases.
    3) Construct the temperature curve for baking process and estimating the pressure curve of the produced gases.

- Preparing a packed tower design according to the estimated flow rate in the industrial process and density of gas, and checking the results using packed tower calculator software.
- Sourcing materials and various project components.
- Building a practical packed tower, and test the efficiency of it.
- Implementation of control and monitoring system.
- Preparing the estimated budget.

1.5.2 Time Table

The following tasks were planned to be done during the semester. Table 1.1 describes the distribution of these tasks over the semester weeks:

- Field visits to Eagleflex factory for confirming data measurement and obtaining new data.
- Complete evaluation of the pollutants removal system in Eagleflex factory.
- Complete evaluation of the industrial operation in Eagleflex factory.
- Reviewing and finalizing the packed tower design.
- Sourcing and purchasing the required project components.
- Building the designed packed tower.
- Implementation of the control and monitoring system.
- Testing of the implemented tower and control system within the semester.
- Preparing documentation, summarizing the results and recommendations, and making presentation about the project.

Table 1.1: Time table

No.	Output	Output indicator	Activities	Milestone	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Collecting more and precision data about gases and the industrial operations	Results that are obtained from visiting Jelanco company	1.1 Measuring pollutants concentrations again.	Field visits to Jelanco company		■		■		■		■		■		■				
			1.2 Estimating exact gas flow rate.			■														
			1.3 Full understanding of the industrial operations.					■		■										
2.	Complete evaluation of pollutant removal system in Jelanco company	Quantified system efficiency	2.1 Obtaining pollutants concentrations.	Full measurement results		■		■		■		■		■		■				
			2.2 evaluating the system efficiency.														■	■		
			2.3 Suggesting efficiency improvements.														■	■		
3.	Complete evaluation of the industrial operations in Jelanco company	Suggestions for improving the process	3.1 Well understanding of the industrial operation for making cut-off wheels.	Field visits to Jelanco company				■	■	■	■	■								
4.	Finalizing the packed tower design	Obtained tower diameter height, pump fan power and mechanical design	4.1 Obtaining data from filed visits.	Full design		■														
			4.2 Complete design calculations			■	■													
			4.3 Checking results using software.					■	■											
			4.4 Pump and fan calculations.				■													

No.	Output	Output indicator	Activities	Milestone	Schedule Week =															
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
5.	Builing of packed tower	Packed tower ready to be tested	5.1 Obtaining tower diameter and height from design calculations.	Complete building procedures	■	■														
			5.2 Purchasing tower components.				■	■	■	■	■	■	■	■	■	■	■	■	■	■
			5.3 Building of packed tower.						■	■	■	■	■	■	■	■	■	■	■	■
6.	Implementation of control and monitoring system	Control and monitoring system ready to be tested	6.1 Implementing of control and monitoring system theoretically for the packed bed and the factory	Complete building procedures		■	■	■												
			6.2 Purchasing system components.			■	■	■	■											
			6.3 Developing practical control and monitoring system for the packed bed.									■	■	■	■	■				
7.	Testing of implemented packed bed and control and monitoring system	Obtain the efficiency	7.1 testing of the packed tower efficiency.	Full system test						■	■	■	■	■	■	■				
			7.2 Testing the control and monitoring system									■	■	■	■	■				
			7.3 Summarizing results														■	■		
8.	Preparing documentation and power point presentation	Complete chapters and power point presentation	8.1 Summarizing project results and recommendations.	Full chapters components													■	■	■	
			8.2 Preparing project chapters.		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
			8.3 Preparing powerpoint															■	■	

1.6 The Estimated Budget

Estimates are made for the project components (packed bed process), as listed in table 1.2

Table 1.2: Estimated budget.

Item		No. of items	Cost ($)
Acrylic pipe of 40cm diameter and 2m height		1	100
Iron Flanges		4	120
Steel cylinders 'four cylinders with dome and base'		6	100
Anemometer		1	50
Labor and construction costs	Muffa, Nipple, Support Bars, Screws, Cascade, Distributer, Pipes, and kalkal	---	250
	Welding, Threading...Painting	---	230
	Galvan	---	25
	Steel Conic	1	50
Pump		1	50
Fan		1	50
Packing material		300 meter	100
Water container		2	20
Control and monitoring system components	Microcontroller chip, LCDs, and accessories	---	100
	12V relays	4	25
	Contactors	2	50
	Electrical valves	2	150
	NH_3 sensor	2	400
Experiments:	Acrylic plate (2m*1m*4mm)	2	30
	Acrylic plate (20cm*126cm)	1	10
	Acrylic plate (50cm*126m)	1	15
Others		---	100
Total			2025

These estimates were determined after finalizing process design and sourcing required parts in local markets. The Industrial Synergy Center (PPUISC) approved funding this project with $2000 assigned for building the packed bed process.

The budget of implementing of the process modifications in Eagleflex Company is determined after establishing the building of the packed tower, and is shown in table (1.3).

Table 1.3: Budget for the proposed modifications in Eagleflex.

Component	# of pieces	Cost ($)
NH_3 sensor	3	600
HCN sensor	3	250
VOC sensor	3	1000
Circuitry (ICs) and wiring	---	150
LCD and Computer		500
Others	---	300
Total		2800

Chapter Two

Gas Pollution and its Treatment by Absorption

- Introduction to Air Pollution Problem.
- Environmental Impacts of Gases.
- Gas Absorption Treatment Method.
- Packed Column Design Parameters.

Chapter 2
Gas Pollution and Its Treatment by Absorption

2.1 Introduction to Air Pollution Problem

Air pollution problem becomes one of the most important global problems overall the world. It occurs as a result of pollutants entering into atmosphere which come from combustion processes, fuel burning, factories chimney, and other operations that produce pollutant gases.

Pollution affects creature's health and the quality of life; it causes a lot of diseases for human beings such as breathing problems and cancer, it doesn't only affect human beings, but also animals, plants, and ecosystem will be threatened.

Pollution changes earth's atmosphere; it allows more harmful radiation from the sun. At the same time this polluted atmosphere is becoming a better insulator, preventing heat escaping back into space and leading to a rise in global average temperatures. Scientists predict that the temperature increases referred to as global warming, will affect world food supply, alters sea level, makes weather more extreme, and increases the spread of tropical disease.

The baking process of cut-off wheels, releases hazard pollutant gases into the atmosphere. These may include carbon monoxide, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ammonia (NH_3), H_2S, HCN, and volatile organic compound (VOCs). These gases cause various healthy impacts.

2.2 Environmental Impacts of Main Polluting Gases

The pollutant gases have environmental impacts, which affect all aspects of life on the planet. The effects of these pollutants are illustrated in table [A.1] in appendix [A]. The following subsections highlights major points related to these impacts. Table 2.1 summarizes the pollutants major impacts.

Table 2.1: Standard Allowable Limits of Pollutant Gases.

No.	Gas	Major impact
1.	CO	* Reduces the amount of oxygen carried by hemoglobin.
2.	NO_2	* Contributes to the formation of photochemical smog. * Respiratory problems
3.	SO2	* Irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest.
4.	H_2S	* Causes the nose to stop perceiving its smell after a few inhalations. * Can cause death within just a few breaths at high concentrations.
5.	HCN	* Affects the nervous systems. * Can cause death.
6.	VOC	* Eye, nose, and throat irritation.

Table 2.2: The allowable limits of main pollutants.

Gas	Allowable ppm	Average (Minutes)	Allowable ppm	Average (Hours)	Allowable ppm	Average year	Ref.
CO	35	60	9	8	0.2	1	17
NO_2	5	15	25	8	0.053	1	18
SO_2	0.2	10	2	8	0.03	1	18
H_2S	10	10	20	8	0.23	1	18
HCN	4.7	15	10	8	0.2	1	18
NH_3	35	15	25	8	1-5 ppb	1	18
VOC	5	10	25	8	0.35	1	19

2.2.1 Carbon Monoxide (CO) [5]

High levels of carbon monoxide are poisonous to humans, and it can't be detected by humans as it has no taste or smell and can't be seen.

Increased levels of carbon monoxide reduce the amount of oxygen carried by hemoglobin around the body in red blood cells. The result is that vital organs, such as the brain, nervous tissues and the heart, do not receive enough oxygen to work properly. At very high concentrations of carbon monoxide, up to 40% of the hemoglobin can be bound to carbon monoxide in this way. This level will almost kill humans.

2.2.2 Nitrogen Dioxide (NO_2) [5]

Nitrogen dioxide is a nasty-smelling gas. Some nitrogen dioxide is formed naturally in the atmosphere by lightning and some is produced by plants, soil and water. NO_2 is an important air pollutant; because it contributes to the formation of photochemical smog, which can have significant impacts on human health.

The main effect of breathing in raised levels of nitrogen dioxide is the increased likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis, according to table (2.2).

2.2.3 Sulfur Dioxide (SO_2) [5]

It is invisible and has a nasty, sharp smell. It reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.

Sulfur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest. The effects of sulfur dioxide are felt very quickly and most people would feel the worst symptoms in 10 or 15 minutes after breathing it in.

2.2.4 Hydrogen Sulfide (H_2S) [6]

The health effects standard for hydrogen sulfide gas is 15 ppb (Parts per billion), daily maximum one-hour average, not to be exceeded more than seven times per year.

At low levels of H_2S, the odor of hydrogen sulfide gas can be perceived at levels as low as 10 ppb (parts per billion).At levels of 50-100 ppm (parts per million), it may cause the human sense of smell to fail. Exposure to lower concentrations can result in eye irritation, a sore throat and cough, shortness of breath, and fluid in the lungs. These symptoms usually go away in a few weeks. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory, and dizziness.

At high levels exposures (usually greater than 300 ppm), H_2S has the amazing effect of causing the nose to stop perceiving its smell after a few inhalations, which may lead to the inhalation of a toxic or fatal dose (which can occur at 600 ppm). Breathing very high levels of hydrogen sulfide can cause death within just a few breaths. There could be loss of consciousness after one or more breaths. At high levels, hydrogen sulfide gas may paralyze the lungs, meaning that the victim may then be unable to escape from the toxic gas without assistance.

2.2.5 Hydrocyanic Acid (HCN) [7]

Hydrocyanic Acid (HCN) has a dangerous effect on human health, nevertheless, it has a healthy impact according to the table (2.1), which shows that this toxic gas affects the nervous systems and can cause death, the toxicological endpoints considered for chronic toxicity are the central or peripheral nervous systems.

2.2.6 Volatile Organic Compounds – (VOCs) [8]

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. Table (2.3) includes a list of various VOC types. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands. Examples include: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.

Health Effects of VOCs include Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctive irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.

Table (2.3): Various VOC Types [16].

Types of VOC Air Releases

VOC Type	Process Source	Emission Type	Quantifiable
Methane	Anaerobic Digestion	Fugitive	No
Acetaldehyde	Fermentation/Product Storage/Boiler	Vent/Fugitive	Yes
Acetic Acid	Fermentation	Fugitive	No
Formic Acid	Fermentation	Fugitive	No
Propionic Acid	Fermentation	Fugitive	No
Formaldehyde	Boiler	Vent	Yes
2-Furfural	Pretreatment	Fugitive	No
Ethyl Alcohol	Fermentation/Product Storage	Vent/Fugitive	Yes
Isopropyl Alcohol	Fermentation/Product Storage	Fugitive	No
N-butyl Alcohol	Fermentation/Product Storage	Fugitive	No
N-propyl Alcohol	Fermentation/Product Storage	Fugitive	No
S-butyl Alcohol	Fermentation/Product Storage	Fugitive	No
Isobutyl Alcohol	Fermentation/Product Storage	Fugitive	No

2.2.7 Ammonia (NH_3)[16]

Ammonia is a nasty-smelling gas, although its concentration may be less than 25 (ppm); it can be detectable by smell according to the table (2.4).

Ammonia concentration in air (ppm)	Health Symptoms
< 25	Detectable by smell. Maximum Permissible Exposure Limit (PEL)[1)]
30	Uncomfortable, breathing support required. Maximum exposure 15 minutes[1)]
50	OSHA[2)] maximum exposure limit
100	Irritated eyes, throat and mucous membranes. Mild eye, nose, and throat irritation, may develop tolerance in 1-2 weeks with no adverse effects.
140	Moderate eye irritation, no long-term effect in exposures of less than 2 hours
400	Moderate throat irritation. Damage of mucous membranes with more than one hour exposure
500	Immediate danger to life limit (IDLH)
1,000	Caustic to airway
1,700	Fatal after short exposures - less than half an hour
5,000	Immediate hazard to life
> 15,000	Full body protection required
160,000 - 170,000	Flammable in air at *50°C*

2.3 Gas Absorption Treatment Method[9]

Gas absorption is one of the main techniques used in pollution control devices such as wet scrubbers and spray-dryer-type dry scrubbers for the removal of acid gas compounds and water-soluble organic compounds. The acid gas is absorbed as it comes into contact with the liquid. The rate of pollutant capture increases as the contact between the liquid and the pollutant laden gas increases. Therefore, factors such as (1) sufficient mixing of the pollutant containing gas stream and the liquid, and (2) increased surface area of droplets promote absorption.

In absorption processes, the gas phase pollutant is brought into close contact with the liquid to facilitate diffusion across the gas-liquid interface. The gaseous pollutant must diffuse through a thin boundary layer on the gas side of the interface (gas film) and a thin boundary layer on the liquid side of the interface (liquid film.)

Once the pollutant enters the liquid phase, it can simply dissolve, or it can react with other chemicals also in the liquid. In the case of simple dissolution, there may be a definite limit to mass transfer. Once the pollutant in the liquid phase has reached its solubility limit, there is no net transfer of pollutant across the gas-liquid interface. At this point equilibrium has been reached whereby the amount of gaseous pollutant that continues to dissolve equals the amount coming out of solution and reentering the gas phase.

2.4 Gas-Liquid Equilibrium and Solubility

Henry's law can be used to determine the solubility limit of absorption, each gas has certain solubility limit in water depending on temperature. The solubility limits of various common gases are listed in table (2.5).

Table (2.5): Solubility of Common Gases in Water [18].

Gas	NH_3	SO_2	H_2S	Cl_2	O_2	CO	CH_4	NO_2	HCN
Solubility (g/L)	654.9	228.04	7.1	0.64	0.06	0.043	0.038	REACTS	Not Available

Gas solubility decreases with temperature. Figure (2.1) presents the solubility of CO, H_2S, NH_3, O_2, and SO_2 in water as functions of temperature. For this reason, absorption is usually done at low temperature[illegible].

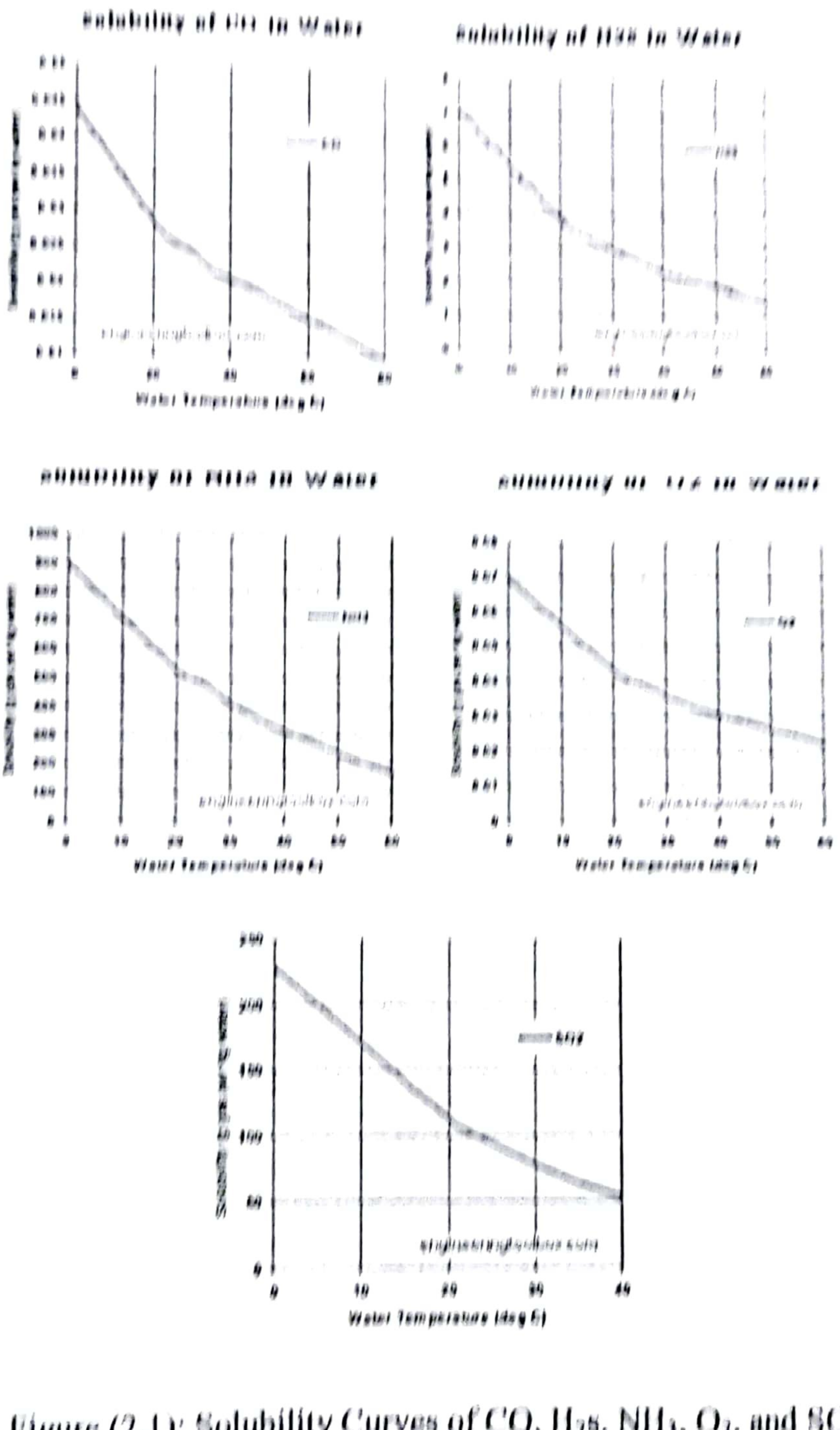


Figure (2.1): Solubility Curves of CO, H_2S, NH_3, O_2, and SO_2 in Water as Functions of Temperature.

When the gaseous phase is a mixture of two or more gases, the equilibrium distribution of a particular gas between gaseous and liquid are given by equilibrium curve. It is a relationship between concentrations of the gas in the gas phase (ex. mole %) versus its concentration in the liquid phase.

Such equilibrium curves are essential for designing absorption processes. At low concentrations, the equilibrium relationship becomes linear, and obeys Henry's law, given by the following equation:

$$y = H / x \qquad (2.1)$$

Where:

y: Mole fraction in gas (eg. NH_3 in air).

H: Henry's constant.

x: Mole fraction in liquid (eg. NH_3 in water).

Table (2.6) provides Henry's constants expressed as k_H for various gases at 298K.

Table (2.6) Henry's constants [17].

Gas	k_H	units
CO	1052.63	L·atm/mol
H_2S	515	L·atm/mol
O_2	4.3×10^4	L·atm/mol
NO_2	1.0×10^{-2}	mol/atm
NH_3	0.76	Dimensionless
SO_2	38	L·atm/mol
HCN	0.122	L·atm/mol
O_3	5×10^3	L·atm/mol

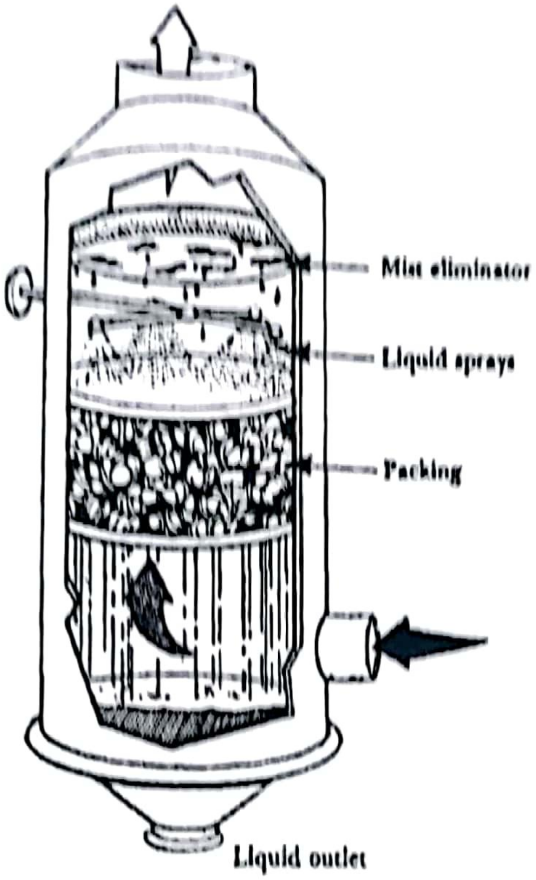
2.5 Packed Column Design Parameters[19]

This section analyses the design parameters for a packed tower used for removal of toxic acid gas from a process gas stream for environmental health protection purposes.

The design methodology is summarized below and implemented in chapter 5:

- The packed tower consists of gas inlet, gas outlet, liquid inlet, liquid outlet, liquid distributer, and packing material as shown in figure (2.2)
- Various packing materials are used such as (Rasching Ring) which is dependent for the implemented design, and is used to increase the contact area between the gases and the water.
- Designing packed beds include selecting and determining the following:
  1) Packing material and construction material.
  2) Liquid and gas flow rates.
  3) Bed diameter.
  4) Bed height.
  5) Distributer.
  6) Pump, fan and valves.

The design plans should consider the factors such as exhaust gas characteristics (average and maximum flow rates to the absorber), and solubility of the toxic pollutant to be removed should be measured or accurately estimated. Another important parameter is the liquid flow (the type of scrubbing liquid and the rate at which the liquid is supplied to the absorber).



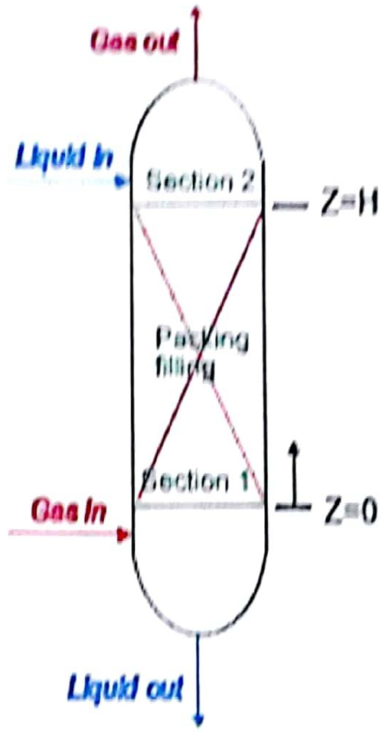


Figure (2.2): Packed tower absorber.

Starting from the equilibrium data, Henry's law constant is needed and can be determined from the slope of the y-x diagram. Based on mass balances across the absorber and equilibrium data, the minimum liquid-to-gas ratio can be determined from which the minimum liquid flow rate and the actual operating conditions are established. This step is illustrated in figure (2.3).

After selecting the packing material, using the generalized flooding and pressure drop correlation (or chart, see Appendix [I]), the mass flow rates of liquid and gas, and the fluid and packing characteristics, the mass flow rate of the gas per unit cross sectional area of the tower was determined.

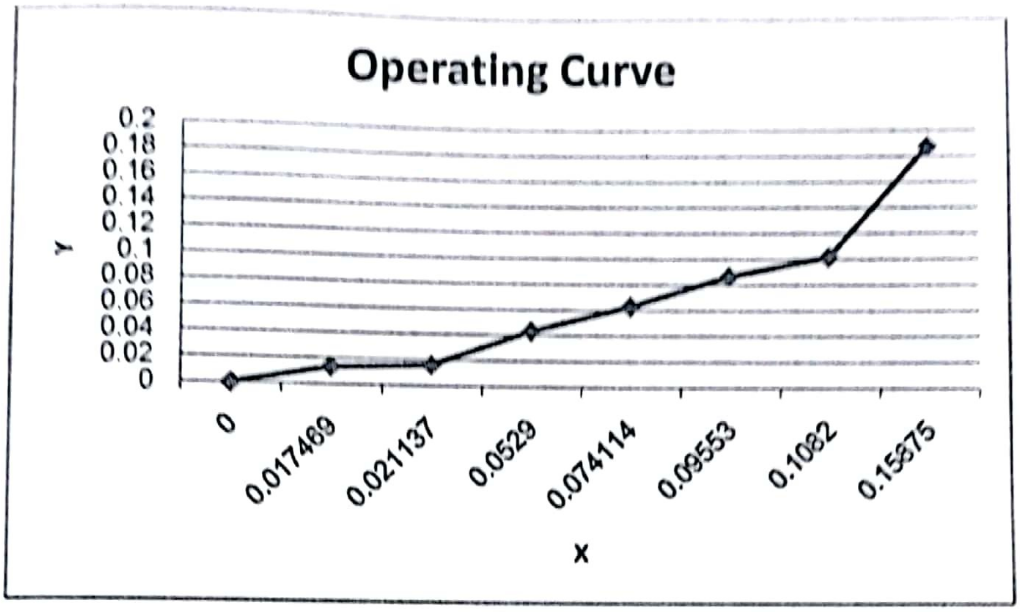


Figure (2.3): Illustration of Step-1 in Column Design for Obtaining Required Liquid Flow Rate.

The operating liquid flow rate depends strongly on the inlet gas flow rate, solute concentration in the inlet liquid, and solute removal efficiency.

The operating point (ranging from 50 to 75% of flooding velocity) will be used to determine the required cross-sectional area and diameter of the absorption tower. This step is illustrated in figure (2.4).

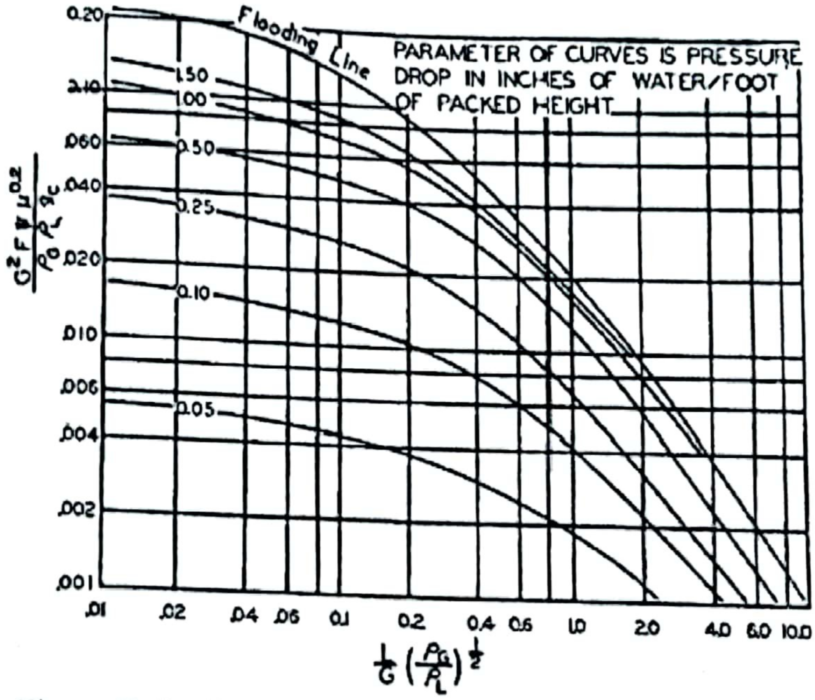


Figure (2.4): Illustrates the step 2 of obtaining the column diameter.

The tower diameter depends strongly on: the inlet total gas flow rate, percent of the flooding velocity selected, packing factor, size of packing, and on the type of material used (at fixed size of packing), and the properties of this material are in appendix [I]. The tower height depends on toxic gas concentration in the inlet gas, and on the required toxic pollutant removal efficiency, as well as an equilibrium data, however, independent of gas and liquid flow rates, and the general equation for estimating bed height is:

$$Z_t = H_{OG} \times N_{OG} \qquad (2.2)$$

Where:

Z_t: Tower height.

H_{OG}: The height of gas phase mass transfer unit.

N_{OG}: Number of gas phase mass transfer unit.

Chapter Three

Industrial Operation in Eagleflex Factory

- Introduction.
- Factory Layout.
- Raw Materials Used in the Cut-off Wheels Production.
- Equipments Used in Cut-off Wheels Production.
- Industrial Operation of Cut-off Wheels.
- Description of Industrial Operation in Eagleflex.
- Introduction to the Existing Treatment Process.

Chapter 3

Industrial Operation in Eagleflex Factory

3.1 Introduction

When a spot of light has been focused on the cut-off wheels manufacturing in Eagleflex factory; many production procedures showed up, and the manufacturing processes of the cut-off wheels passed through many challenges, either in the sourcing of raw materials, or in the environmental impacts of the industrial operation.

Neither the sourcing of raw materials, nor the environmental impacts of the manufacturing of the cut-off wheels have been an obstacle for developing this industry in Palestine, and more precisely in Hebron city. Furthermore, the products of Eagleflex factory which label is called "Eagle Flex" had passed through many quality tests made in USA. However, its products had overcome the quality of the cut-off wheels of "Israel", the competition with which could be the main obstacle in developing this industry in Palestine.

In order to handle the pollution problems in Eagleflex and develop a solution of these problems, it is essential to figure out the industrial operation of making cut-off wheels (fibers), and analyze the operation of the existing treatment process (waterfall scrubber).

This chapter summarizes the manufacturing process, including a detailed literature description of the process and the main raw materials for manufacturing cut-off wheels. In addition a complete description of the process in Eagleflex factory is mentioned within the following sections.

The cut-off wheels are used in cut-off applications of all kinds, in the metal, construction, rail, and other industries, and so they are made of mixing chemical compounds that will produce the desired cutting wheels properties.

The detailed manufacturing processes of cut-off wheels are considered to be confidential industrial information, but the general description of the process can be obtained from literature. The main raw materials need to be studied in order to understand their chemical formula, and to identify the main gases that cause the pollution problem in Eagleflex Company. The following raw materials are used for manufacturing cut-off wheels:

1) Vitrified bond: this bond affects the product rigidity.
2) Resin bond - Organic bond makes the wheel tougher, suited for heavy-duty operations, high operating speeds, rough grinding, and cut-off applications.
3) Silicon Carbide.
4) Aluminum Oxide.

3.2 General Production Process

Manufacturing of cut-off wheels is based on blending various raw materials, including particulate matters and bonding polymer, and then baking these material after being attached to the fibrous structure of the wheels. Baking is accomplished in large ovens up to temperature higher than 170 C° for long periods. This would result in the release of various gases as a result of polymeric reactions in the oven. Upon baking completion, the oven exit is opened to release the gases and cool the products, while the door is slightly opened. A generalized block diagram for the industrial process is shown in figure (3.1)

Eagleflex developed a simple absorption process, which it calls waterfall, to treat the effluent gases. The idea was captured by Eagleflex from its observation of reduced environmental impacts during rainfall in winter.

Figure (3.2) and figure (3.3) show the layout of Eagleflex factory in 2-D and 3-D respectively, and the locations of the ovens and the nozzle that collect gases from exit, which lead the gas through a twelve meters pipe to the waterfall scrubber.

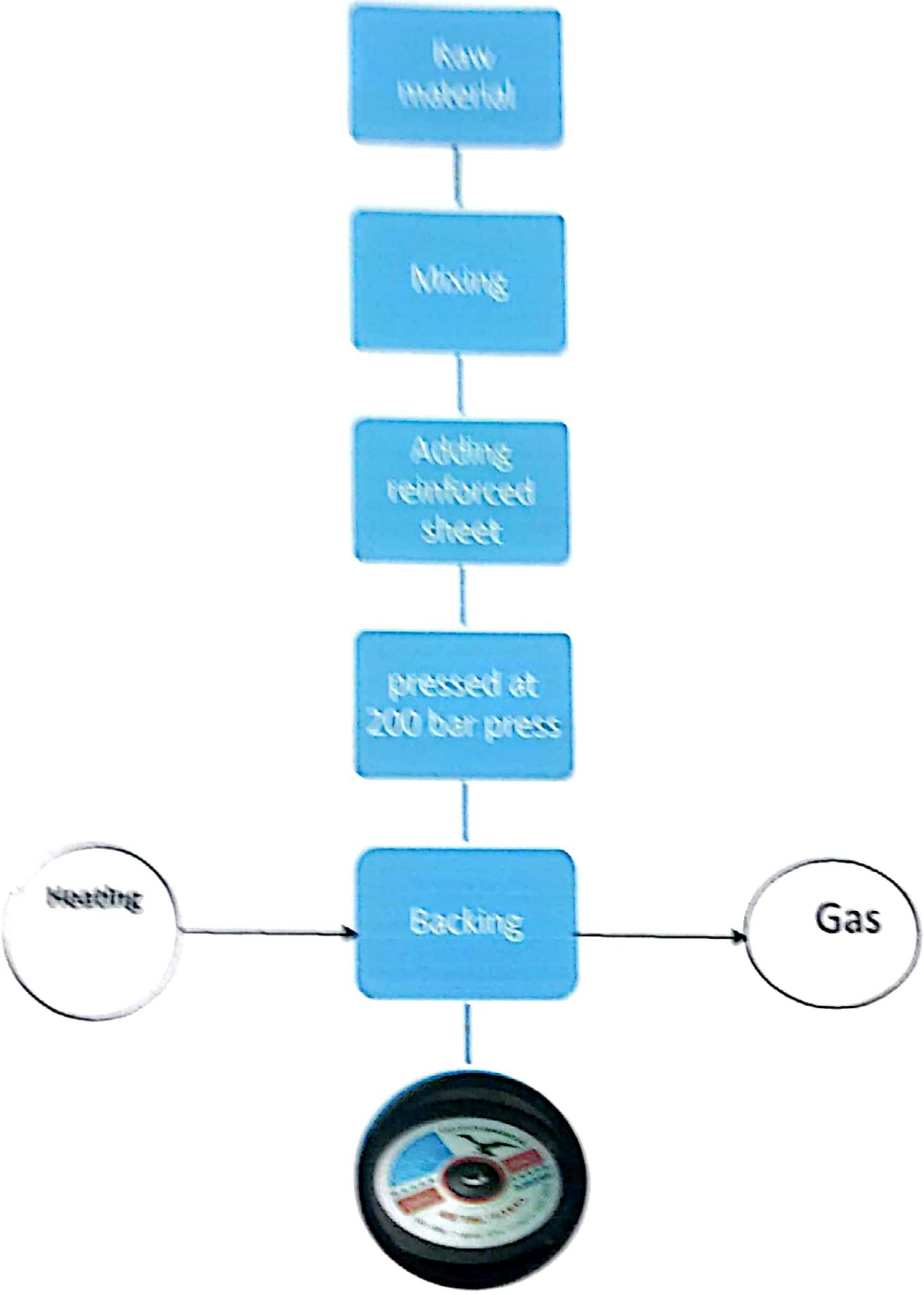


Figure (3.1): Generalized Block Diagram for the Industrial Process.

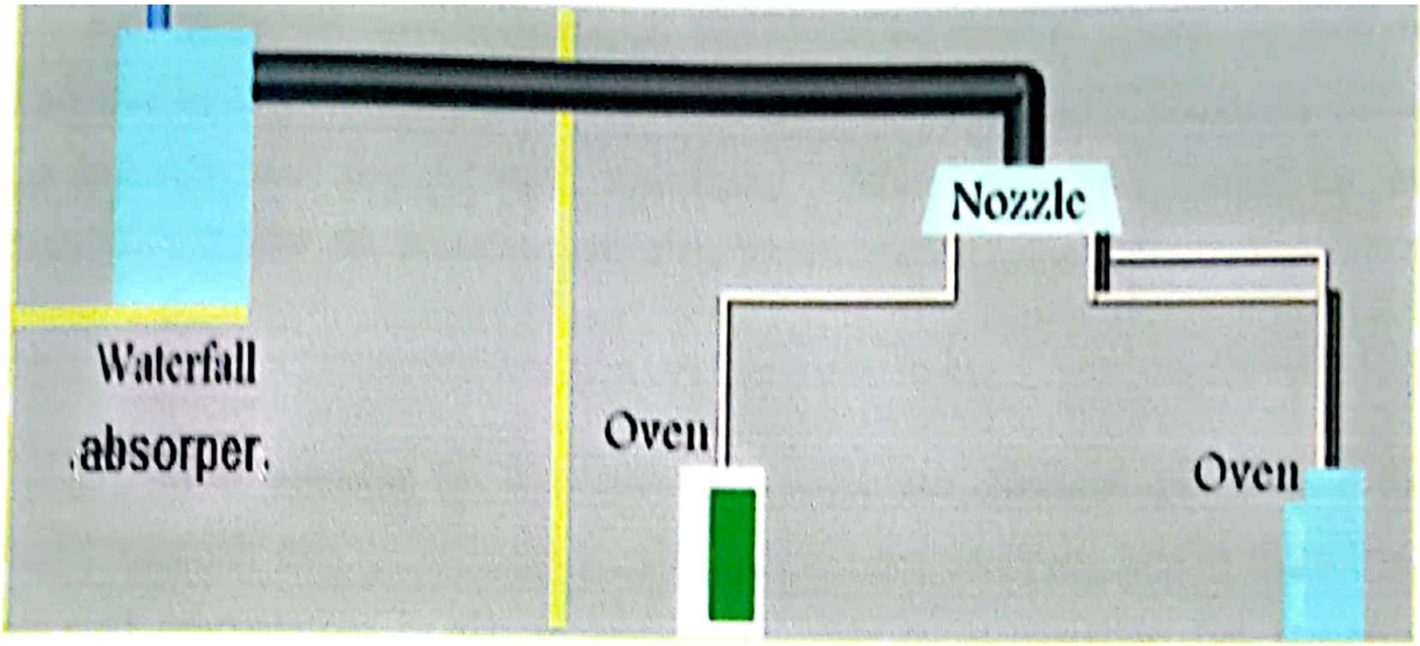
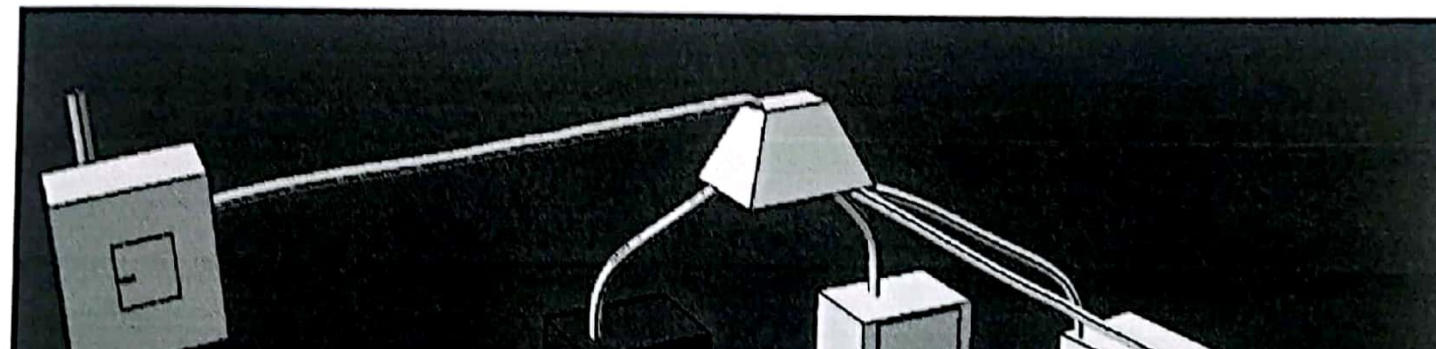


Figure (3.2): 2-D Layout of Eagleflex factory



3.3 Raw Materials

Raw materials are the bases of manufacturing cut-off wheels as well as manufacturing any other products. Israeli occupation forces a lot of obstacles on the local industry, and due to many restricting policies that were forced on the Palestinian industry; the development of the local industry is limited.

So, when ordering the raw materials, which are chemical compounds, the brought materials may be different from the needed raw materials, and as there is no developed laboratories in the factory or in Hebron to examine the chemical compounds, the chemist, has developed a way to determine wither the raw material are adequate or not for manufacturing the cut-off wheels.

There are a lot of raw materials used in the manufacturing process of the cut-off wheels, and the following table describes the chemical compounds that are the main raw materials and their chemical formulas:

Table (3.1): Main Raw Materials and their Chemical Formulas.

Raw material	Chemical formula
Resin	Confidential
Bacalite	Confidential
Brolite	Confidential
Pyrix	Confidential
Iron(II) Sulfide	FeS
Fused Aluminum	AL_2O_3
Silicon Carbide	SiC
Calcium Sulfide	CaS

3.4 Equipments Used in Fibers Making Process

There are a lot of equipments used in the manufacturing of fibers, and these equipments can be categorized as manufacturing tools, testing tools, and packing tools.

3.4.1 The Mixers

When a chemical mixture of the fibers is to be prepared, the mixers are used to establish the manufacturing process, so these equipments are used to mix the chemical compounds with the appropriate percentage of each compound, these mixers are shown in the figure (3.4).

Figure (3.4): The Mixers.

3.4.2 The Piston Press

This press is used to develop a sufficient pressure on the chemical mixture and reinforced plastic sheet, in order to compress these components together; so the baking process of the fibers will take place in the oven.

The pressure generated by the press equals two hundred bars, and the press is shown in the figure (3.5).

Figure (3.5): The press.

3.4.3 The Ovens

Fibers are baked in ovens that supplies heat energy, by a mean of coils, to bake the fibers. The temperature which increases with time, starts from room temperature, and ends lower than 200 C°, as shown in figure (3.6), the outer and inner dimensions of the ovens are illustrated in the table 3.1 [see appendix B].

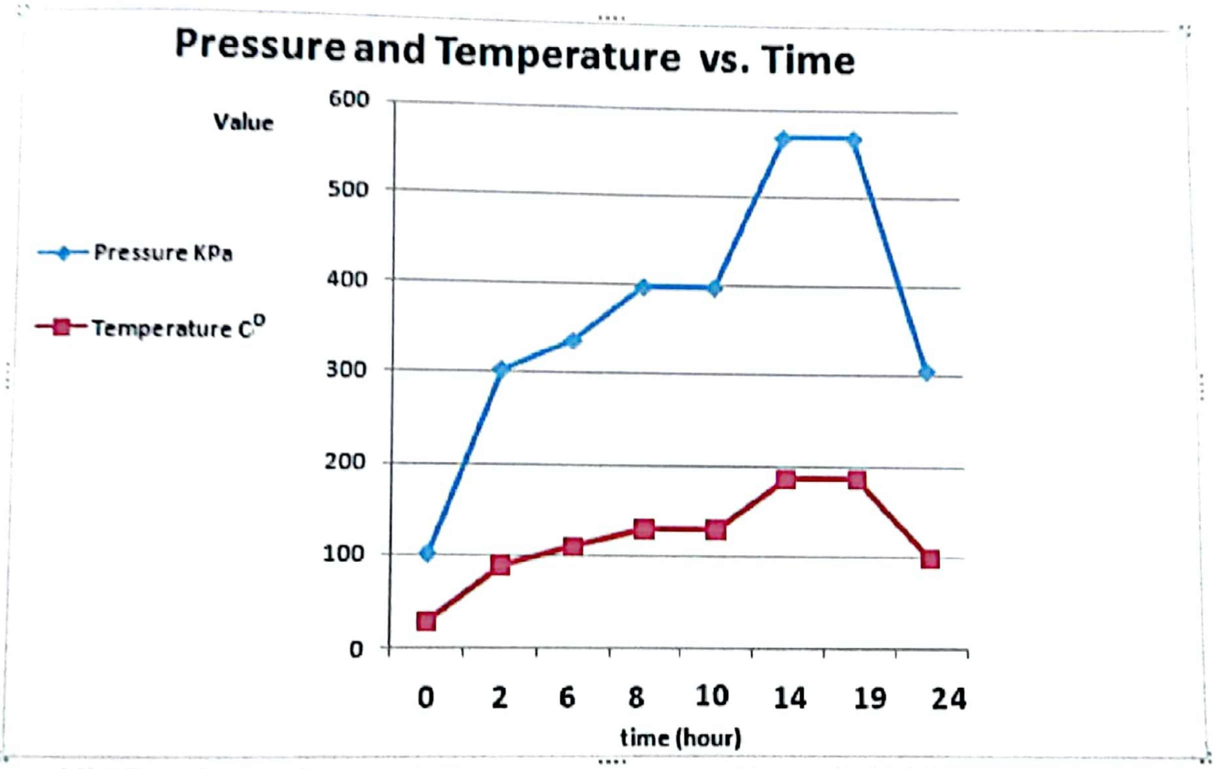


Figure (3.6): The temperature and pressure curves in the ovens with time.

The pressure curve shown in figure is estimated from temperature curve assuming ideal gas law (closed system).

Walls of the ovens are insulated by fiber glass isolating material, in order to keep the ovens under the desired temperature, by isolating the ovens from the surroundings. The ovens exit is connected to pipes of 4.5in (125mm) diameter, which are collected to a nozzle that will lead the gases to the waterfall scrubber; figure (3.7) shows a figure of an oven.

Figure (3.7): The Oven.

3.4.4 Testing Devices

For making the optimum performance at working conditions of the manufactured fibers, a test for static balance must be done, and the device is manually operated, and the maximum allowable undesired weight is three grams in the fiber. The testing device is shown in the figure (3.8).

A second testing device is used for dynamic balance, where the speed of the fiber disk is taken into consideration, however, the fibers must not fail at the speed of 7000 rpm (rev/min), but in the local usage of fibers, it is only operated on 3000 up to 5000 rpm. However, Eagleflex products exceed 15000 rpm (based on report author's observation).

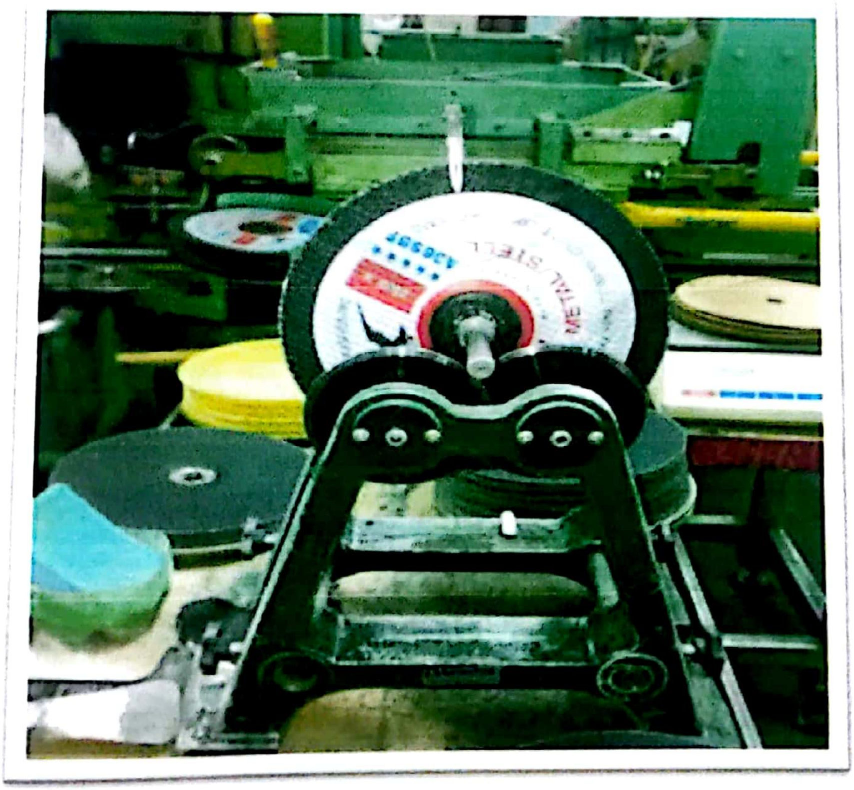


Figure (3.8): Static Balance Testing Device.

3.5 Description of Industrial Operation

After introducing the equipments used for making fibers, it is clear now that the industrial process is preceded by a chemical process. However, the main chemical compounds that are mixed to produce fibers, are fused aluminum, silicon carbide, calcium sulfide, chemical bonding material called (Resin), which is used for combining these chemical compounds together. Resin is two types; one is liquid, and the other type is in the form of powder, which is called (Bacalite) and it has an industrial code number, also (Brolite) material is used, and (Pyrix) material, but in case that there is a mixture for making fibers of 9" diameter.

- The weights of the chemical raw materials are determined for a specified type of wheels; the materials are illustrated in the figure (3.9).
- Materials are mixed in two different mixers, the first mixer is used to mix the Bacalite, Brolite, Pyrix, and some additives, and the second mixer is used for mixing the Resin material with the iron fillings (FeS), as illustrated in the figure (3.4).
- Both mixtures are mixed again in the main mixer, with a 120 rpm speed, as shown in the figure (3.10).
- The produced mixture is then filled in boxes, and left from 30 up to 60` minutes; to make a fermentable mixture, which is illustrated in the figure (3.11).

Figure (3.9): Chemical materials. Figure (3.10): The main mixer.

Figure (3.11): The mixture is resting in boxes.

- Then the mixture is put into a Sieve, in order to remove the big undesired particles from the mixture, which is illustrated in the figure (3.12).
- Now the mixture is ready to be loaded into the press molds, after putting the reinforced plastic sheets, which is illustrated in the figure (3.13).
- Then they are pressed in a gradual pressure up to 200 bars.
- The produced unbaked fibers are loaded into special disks as molds.
- These molds are loaded into the ovens, to be baked.
- Fibers are loaded on plates inside the oven, which are designed to bear a big amount of heat inside the ovens, where the temperature reaches 185 C°, which is illustrated in the figure (3.14).

Figure (3.12): The sieve.

Figure (3.13): The reinforced plastic sheets

- Then the oven is completely closed and is not opened till the twenty four hours period is passed, since baking fibers is very precise manufacturing operation and needs special conditions to be done accurately.
- During the first nineteen hours a heater works and heat is developed inside the oven, temperature must increase till it reaches 185 C°.
- On the other hand, for the next five hours the heater must shut down, but the inside fan must still work; to make the air in a cyclic rotation through out the oven, however, the temperature of the oven will decrease approximately to 140 C° in winter and to 150 C° in summer.
- Simultaneously, a valve located in the pipe above the oven opens manually in one oven and automatically in the others, for evacuating the gas from the oven.
- And after 24 hours of baking fibers, oven's door is opened slightly.
- fter the baking of fibers is finished, a sample from the fibers is taken to the dynamic balance test, by a mean of centrifugal device, cut-off wheels are tested on a speed of 7000 rpm, but the whole products of fibers must be tested by static balance device.
- The tested products are packed and shipped, to be sold either locally, or exported to the international markets; the product now is carrying the factory label as illustrated in the figure (3.15).


METALISTEEL

Chapter Four

Evaluation of Gas Treatment Process in Eagleflex

- Introduction.
- Existing Treatment Process
- Qualitative Study of Treatment Process.
- Quantitative Study of Treatment Process.
- Experiments.

Chapter 4

Evaluation of Gas Treatment Process in Eagleflex

4.1 Introduction

It is clear that the manufacturing process of cut-off wheels releases pollutant gases, and as said before, for developing a solution of this problem, it was essential to figure out the industrial operation of making fibers, after that, an evaluation (qualitative and quantitative evaluation) is done in this chapter, and in order to find out the efficiency of the system for potential improvement, and in order to develop a new technique to reduce the environmental impact, which is designing and building a scrubber called "Packed Tower"; to increase the efficiency of the pollutant gas treatment process (Waterfall) in Eagleflex.

4.2 Existing Treatment Process

As stated before, the existing treatment process (waterfall scrubber) in Eagleflex factory is made with no engineering background of scrubbers, but the art of developing such an idea, has came from the famous proverb "Necessity is the Mother of the Invention", consequently, after noticing the reduction of the bad smell in winter, an idea of using the water in treating the polluting gases had been born. However, a gas absorption process is well documented in engineering literature and implemented in various industries.

Figure (4.1) illustrates naturally occurred acid rain process which is the base for the idea of the waterfall scrubber in Eagleflex, however, the creative idea also had been brought to life, and the equipment was produced, and the bad smell in the area surrounding the factory had been reduced, and no complains came from the factory's neighbors, on the other hand, the workers were able to do their works with more comfortable conditions.

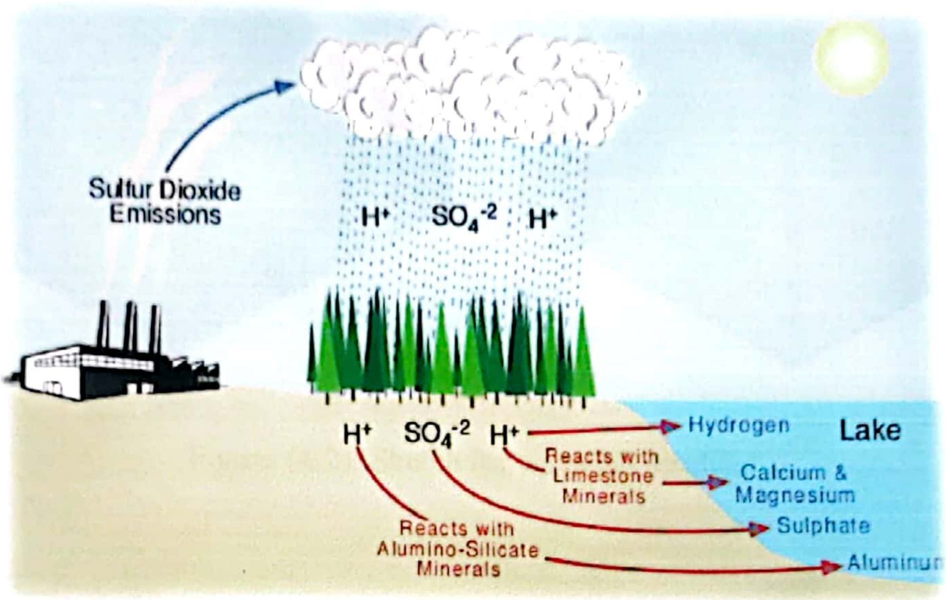


Figure (4.1): The absorption process in the nature.

The figure (4.2) and figure (4.3) show the existing treatment process in Eagleflex factory, and so the operation of this equipment can be described as following:

The pollutant gases that come from the ovens enter the equipment, through the pipe that is connected to the nozzle, by a suction force drained from the fan that is located above the waterfall, consequently, the water pump delivers the water required to establish the treatment process, and then water droplets will contact with gas, and the polluting gases will be absorbed as it is soluble in water.

Also the schematic in the figure (4.3) shows the inner details of the waterfall scrubber and for more details see appendix [C].

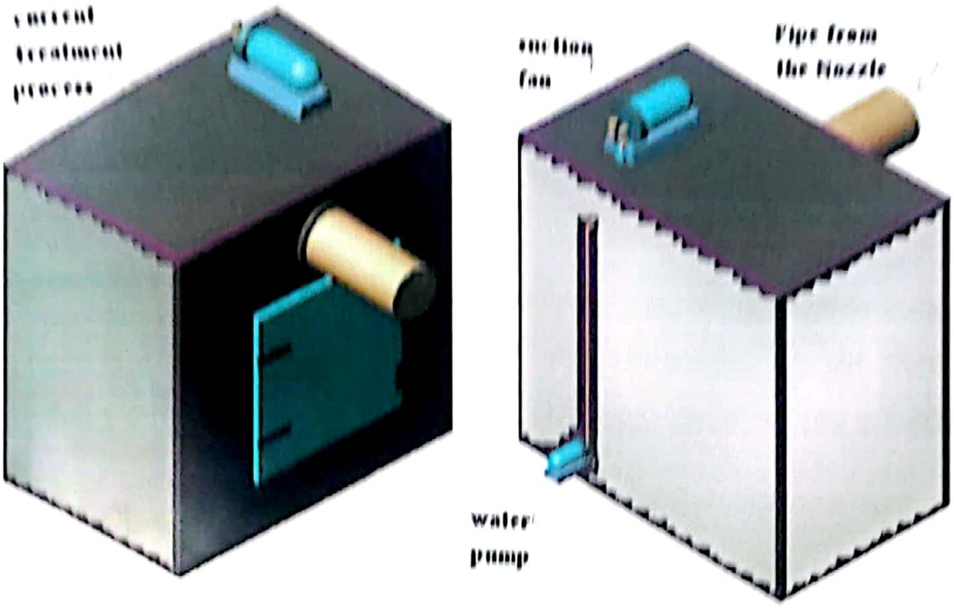


Figure (4.2): Sketch for waterfall scrubber

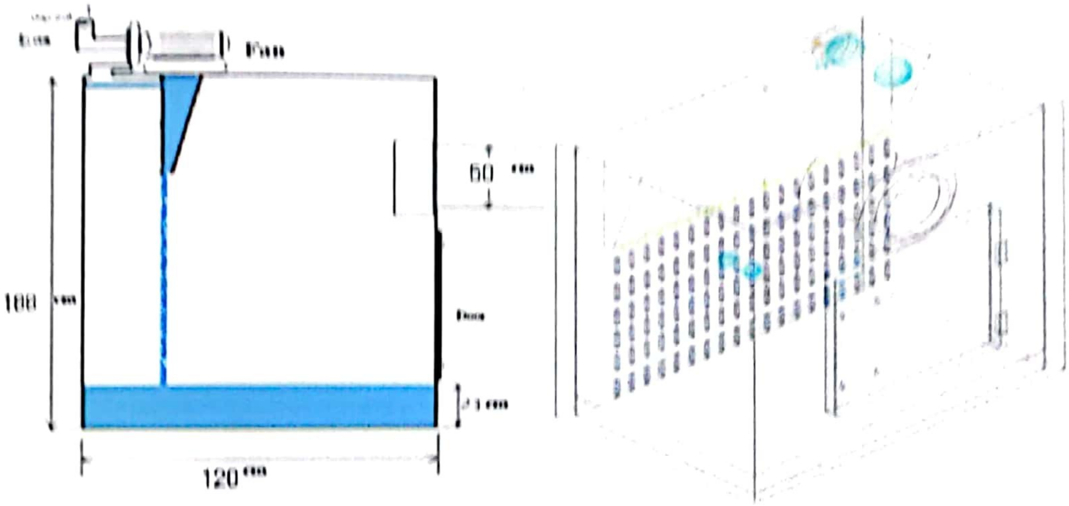


Figure (4.3): Schematic for waterfall scrubber

4.3 Qualitative Study of Treatment Process

The purpose of the evaluation that was done in the factory is to consolidate methodology for design of the packed tower, as well as improving the efficiency of the existing treatment process, and to give data readings and interpretation.

The system conceptual manufacture is based on the absorption technique, which is defined as the transfer of a gaseous component from the gas phase to a liquid (absorbent) phase through a gas-liquid interface, based on gas solubility in liquid.

But it has got limitations and shortages, and the qualitative performance evaluation of this scrubber, shows that a corrosion due to chemical substances, which come from the pollutant gases that are generated in the ovens, due to the baking process of fibers, the corrosion is shown in the figure (4.4), which is expected to be due to Sulfur dioxide (SO_2), and also from the Hydrogen Sulfide (H_2S).

Figure (4.4): Treatment equipment corrosion due to pollutant gases.

4.4 Quantitative Study of Treatment Process

4.4.1 Measurement Devices

When focusing on the mixing the raw materials of the cut-off wheels' chemicals, it is clear that these chemical compounds will produce gases when the cut-off wheels are baked in the ovens. So, from the expected produced gases from the baking process, and from the available devices which exist in Palestine Polytechnic University (PPU), specifically in Renewable Energy and Environment Research Unit(REERU), the data that was taken from the factory has given very important quantitative concentration of the polluting gases. The following figures show the devices that were used in measuring the polluting gases concentration.

The pollutant gases (NO_2, SO_2, NH_3, and HCN) are measured by Multi Gas Monitor PGM 3000, and the pollutant gases (CO, H_2S, O_2, VOC and LEL) are measured by EntryRAE PGM 3000, which are shown in the figure (4.5).

Multi Gas Monitor PGM 3000 EntryRAE PGM 3000

Figure (4.5): Multi Gas Monitor and EntryRAE PGM

4.4.2 Concentration of the Measured Gases

For the concentration measurements, when they were done, it was assumed that the flow rate of gas was steady at working condition when ovens release gases, and the gas has no resident time at the existing treating process, with a pressure of one atm.. Also it was assumed that the devices that measures gases concentrations were calibrated.

Strictly speaking, after taking measurements for gases from Eagleflex factory, it was noticed that there were a lot of pollutant gases in the factory, that are produced from the manufacturing of the cut-off wheels, and these measured values were very large, and some concentration of gases had reached the max value that the device could measure, such as the ammonia, so the baking of fibers results in hazard gases.

The main locations that have been taken as a field of measuring pollutant gas concentration are shown in the figure (4.6), as the data was taken after a number of field visits to Eagleflex factory, and it shows the quantities of polluting gases in the factory. Table [4.1] summarizes the data taken from various locations in the factory, and for more detailed data, see appendix [D].

Table [4.2] lists the efficiency of the waterfall scrubber (existing treatment process) in Eagleflex factory. It indicates that there was no reduction for pollutants, on the contrary, there was a stripping process were the polluting gases return from the water to the air, this is an opposite process to the absorption, and this is resulted from the long cycle of the water used in the absorption process, however, a chemical compound is added to the water to increase the contacting surface between the water and gas particles.

Table [4.2]: The efficiency of the waterfall scrubber

Gas(ppm)	(oven)	(waterfall)	(outlet to atmosphere)	Efficiency
CO	92.4	0	1	Stripping
H_2S	0	0	0.2	Stripping
VOC	459	10.2	17.8	Stripping
NO_2	2.42	0.1	0.4	Stripping
NH_3	200	41.3	145.6	Stripping
SO_2	0.6	0.1	0.16	Stripping
HCN	11.4	0	0.2	Stripping

Table [4.3]: Average gas measurement concentration (ppm)

Average Gas measurement concentration (ppm) The water cycle is 32 days.						
Gas	The Oven	The Nozzle	The Outlet	Efficiency % between the Nozzle & outlet	Allowed limit In one year	Expected Gas from industrial process
CO	65.7	1	0.9	10%	0.2 ppm	Yes
H_2S	0	0	0	Not Measured	0.23 ppm	No
O_2	20.13	20.9	20.9	Not Included	Not Included	No
VOC	698.3	30.57	20.0	34.57%	0.35 ppm	Yes
NO_2	1.68	0.0714	0.36	-403.99%	0.053 ppm	Yes
NH_3	200	63.143	69.2	-9.59%	1-5 ppb	Yes
SO_2	0.91	0.257	0.23	10.5%	0.03 ppm	Yes
HCN	11	1.143	1.5	-31.23%	0.2 ppm	Yes

To see the allowable limits in average minutes and hours, see appendix [E].

The main reason that the concentration of the pollutant gases in the oven is different from the nozzle is due to the fact that the nozzle is opened to the atmosphere, and there is a dilution process. Consequently, the pollutant gases that are produced through the baking process of cut-off wheels, reach the existing treatment process with very lower concentration. On the other hand, H_2S that has been measured at the outlet of the waterfall scrubber may be a result of reactions between gases after the chemical compound, which is added to the water to improve the contacting surface, acts as catalyst that promotes the evolution of H_2S.

The charts below illustrate the data in tables [4.2] and [4.3], where the gas concentrations are taken in different locations.

Figure (4.7a):

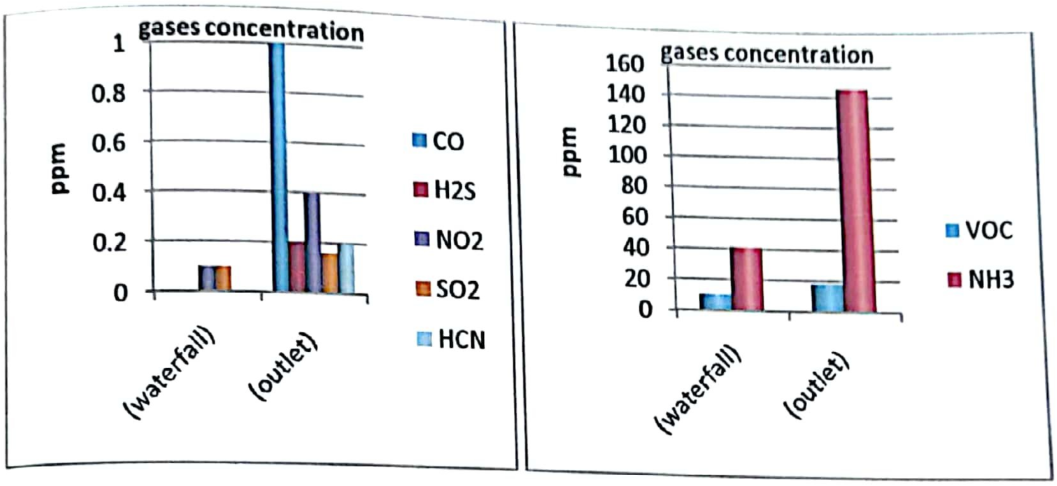
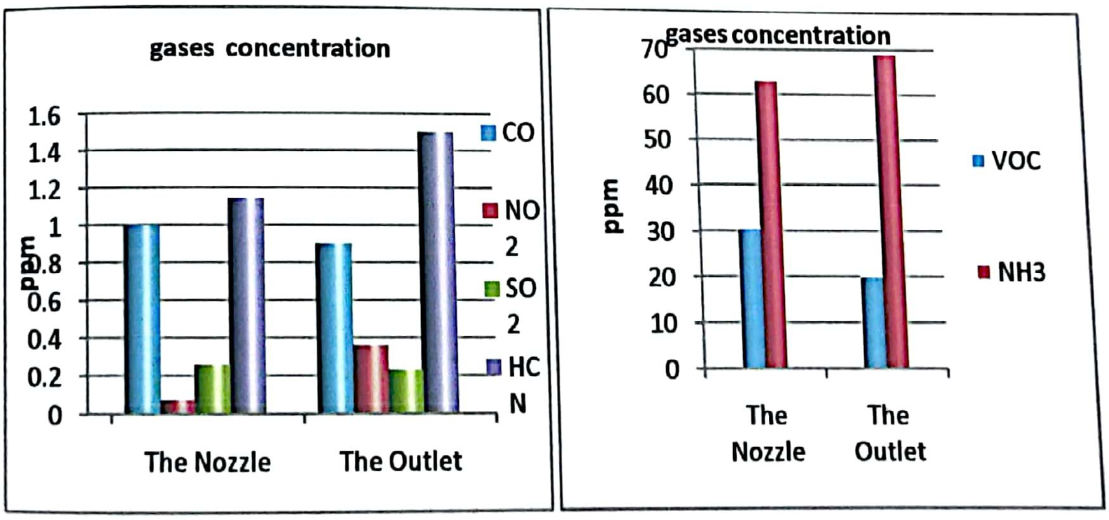
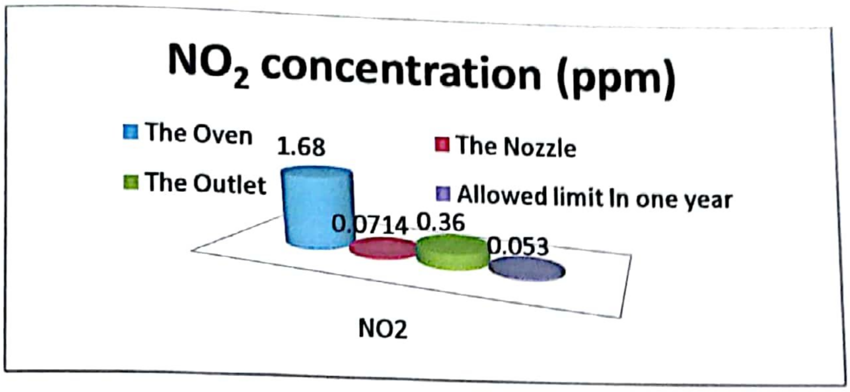
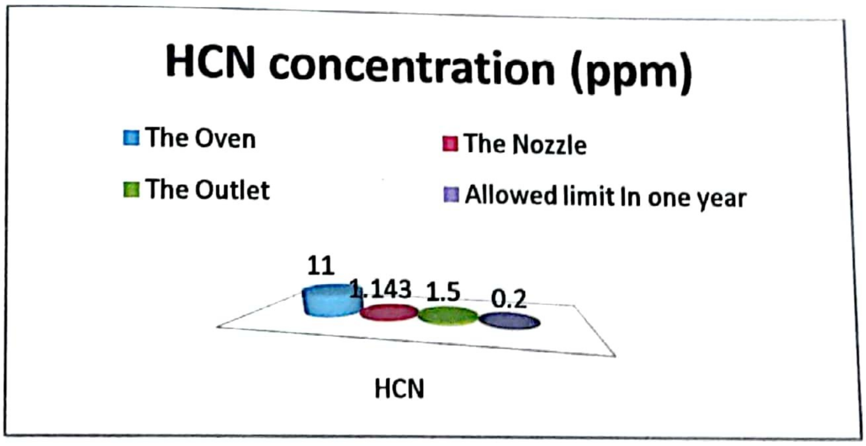


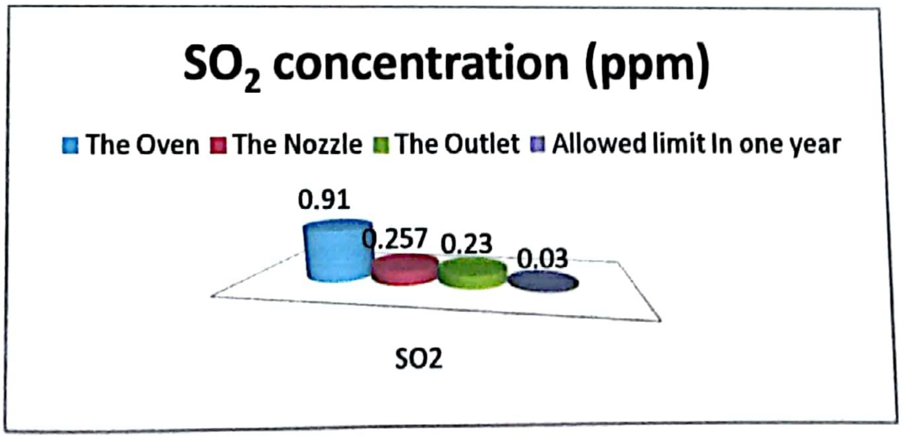
Figure (4.7b):

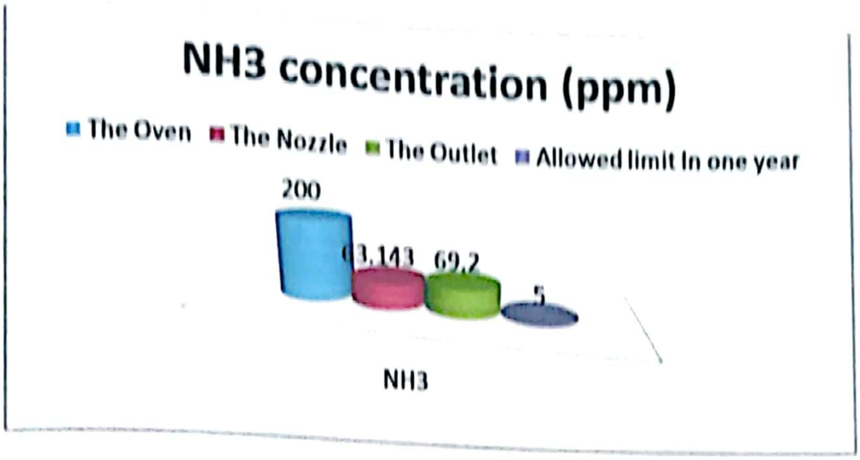


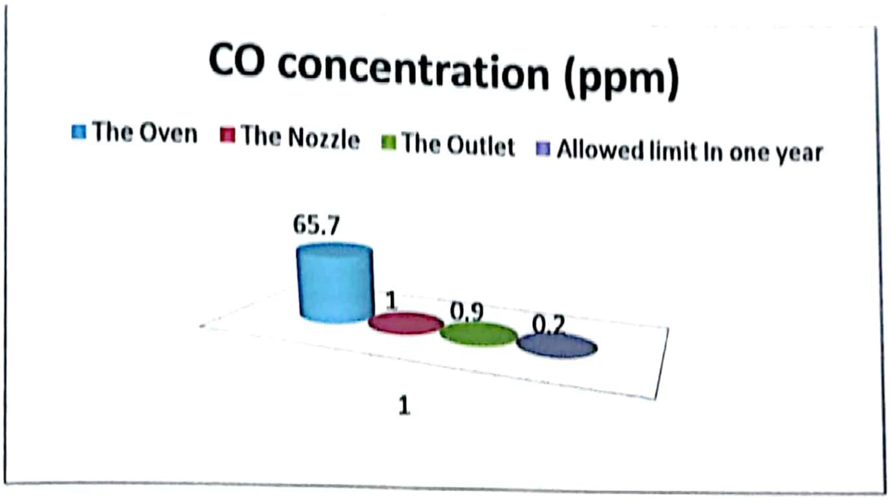
The following charts show the pollutant gases concentration in a different locations from the table [4.3], compared to the allowable value that is not to be exceeded in one year average. The data indicates that if these gases are not controlled in the correct way; there will be very hazard conditions surround the workers in the factory, and there are a lot of environmental impacts due to the large amount of toxic gases released to the atmosphere.











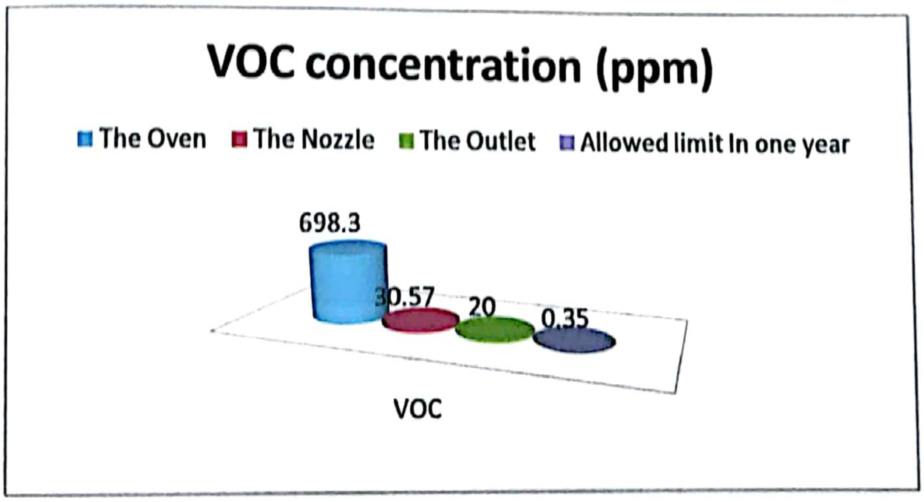


Figure (4.8): Concentration of Pollutant Gases According to (Table 4.3).

These preliminary results of the concentrations of gases have not been confirmed, as the calibration of the measuring devices has not been done yet for logistic delays, but for more convenient measurements, data were taken at the outlet of the waterfall scrubber at the factory, after some recommendations that were given to Eagleflex factory.

Table (4.4): Gases Measurement Results.

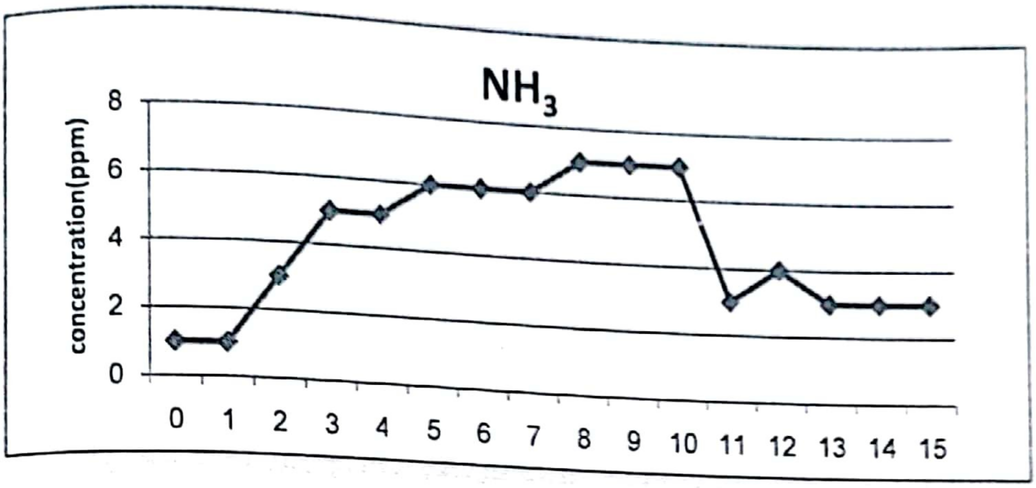
Description	minute	Time	Gases (ppm) Outlet from waterfall							
			CO	H_2S	O_2 %	VOC	NO_2	NH_3	SO_2	HCN
These measurements were taken every one minute	0	8:54AM	0	0	21	13	0.3	1	0	0
	1		0	0	21	18	0.4	1	0	0
	2		0	0	21	13	0.3	3	0	0
	3		0	0	21	5	0.2	5	0	0
	4		0	0	21	16	0.2	5	0	0
	5		0	0	21	6	0.2	6	0	0
	6		0	0	21	5	0.2	6	0	0
	7		0	0	21	7	0.1	6	0	0
	8		0	0	21	15	0.2	7	0	0
	9		0	0	21	13	0.1	7	0	0
	10		0	0	21	5	0.1	7	0	0
	11		0	0	21	5	0.2	3	0	0
	12		0	0	21	5	0.1	4	0	0
	13		0	0	21	5	0.1	3	0	0
	14		0	0	21	5	0.1	3	0	0
	15		0	0	21	5	0.1	3	0	0
	18	9:18	0	0	21	3	0	3	0	0

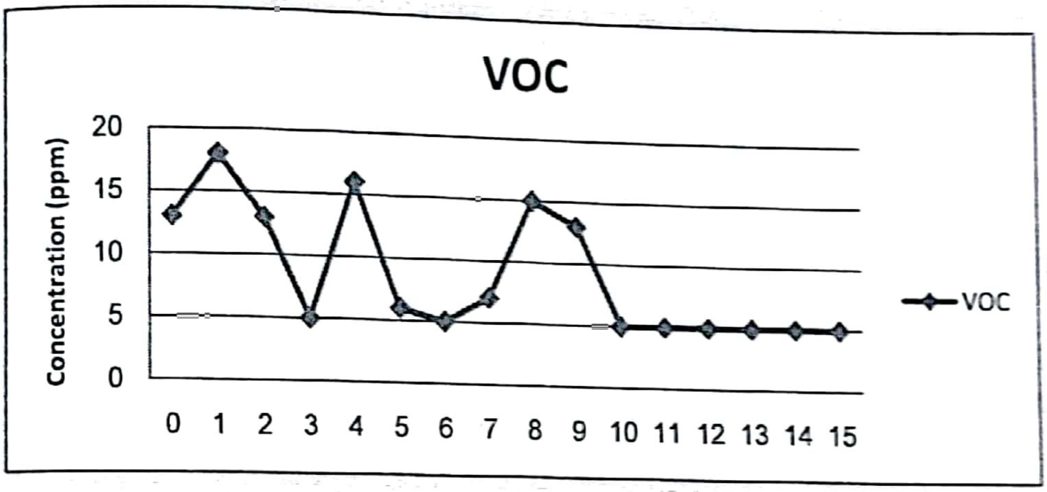
These measurements were taken every three minutes	21		0	0	21	6	0.1	4	0	0
	24		0	0	21	3	0	4	0	0
	27		0	0	21	3	0	3	0	0
	30		0	0	21	4	0.2	5	0	0
These measurements were taken every one minute	31		0	0	21	4	0.1	6	0	0
	32		0	0	21	4	0.1	6	0	0
	33		0	0	21	4	0.1	7	0	0
	34		0	0	21	4	0.1	7	0	0
	35		0	0	21	4	0.1	7	0	0
every ten minutes	56		0	0	21	2	0.3	1	0	0
	66		0	0	21	3	0.2	3	0	0
	76		0	0	21	4	0.3	5	0	0
every one minute	77		0	0	21	4	0.2	5	0	0
	78		0	0	21	5	0.2	5	0	0
	79		0	0	21	6	0.2	6	0	0
	80		0	0	21	4	0.2	6	0	0
	81		0	0	21	4	0.2	6	0	0
	82		0	0	21	3	0.2	4	0	0

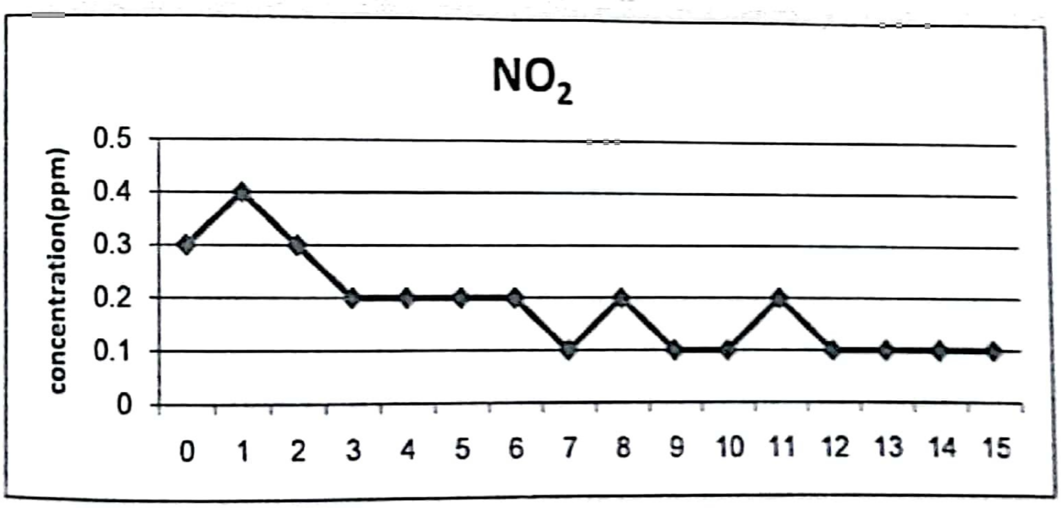
The water (which is used for absorption) was replaced with fresh water at these measurements at the same day of taking these data, the above data shows that the recommendations of replacing water earlier than a month or even two weeks has a great effect on the efficiency of the waterfall scrubber.

The water that has been used in the absorption process of the gases at the time of taking these data was analyzed at biotechnology department and showed that there are growths in the concentration of the contaminants in water, and this experiment is illustrated later in section 4.4.3.3.

Charts show the variation of the gas concentrations with respect to time (minutes).







4.4.3 Experimental Work

4.4.3.1 Measuring Flow Rate

As the Anemometer is not available locally, alternative solutions have been developed for measuring the gas flow rate, constructed a device for measuring the flow rate that will be used in many measurements of gas flow.

The anemometer device was implemented, and the base of designing such a device is the change of voltage of a DC fan when the gas or air passes through its blades, and so, the kinetic energy of the gas is converted to electrical energy.

This base has established a strong methodology for implementing the anemometer, and using the microcontroller to process the output voltage from the DC fan, furthermore, the results are showed on LCD for both average velocity (m/s) and flow rate (m^3/s).

Strictly speaking, after many experiments, the anemometer device had been constructed with the final shape as the following pictures illustrate it:

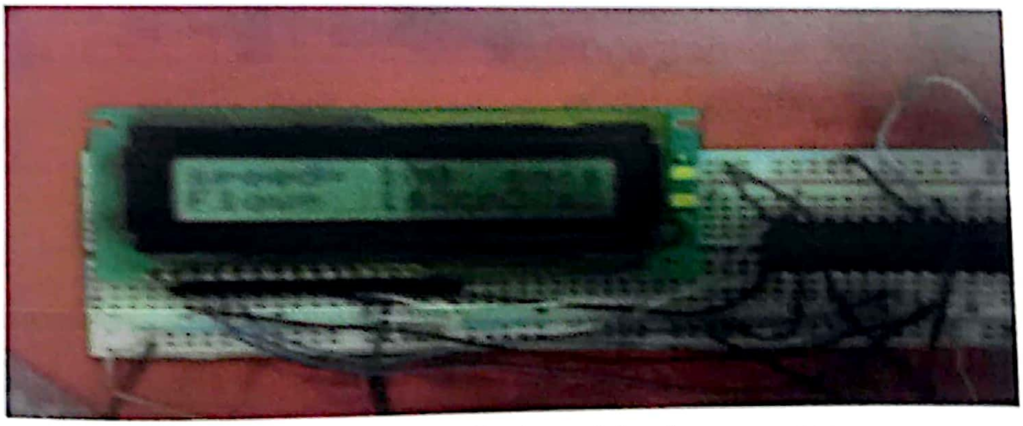


Figure (4.9a): LCD display of the Anemometer.

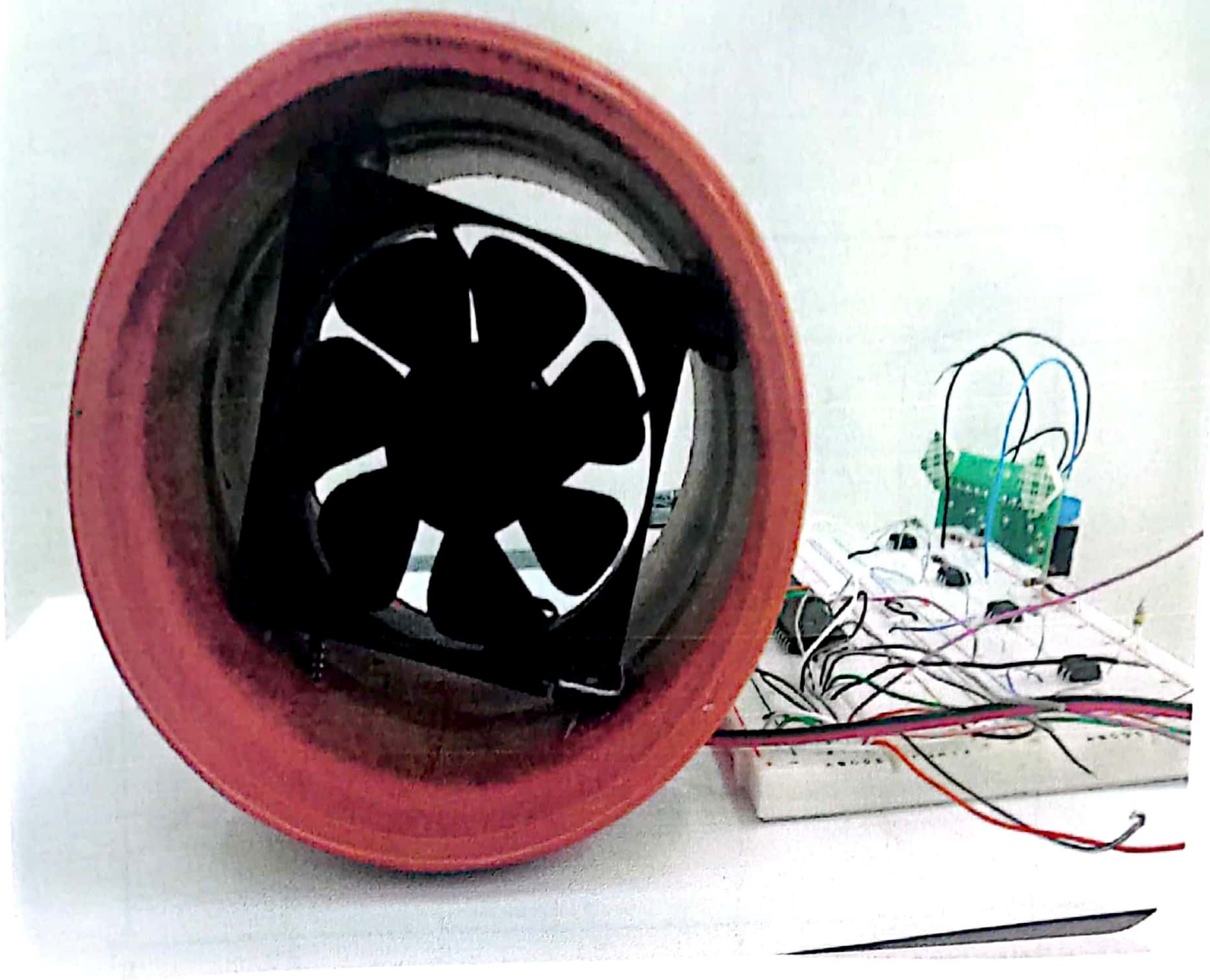


Figure (4.9b): Constructed Anemometer.

The device was calibrated in the Thermodynamic lab. by a device that roduces a known velocity of air, and so the device was located in a way that the air vith known velocity passes through the anemometer, which will produce an output oltage, and the relationship between these measured data will pave the way to alibrate the device, and so, the results were processed by (Matlab Software) and the inearization was performed as showed in figure (4.10).

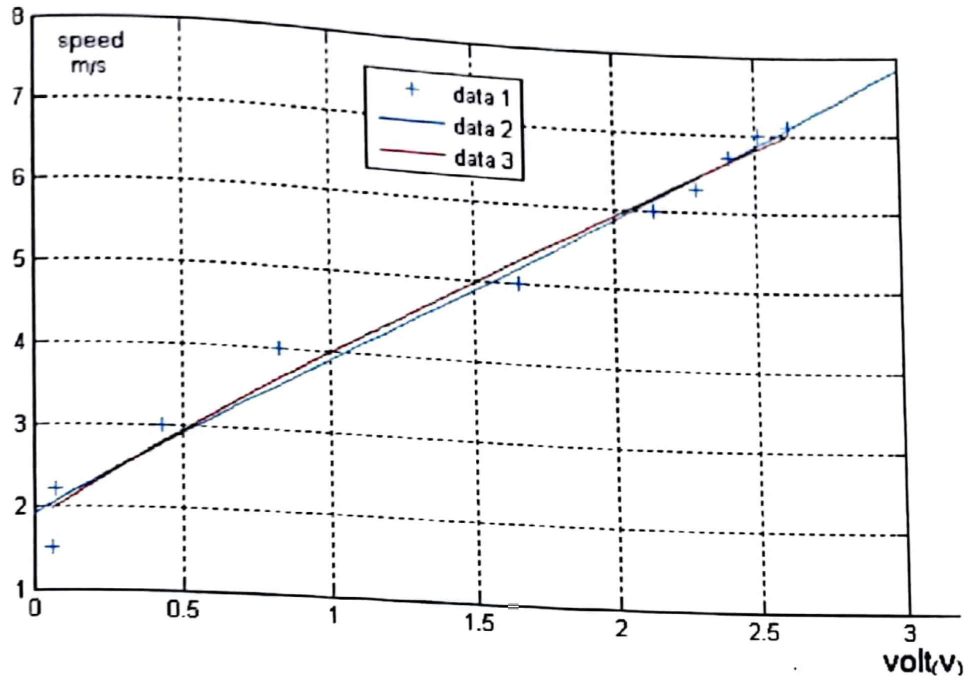


Figure (4.10): Calibration Data Curve

Matlab code:

```
>> v=[0.061 0.072 .43 .825 1.66 2.14 2.29 2.41 2.51 2.62];

>> s=[1.5 2.22 3 4 5 6 6.3 6.7 7 7.1];

>> p=polyfit(v,s,1)
```

The linear eqn. becomes :

Speed= [1.9661* volt + 1.9294] (m/s)

4.4.3.2 Implementing a Water Circulation Control System

The implemented control system is used to give an idea about the functionality and the integrity of the control system and its effect on the absorption process, the control devices used here are contactors, relays, switches and some other components.

4.4.3.3 Measuring the Density

Other experiments have been done in order to measure the density of the polluting gas, and these experiments were made with assumptions same as the flow rate measurement assumptions.

The experiments were made with assumptions, to simplify the measuring process, such as the measurements were taken under the standard conditions of 1 atm. Pressure, and room temperature, and so the average flow rate of the outlet gas from the oven which is at the nozzle is approximately 0.0078 m^3/s, and the outlet flow rate to the atmosphere is 0.0525 m^3/s, see appendix [E].

4.4.3.4 Analyzing Water Samples

Spectrophotometer shown in figure (4.9) is a device used for analyzing water samples, which was used in the absorption process at the factory, and this device shows the percentage of suspended particles in water compared with fresh water, not the type of them. Thus it can give an impression about the water status whether is it useful or not. Fresh water was used as a reference to compare the samples with, the test is mainly checks the availability of light passing through the water specimen

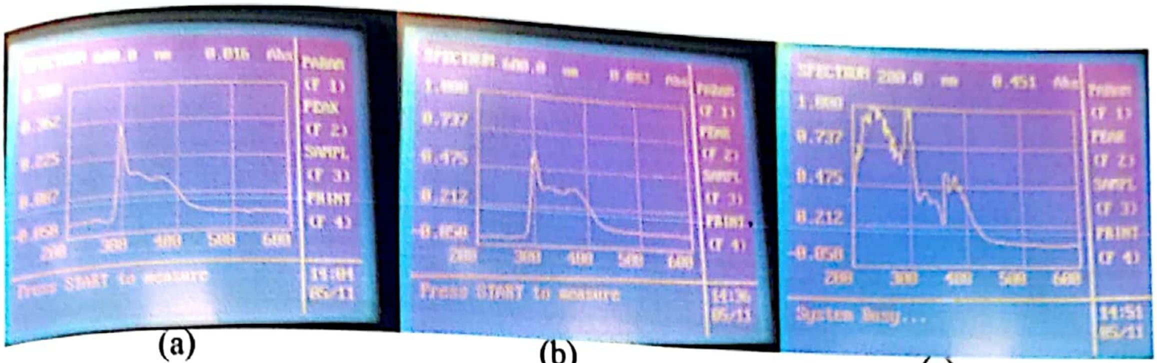
Figure (4.11): Spectrophotometer device.

Water samples were taken daily for one week period and all were analyzed, according to the following table.

Table (4.5): Schedule of Water Samples.

No.	Date	No. of open Ovens	Time		Notes
			PM	AM	
1	29/3/09	1		7:00	Start
2	29/3/09	2	4:00		
3	30/3	1		7:00	
4	30/3	2	4:00		
5	31/3	1		7:00	
6	31/3	2	4:00		
7	1/4	1		7:00	
8	1/4	2	4:00		
9	2/4	2		7:00	
10	2/4	3	4:00		
11	4/4	-			No Work
12	4/4	-			
13	5/4	1		7:00	
14	5/4	1	4:00		
15	6/4	2		7:00	
16	6/4	2	4:00		

The device shows the analysis result as a curve that represents the ability of light passing through water specimen, the peaks of the curves indicates that there is a certain contaminants in water, which means that there is an absorbed gas with certain concentration. Figure (4.10) shows a difference between different randomly chosen samples.



(a) (b) (c)

Figure (4.12): Curves Shows Analyzing Results at the 3rd , 9th, and 14th days respectively.

The x-axis of the coordinate represents the wave length λ (nanometer), which is a characteristic of a material which is here the absorbed gas, the y-axis represents the concentration of the gas in the contaminated water.

It is noticed from the figures that there is a growth in the peaks whenever the water is reused several times, and so, the contaminants are increasing proportionally with number of water usage, and the water is saturated after day five, and no other gases can be dissolved in the water due to the solubility limits.

And this is the main reason of the stripping process noticed at the waterfall scrubber in Jealnco, when water duration cycle was about 32 days, consequently, the factory was advised to change the water every weak at least, and so the result of that was illustrated in the table (4.4). and for more details, see appendix[F].

More results can be noticed by the observer eye since changes of the water color appears clearly as shown in the following figure.

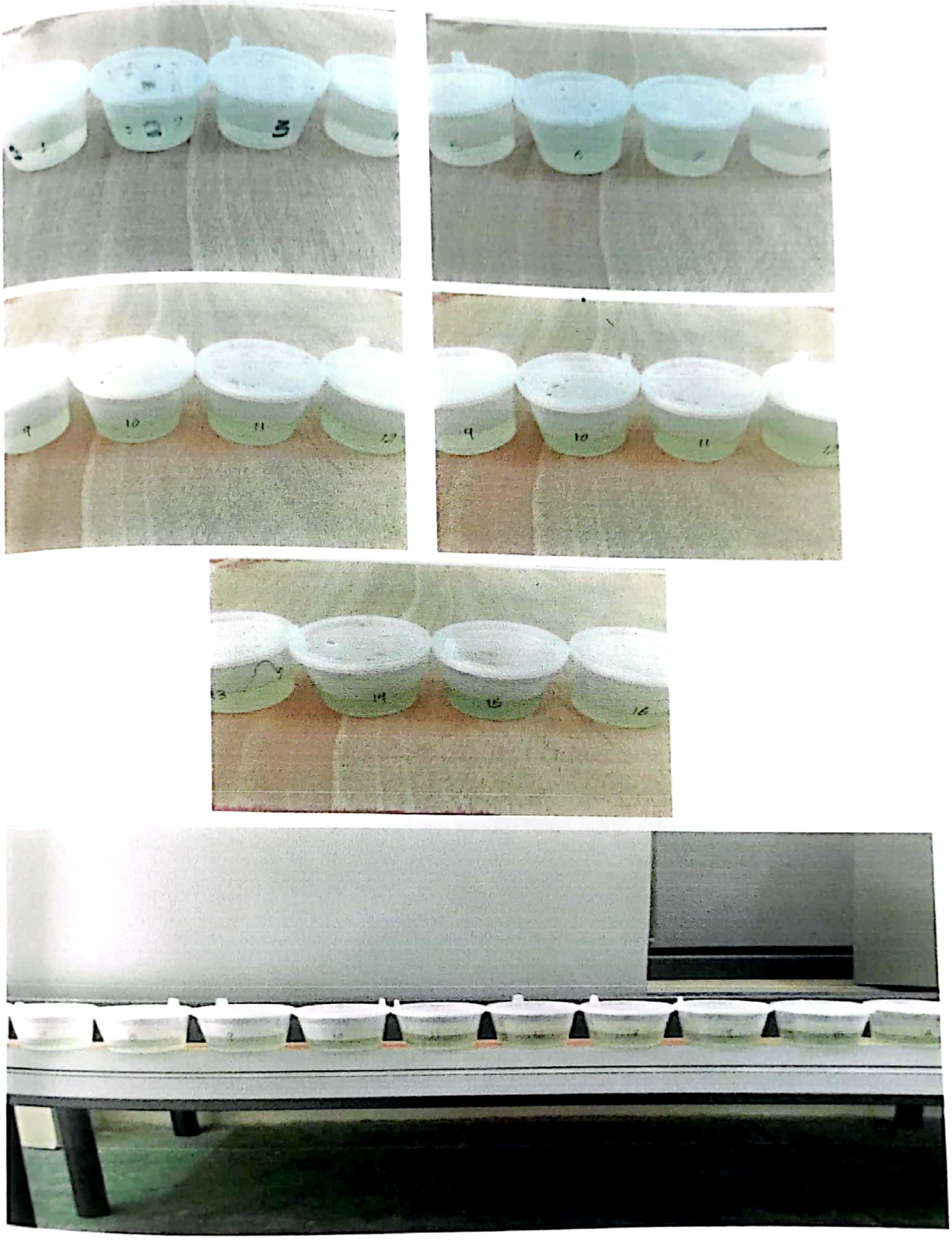
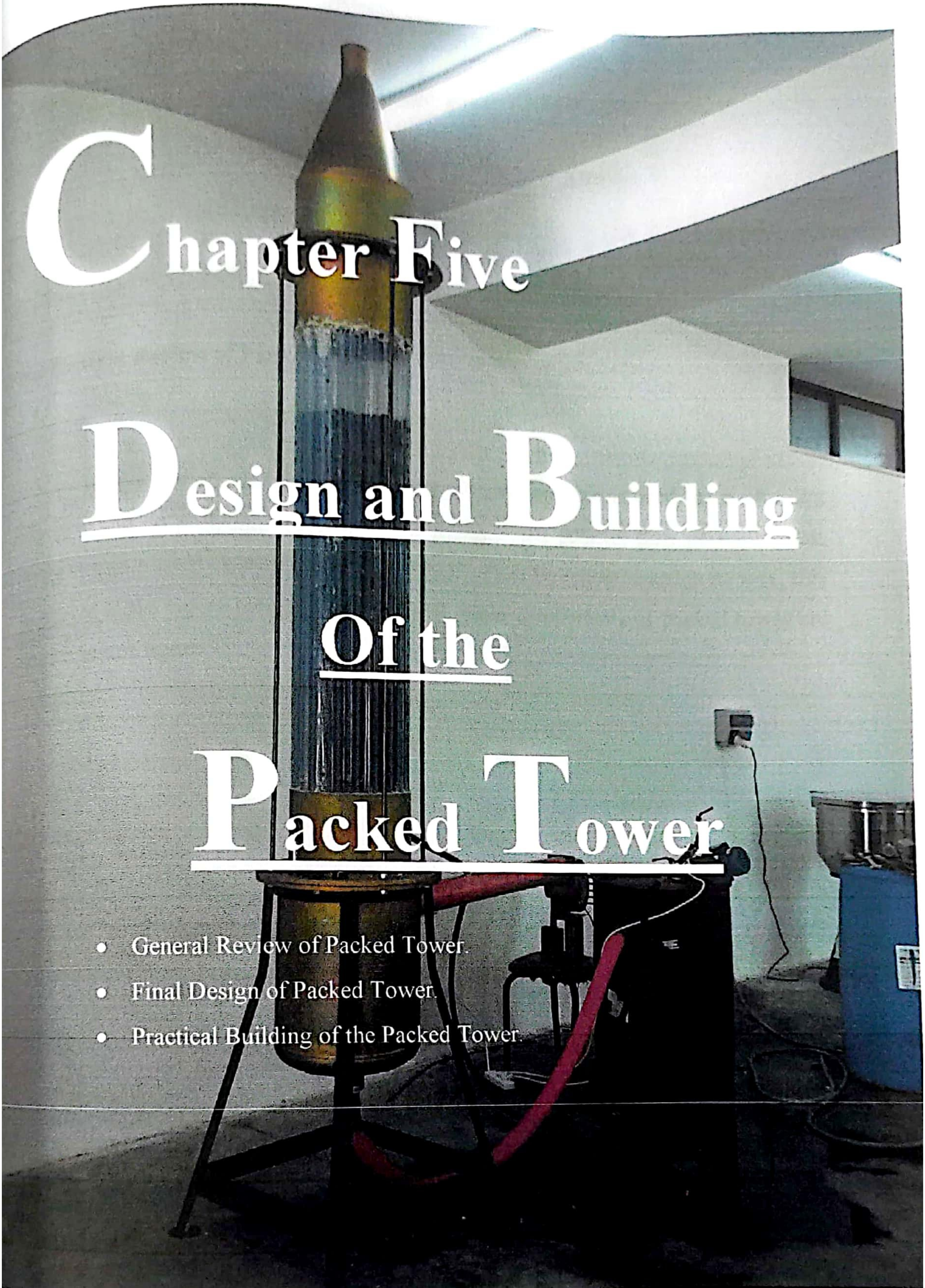


Figure (4.13): Color Changes of Water Samples.



Chapter Five

Design and Building

Of the

Packed Tower

- General Review of Packed Tower.
- Final Design of Packed Tower.
- Practical Building of the Packed Tower.

Chapter Five

Design and Building of Packed Tower

5.1 General Review of Packed Tower

Packed tower is a well known absorption system that is used for controlling the air pollution problem, and is built according to the counter-flow principle; thus gases stream travels upward meeting the water which flow downward in its way, this is shown in the figure below. In addition the main components of packed tower are shown in this figure [12].

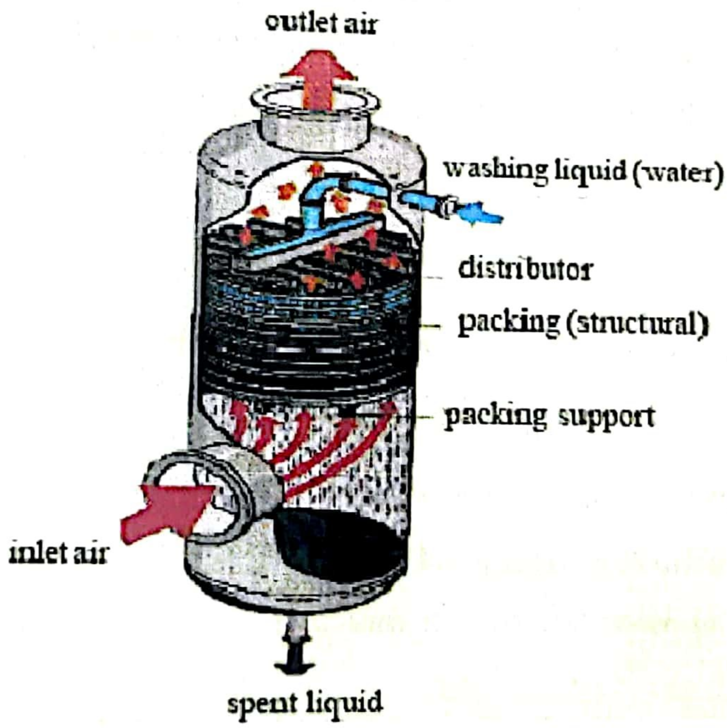


Figure 5.1: Packed tower components and flow rate directions.

Packed tower can handle strong flow fluctuations, ideal for tackling emergency situations, and provides high efficiencies with a well structured packing, thus it's considered for improving the efficiency of the existed pollutant removal system in Eagleflex factory, or that system may be replaced with packed tower.

5.2 Final Design of the Packed Tower

Packed tower design depends mainly on the inlet concentration of a given pollutant and the molar flow rate of gas stream. The type of tower material that is to be used for implementation is Acrylic pipe, as it resists both the corrosion and erosion, can't be broken easily, and fulfills scientific purposes. In addition the type of packing material has to be chosen, the main packing material types and some information about them are mentioned in appendix [I].

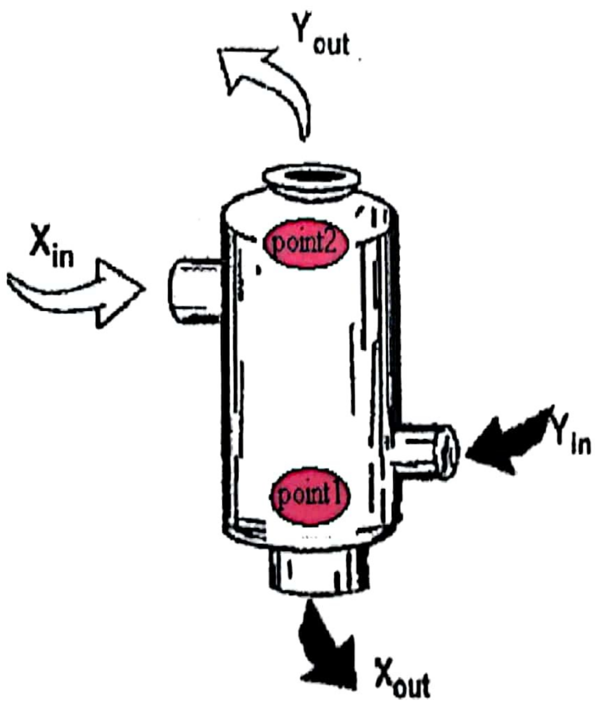
Ammonia gas is considered as the base of the design in this project because:

- Its concentration is the highest, see appendix [D].
- It is the main gas that causes the bad smell in the work site.
- VOC concentration was high also but it consists of different compounds, while NH_3 is a single gas; thus it becomes easier to perform design calculation considering it.

Design calculations are made according to the data that were obtained from the field visits to Eagleflex Company at the previous semester including the necessary modifications. The inlet gas flow rate was 0.05398 m^3/sec and the concentration of NH_3 was nearly to 70.9 ppm, ceramic Rasching ring of 25mm size is considered as a packing material although the used packing material is plastic Rasching ring because of their lower cost and availability than ceramic type, the system efficiency assumed to be 90% and 1.2 atm pressure at 23C.

5.2.1 Design Procedures [1]

Applying the mass balance principles at both points 1 & 2 shown in figure (5.2) gives the output NH_3 concentration in gas and water, and the gas and water flow rate:



- *From mass balance*

Inlet NH_3 concentration in gas (Y_{in}) = $70.9 * 10^{-6}$

$$y_{in} = Y_{in} / (Y_{in}+1) \quad (5.1)$$

$$y_{in} = 70.9 * 10^{-6} / (1 + 70.9 * 10^{-6}) = 7.08 * 10^{-5}$$

Then, the efficiency assumed to be 90%:

$$\eta = 1 - (y_{out}/y_{in})$$

This gives that $y_{out} = 7.08 * 10^{-6}$

Now: $Y_{out} = y_{in}/(1 - y_{in})$

$$Y_{out} = 7.08 * 10^{-6} / (1 - 7.08 * 10^{-6}) = 7.08 * 10^{-6}$$

Where:

y: Mole fraction of NH3 in gas.

Y: Mole Ratio of NH3 in gas.

η: Tower efficiency.

Then the molar gas flow rate will be ,

{using gas density=1.42Kg/m^{3}which will be calculated later at equation (5.10)}

$$G_{T1} = (Gas\ flow * Gas\ density)/molar\ mass \quad (5.2)$$

$$G_{T1} = ((0.05398)\ m^3/sec * (1.42)\ Kg/m^3) / 17(g/mol)$$

$$G_{T1} = 4.508 * 10^{-3}\ Kmol/sec$$

$$And\ Gs = G_{T1} * (1 - y_{in}) \quad (5.3)$$

$Gs = (4.508 * 10^{-3}) * (1 - 7.08 * 10^{-5}) = 4.509 * 10^{-3}\ Kmol/sec$

or more certainty ,another way to calculate Y_{in}, Y_{out}

Then: $In\ feed = yin * G_{T1}$

$In\ feed = 7.08 * 10^{-5} * 4.508 * 10^{-3}\ Kmol/sec = 3.19 * 10^{-7}\ Kmol/sec$

$Removed = \eta * (in\ feed)$ (5.4)

$Removed = 0.9 * 3.19 * 10^{-7}\ Kmol/sec = 2.871 * 10^{-7}\ Kmol/sec$

$Remaining = (1 - \eta) * in\ feed$ (5.5)

$Remaining = 0.1 * 3.19 * 10^{-7}\ Kmol/sec = 0.319 * 10^{-7}\ Kmol/sec$

So; $G_{T2} = G_{T1} - removed$ (5.6)

$G_{T2} = 4.508 * 10^{-3}\ Kmol/sec - 2.871 * 10^{-7}\ Kmol/sec$

$= 4.509 * 10^{-3}\ Kmol/sec$

And $y_2 = NH_3\ (remaining) / G_{T2}$ (5.7)

$y_2 = (0.319 * 10^{-7})(Kmol/sec)/(4.509 * 10^{-3})Kmol/sec = 7.08 * 10^{-6}$

Then: $Y_2 = y_2/(1 - y_2)$

$Y_2 = 7.08 * 10^{-6}$

To find the value of X^* *, Henry low will be used :*

$y_{in} = X * H$, ($y_{in} = x^* H$) *while H is Henry constant for* NH_3

$H = 0.7614$ *(dimensionless)*

Then $x^* = 7.08 * 10^{-5}/0.7614 = 9.298 * 10^{-5}$

And $X* = x^*/(1 - x^*)$

which gives that $X^* = 9.299 * 10^{-5}$

where G and L are the gas molar flow rate and liquid flow rate respectively.

Then: Slope $= (Y_2 - Y_1)/ (0 - X^*)$ (5.8)

$$= (7.08 * 10^{-6} - 70.9 * 10^{-6})/(0 - 9.299 * 10^{-5}) = 0.686$$

And Slope $= Ls\ min / Gs\ min$ (5.9)

Then: $Ls = 0.686 * 4.509 * 10^{-3}$ $(Kmol/sec) = 3.09 * 10^{-3}$ $Kmol/sec$

Assuming that L_{T2} *operating* =
1.5 *Ls min, and this is acommonused factor.*

Then:

$$L_{T2} = 1.5 * 3.09 * 10^{-3}\ (kmol/sec) = 4.63 * 10^{-3}\ Kmol/sec$$

- <u>*Estimation of tower diameter:*</u>

Ithad been chosen that G *operating* $= 0.5\ G$ *flooding*

To get G *flooding*:

$P = 1.2atm = 1.2 * 101 = 121.2\ KPa$

Water density $\rho l = 997\ Kg/m^3$

Assuming ideal gas:

Gas density $(\rho gas) = P * molar\ mass\ /\ (T * R)$ (5.10)

Where R is the gas constant which equals to $8.314\ [Kpa * m^3/mol * K]$

$\rho Gas = (121.2\ [Kpa] * 29[Kg/Kmol])/(8.314[Kpa * m^3/mol * K] * 296[K])$

Then: $\rho Gas = 1.42\ Kg/m^3$

After finishing the design calculations oof the gas inlet and water outlet , then the wate

(out flow rate) will be:

$L_{T1}=L_{T2}+NH_3$ (removed)

$LT1 = 4.63 * 10^{-3}\left(\frac{Kmol}{sec}\right) + 2.871 * 10\text{-}7(Kmol/sec)$

$= 4.64 * 10^{-3}\ Kmol/sec$

$mwH_2O = 18g/mol$

$A_{CL} = mw * L_{T1}$

$A_{CL} = L' = 18(Kg/Kmol) * 4.64 * 10^{-3} (Kmol/sec) = 0.0835 \, Kg/sec$

And Gas (outlet flow rate) will be:

$mw(air) = (y_{in} * mwNH_3) + ([1 - y_{in}] * mw \, gas)$

$mw(air) = (7.08 * 10^{-5} * 17(Kg/Kmol)) + ([1 - 7.08 * 10^{-5}] * 29(Kg/Kmol)) = 28.9Kg/Kmol$

$A_{CG} = G_{T2} * mw(air)$

$A_{CG} = G' = 4.509 * 10^{-3} \left(\frac{Kmol}{sec}\right) * 28.9 \left(\frac{Kg}{Kmol}\right) = 1303 \, Kg/sec$

Then :

$L'/G' * (\rho g / (\rho L - \rho g))^{0.5}$

$= [0.0835(Kg/sec)/0.1301(Kg/sec)] * [1.42(Kg/m^3)/(997(Kg/m^3) - 1.42(Kg/m^3))]^{0.5} = 0.024$

Then from the flooding curve in appendix [I], where 0.024 is the point on X-axis, reading the value of Y-axis with the point 0.024in X-axis gives that:

$(G'^2 * Cf * \mu L^{0.1} * J)/(\rho g * [\rho L - \rho g] * gc) = 0.34$

For Rasching rings (25mm):

$Cf = 155, gc = 1, J = 1, \mu L = 1 * 10^{-3} \, N * sec/m^2$

Then:

$G' = (0.34 * 1.42(Kg/sec) * [997(Kg/m^3) - 1.42(Kg/m^3)]) / [155 * 1 * (10^{-3})^{0.1} (N * sec/m^2)]$

$G' = 2.48(Kg/sec * m^2) = G flooding$

And: $G'\ operating = 0.5\ G'\ flooding$

Then $G'\ operating = 0.5 * 2.48 = 1.243(Kg/sec * m^2)$

$$G_{T1}(Kg/sec) = G' * Area \qquad (5.11a)$$

So: $Area = G_{T1} * molar\ mass/G'$

$$Area = (4.508 * 10^{-3}(Kmol/sec) * 28.9(Kg/Kmol)/1.243(Kg/sec * m^2) = 0.1048\ m2$$

And: $A = \pi(D/2)^2 \qquad (5.11b)$

Then: $Dc = (4 * A/\pi)^{0.5}$

$$Dc = (4 * 0.1048(m^2)/3.14)^{0.5}$$

Then the tower diameter will be $\mathbf{D = 36.54cm}$

- *Estimation of packing height (Zt)*

1) *Estimation of number of gas phase mass transfer unit* (N_{OG}) *by using Henry's constantfor* $NH_3, H = (0.7614)$.

Since the gas concentration is diluted, the following case of N_{OG} *is acceptable (call it Eq. 12):*

$$N_{OG} = (Yin - Yout) /([Yin - Y * in] - [Yout - Y * out]) * ln ([Yin - Y * n]/[Yout - Y * out])$$

Thus: $Y^*in = H*Xout$ (5.12.a)

$$Y^*in = 0.7614 * 9.229 * 10^{-5} = 7.08 * 10^{-5}$$

$Y^*out = H*Xin$ (5.12.b)

$$Y^*out = 0.7614 * 0 = 0$$

$$N_{OG} = [(70.9 * 10^{-6} - 7.08 * 10^{-6})/([70.9 * 10^{-6} - 7.08 * 10^{-5}]-[7.08*10^{-6} - 0]) * ln([70.9 * 10^{-6} - 7.08 * 10^{-5}]/[7.08 * 10^{-6} - 0])]$$

Then: **NOG =2.2** (dimensionless)

2) *Estimation of the height of gas phase mass transfer unit* (H_{OG}).

$H_{OG} = G / [Ky.a * (1 - y) *_{lm}]$ (5.13)

- <u>At the butome of the tower :</u>

$$G = G_{T1}/Area$$

$$G = 4.508 * 10^{-3}(Kmol/sec)/0.1048m^2 = 0.043\ Kmol/m^2 * sec$$

$Molar\ mass\ (mw)\ of\ gas\ assuming\ the\ rest\ of\ gases\ is\ air$
$= 28.9\ Kg/Kmol$

then:

$$G' = G * (mw)\ air \qquad (5.14)$$

$$G' = 0.043(kmol/m^2 * sec) * 28.9(Kg/Kmol)$$

$$= 1.24\ Kg/m^2 * sec$$

And: $L' = LT1 * (mw)water\ /Area \qquad (5.15)$

$$L' = 4.64 * 10^{-3}(Kmol/sec) * 18(Kg/Kmol)/\ 0.1048m^2$$

$$= 0.797\ Kg/m^2 * sec$$

Then: $ky.a = 0.059 * G'^{0.7} * L'^{0.25} \qquad (5.16)$

$$ky.a = 0.059 * (1.24Kg/m^2 * sec)^{0.7} * (0.797Kg/m^2 * sec)^{0.25}$$

$$= 0.065$$

And: $kx.a = 0.152 * L'^{0.82} \qquad (5.17)$

$$kx.a = 0.152 * (0.797Kg/m^2 * sec)^{0.82}$$

$$= 0.126\ Kg/m^2 * sec$$

Then the slope at point $(6.42 * 10^{-6}, 7.08 * 10^{-5})$; $m = 9.9$

$$Then: 1/Ky.a = (1/ky.a) + (m/kx.a) \qquad (5.18)$$

$$1/Ky.a = (1/0.065) + (9.9/0.126)$$

$$Ky.a = 0.01064\ Kg/sec * m^2$$

From table (2) in appendix [I] $(1 - y^*)_{*lm}$ at point $(6.42 * 10^{-6}, 7.08 * 10^{-5})$ $= 0.996$, then by applying (Eq 5.13):

$$H_{OG1} = 0.043(Kg/m^2 * sec)/\ (0.01064\ (Kg/sec * m^2) * 0.996)$$

$$= 4.056$$

- <u>At the top of the tower:</u>

$$G = G_{T2}/Area$$

$$G = 4.509 * 10^{-3}\ (Kmol/sec)/0.1048m^2$$

$$= 0.043\ Kmol/m^2 * sec$$

Then recalling equations (5.14, 5.15, 5.16, and 5.17) gives that:

$$G' = 28.9(Kg/Kmol) * 0.043(Kmol/m^2 * sec)$$

$$= 1.247\ Kg/m^2 * sec$$

And: $L' = 4.63 * 10^{-3}(Kmol/sec) * 18(Kg/Kmol)/0.1048m^2$

$$= 0.795\ Kg/m^2 * sec$$

And: $ky.a = 0.059 * (1.247\ Kg/m^2 * sec)^{0.7} * (0.795Kg/m^2 * sec)^{0.25}$

$$= 0.0648\ Kg/sec * m^2$$

And: $kx.a = 0.152 * (0.795Kg/m^2 * sec)^{0.82}$

$= 0.1259\ Kg/sec * m^2$

And similarly the slope at point $(0, 7.08 * 10^{-6})$ is $m = 9.8$

Then: $1/Ky.a = (1/ky.a) + (m/kx.a)$

$$1/Ky.a = (1/0.0648\ Kg/sec * m^2) + (9.8/0.1259\ Kg/sec * m^2)$$

$$Ky.a = 0.01072\ Kmol/sec * m^2$$

From table (2) in appendix [I] $(1 - y^*)_{*lm}$ at point $(0, 7.08 * 10^{-6})$ $= 0.99$ and by applying (Eq 5.13 again):

$$H_{OG2} = 0.043(Kg/m^2 * sec)/(0.01072\ (Kmol/sec * m^2) * 0.99)$$

$$= 4.051$$

And: $H_{OG\ (ave)} = (H_{OG1} + H_{OG2})/2$

$$H_{OG\ (ave)} = (4.056 + 4.051)/2$$

Then: $\underline{H_{OG} = 4.01}$

And now the tower height is;

$$Zt = H_{OG} * N_{OG}$$

$$Zt = 4.01 * 2.2$$

$$Zt = 8.1\ m$$

By approximation $Zt = 8m$

Estimation of fan power:

$Power = \Delta P * gas\ flow\ rate$

ΔP *from appendix I*

At : $L'/G' * (\rho g / (\rho L - \rho g))^{0.5} = 0.024$

$(G'^2 * Cf * \mu L^{0.1} * J)/(\rho g * [\rho L - \rho g] * gc) = 0.34$, *Now it is used that*

$(G'^2 * Cf * \mu L^{0.1} * J)/(\rho g * [\rho L - \rho g] * gc) = (0.5)$ *that for flouding*

$= 0.34/4 = 0.085$

Read ΔP *from appendix I at point* (0.024,0.085)

$\Delta P = 100\ Pa/m$

Then $\Delta P_T = \Delta P * Z_T$

$\Delta P_T = 100(Pa/m) * 2.2\ m = 220\ Pa$

Then $Q = (G_{T1} * R * T)/P$

$Q = (4.508 * 10^{-3}\ (Kmol/sec) * 296[K] * (8.314[Kpa * m^3/mol * K]/ 121.2\ [Kpa])$

$Q = 0.09153\ m^3/sec$

Now $Power = 220\ (Pa) * 0.09153\ (m^3/sec)$

$= 20.137\ watt$

If overall efficiency of fan and motor is approximately = 55%

Then Power = 20.137 (watt) /0.55 = 36.6 *watt*

5.2.2 Design Results and Conclusions

It is found that the pollutant removal process occurs at a region of the tower that has 37cm diameter and 8m height, but it needs additional parts to be combined with in order to form a complete tower, thus the designed tower has reached a height of 8 m, and this is not acceptable for packed towers to be implemented at the university, so the solution was to build packed tower with just 4m height, and this base is acceptable for a various concentration; because the calculations of the design controlled by the concentration of the inlet gas which is too low (70.9 ppm).

It was also found that the input gas concentration, the efficiency, are the main parameters for designing packed towers, adjusting any of them will appears as a result of tower height.

If the efficiency of the implemented packed tower becomes high then it will be quite enough to serve the factory, thus if both the waterfall and the packed tower are combined together, the efficiency will be duplex.

If the concentration of the inlet gas becomes high then the height of the packed column will decrease and become more comfortable and acceptable.

5.3 Practical Building of Packed Tower

Design results have showed that a packed bed of 40cm diameter and 2m height is useful for 90% removal efficiency as described in the previous section. In addition Rasching rings must be installed in this zone where the process occurs in order to increase the contact area between the gas and the water.

Two models were made at the beginning, in order to make the building of the Tower easier, and these models are shown at the following pictures:

Figure(5.6): The Models of the packed tower.

The theoretical design depends on the Ceramic rasching rings, but according to the unavailability of them, and their high cost (1m^3 costs nearly $500), they were replaced by plastic rasching rings, which are cheaper and available locally.

The implemented packed tower as whole reached a height of 4m since additional parts were installed and combined, and so it consists of three main parts: the upper part, the middle part, and the lower part, and are described in the following subsections.

5.3.1 The Upper Part

This part of tower is in the shape of cone and is made of steel as shown in figure (5.7); it is connected with the middle part by flanges and contains the following main parts:

- Gas outlet: the clean gas stream flows upward and releases from the cone opening at the top of the tower,
- Water inlet: is a thin cylinder that the water source pipe is connected with in order to supply water into the tower.
- Distributer: distributes the washing water to cover a maximum cross sectional area of the tower in order to guarantee that maximum of gas parts to be washed.
- Flange: it plays a role of connecting the tower parts together, it has eight holes, four of them are connected directly with the lower flange using screws, and the others are used to connect the support bars between the upper and the lower parts.

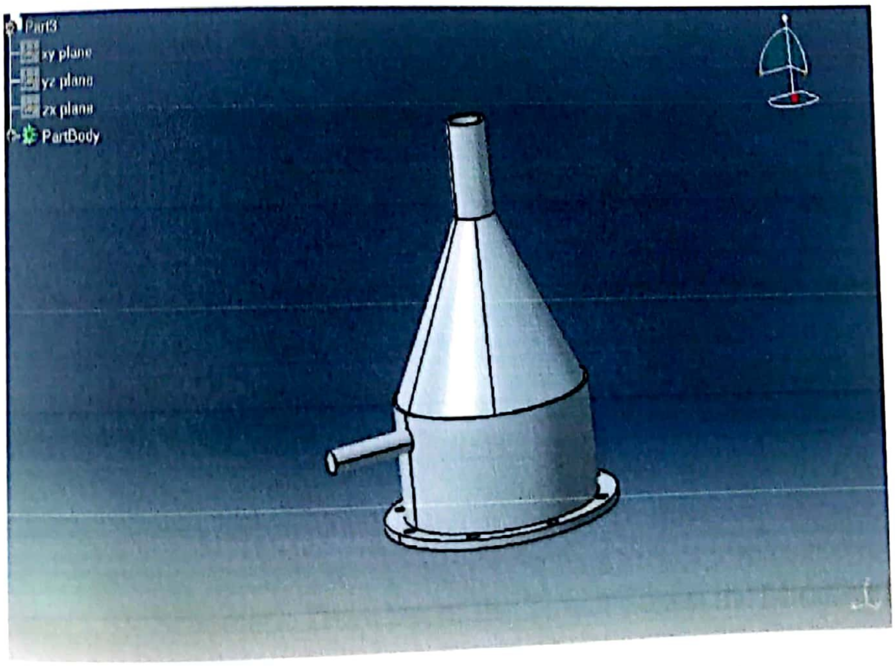


Figure 5.7: The Upper Part of Tower (Cone).

5.3.2 The Middle Part

This part of tower is a hollow Acrylic cylinder of 40cm diameter and 2m height, and is full of packing material; the process occurs at this region of the tower and has flanges at both sides to be connected with the other tower parts. Figure (5.8) illustrates a schematic drawing of the implemented tower including the connection of this part and the other parts; the middle part consists of the following:

- Acrylic hollow cylinder: is the outer body of the process region.
- Flanges: two flanges at both sides to connect this part with the other parts and are the same as described at the previous subsection.
- Packing material: plastic Rasching ring of (25*25*2.5)mm size to increase the contact surface area between the gas and the water.
- Support: carries the packing material and is holed to allow the washing water to pass downward into the lower part.

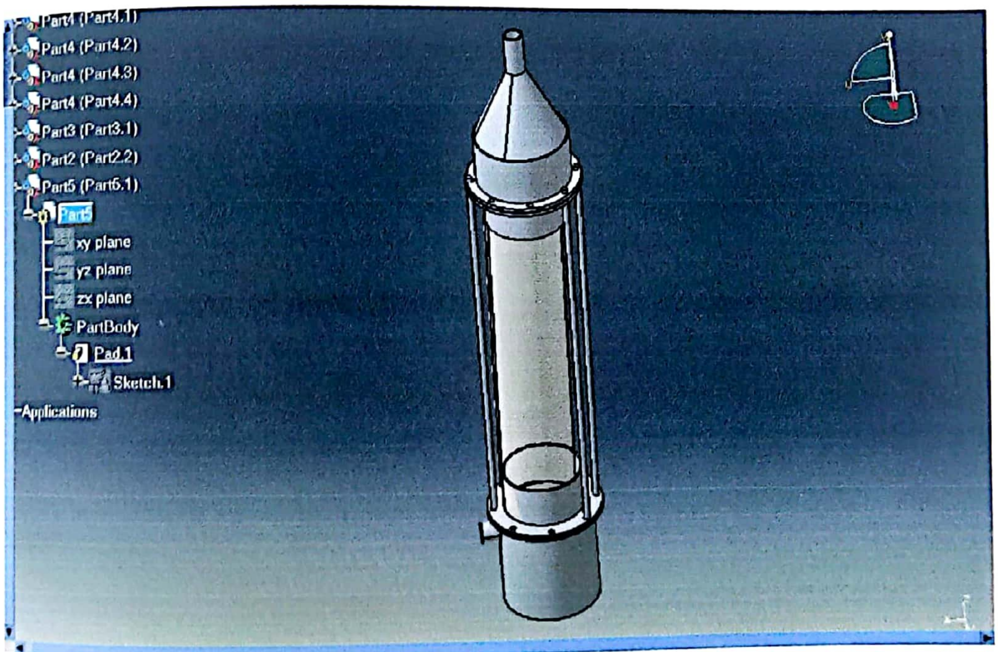
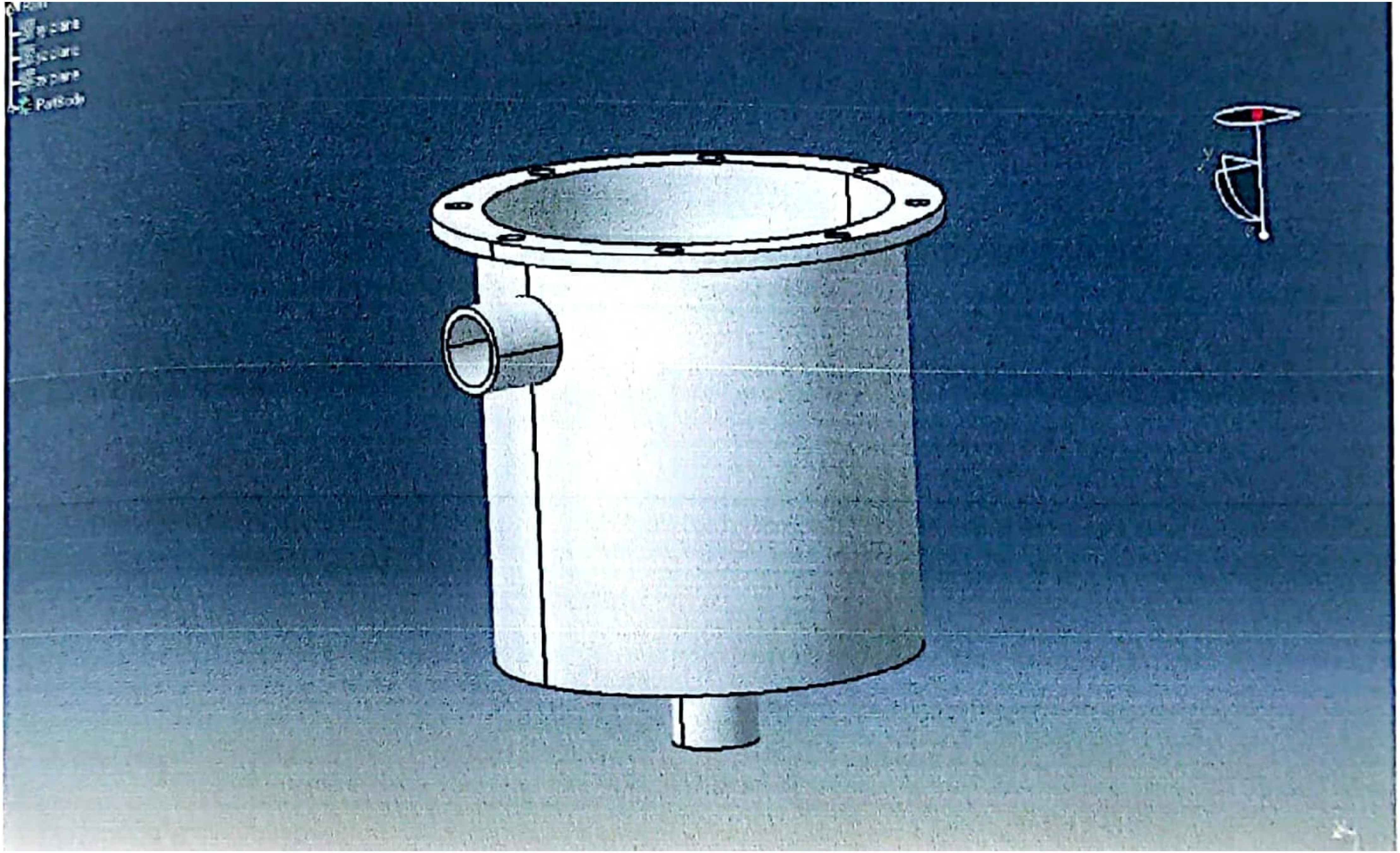


Figure (5.8): Schematic Drawing of the Tower Shows the Middle Part.



5.4 Operations within Building Process

Many operations were made till the tower was built, and some of theses operations were made by the team of the project, but other operations were made in the local factories.

Industrial Processes that have been made in the Building process:

1 - The Operations carried out on the iron sheets.

2 - Operations carried out on the Support plate.

3 - The Operations Carried Out on Flanges.

4 - The Operations Carried Out on Plastic.

5 - Other Operations

5.4.1The Operations Carried out on the Iron sheets

A – Sourcing and bringing the sheets.

B - The Storytelling and Composition

C - Welding

D - Grinding

E - Hole Center Determination

F- Galvanization

A - Sourcing and bringing the sheets

Sheets come at standard scales (i.e., 2m * 1m), which have been brought from local industries and cut by cutting tool.

Figure (5.10): Iron sheets

B - Cutting and Configuration (Bending)

The iron sheets have been cut and bent at the required dimensions, which have made it difficult for the build to be performed directly; as the output data from design calculations has been done previously, and not based on the normative standards in the market.

Cylinders with a diameter of 40cm and 25cm high were bent at the bending machine to form three cylinders as in figure (5.11), these cylinders will be welded at the flanges, the function of them is to install plastic sheet in it, which will be installed within the cylinders.

An Iron sheet has been bended up to the diameter of 48 cm and a length of 50 cm to form a cylinder, which will welded with the dome, which is available in a standard dimension in the market as in figure (5.13), and together constitute as water collector for dirty water that absorbed the gas (during the treatment of gases).

Also a conic shape was manufactured from an iron sheet with a diameter of 40cm and height of 40cm, and Cone is rolled on a special rolling machine, rolling machine-like that for cylinders, but with different manner, so as to accelerate one side more than the other to obtain the conical form.

Fig (5.11)

Fig (5.12)

Fig (5.13)

Fig (5.14)

C- Welding:

The cylinders were processed under welding operations that have been applied to all pieces of iron sheets, the welding operation was performed with a special weld called carbon dioxide (CO_2) welding; to prevent leakage and venting, as in figure (5.15).

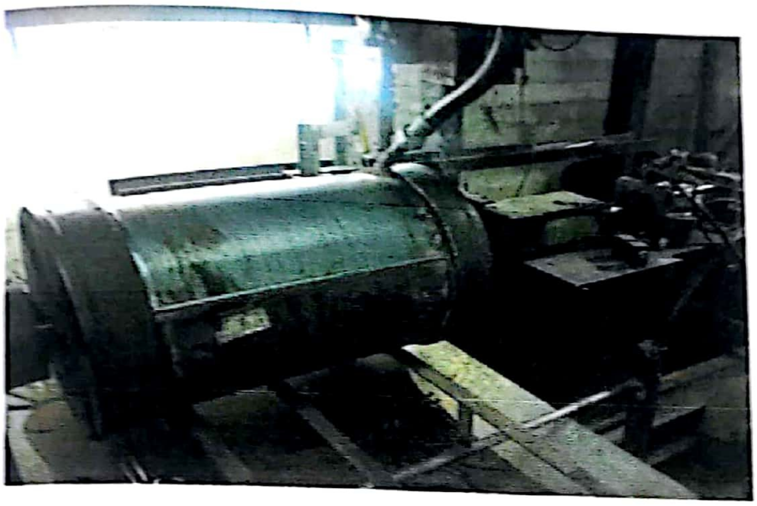


Figure (5.15): Welding machine.

D-Grinding:

The process of grinding is performed by a grinding tool, the grinding process is used for removal of unwanted material that is bad for the external appearance of the tower or has an impact on joining of the parts to each other, as in figure (5.16).

Figure (5.16a)

E- Hole Center Determination

By determining center of the holes which will be used in the joining the flanges together, it was difficult to do that as the flanges' dimensions was too big about 60cm, as the local turning machine doesn't take more than 40 cm diameter.

F- Galvanization[16]

After the manufacturing process has been done on the parts, the Galvanization process had taken place, to prevent the corrosion process due to some corrosive contaminants, such as (H_2S), which appeared in the qualitative evaluation of the waterfall scrubber in chapter four.

In an electrochemical cell, chemical energy is converted into electrical energy. This is accomplished by using a spontaneous chemical reaction to generate an electric current, which we can simply define here as electrons traveling though a wire.

To create the electrochemical cell two half-reactions will be set up in different containers. In one, an oxidation reaction will be used to generate a source of electrons. These free electrons will travel, through an external circuit, to the second container and will cause the reduction reaction to occur. The final requirement for our complete electrochemical cell will be a salt bridge that will permit ions to flow between the two half-cells, thus maintaining electrically neutral solutions.

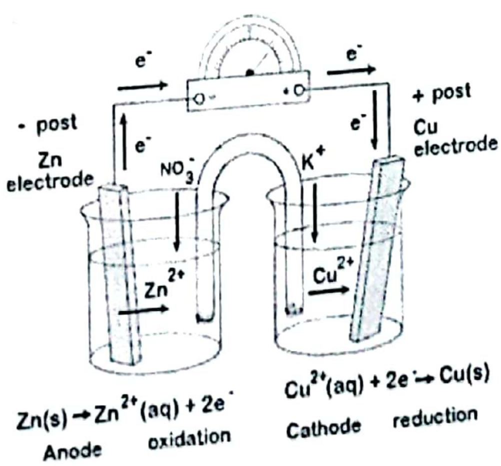


Figure (5.16b)

5.4.2 Operations Carried Out On the Support system

There are three Sections of the support of:

A - A Pillar of Internal Packing Material

The Pillar was brought with a thick iron sheet and was cut in a circular shape, and then several holes have been piercing on it distributed in full shape by milling machine, then the removal of unwanted material was by filings operation , at the University workshop.

Figure (5.17): Support Drilling

Figure (5.18): Finished support

B – Bars of the Tower.

Which were brought of 16 mm diameter columns, and 210 cm height, and were threaded on both sides by the turning machine, the function of them it is to carry the static load of the column (to make the columns bear the entire pregnancy).

Figure (5.19): Bars of the load support

C - The Support of the Tower:

Manufacturing of the pillar to carry the tower has been made as the corresponding figure, and after that the painting process takes place.

Figure (5.20) : Tower Support.

5.4.3 - The Operations Carried Out on Flanges

Four flanges with 0.5 cm thick for the upper flanges and 1.5 cm for the lower flanges, and the following operations were carried out:

A – Cutting

B – make the flanges straight

C – Installation(fixing).

D - Perforating

E - Grinding

F - Welding

A – Cutting:

Flanges been cut in a circular motion over diameter of 60 cm by a special cutting machine, furthermore, three inner diameter of flanges were cut 38cm, and the other was 47cm to fit with the standard cylinder and dome, which was stated before.

B - Make the Flanges Straight:

Flanges have been made straight as a curvature of the outer structure appeared after the cutting operation.

C - Installation:

Four flanges have been place on top of each other and then were to be installed together for drilling process, to drill a holes in all pieces for identical dimensions, in order to install the columns for supporting the tower.

Figure (5.21): making the flanges fixed.

D-Drilling:

Eight holes were made after determining the places of each hole in the flange (the four flanges were welded together), four holes for the screws and the others are for columns.

Figure (5.22) : Flanges drilling.

E-Grinding:

Flanges have been grinded for removal of the unwanted materials by the abrasive, the grinding process may be dangerous if the fine particles produced from the grinding were inhaled.

Figure (5.23) : Grinding operation.

F - Welding:

The four Flanges were welded, each one with the peace (cylinder) allocated to it by CO_2 welding.

5.4.4 The Operations Carried out on Plastic sheets

A - Bring Offers Available:

bringing the Orders prices of plastic sheets and a transparent plastic cylinder, but it was not available in the local market, and has not been possible to manufacture it locally.

Transparent offer is available only at the supply company (Shakov Plast) in "Tel Aviv" and the cost of the offer was $ 1000 for each transparent cylinder of 40 cm diameter and 2m height, and thickness of 4 mm, so it has been, and to begin the testing of plastics available in the local market.

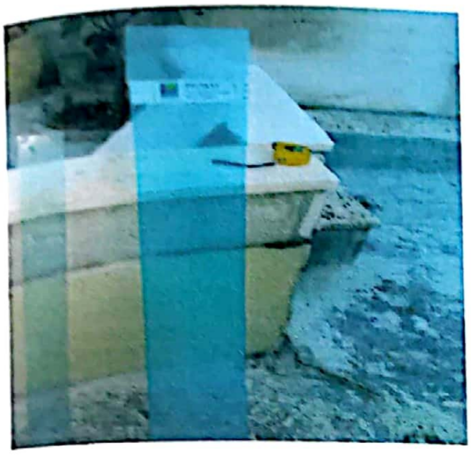
B- Making Experiments and Tests

The lack of clear transparent plastic cylinder has encouraged the team for thinking of a new methods of bringing the desired transparent plastic cylinder with the same specifications (40 cm diameter , length 2 m) as in figure(1), but in the form of two separated sheet , experiments were done with the use of different ways to form a cylinder, and these tests:

1 - The experience of exposing plastic sheets in oven for hot air for an hour, but it did not succeed, due fragmentation of Plastics.

2 - Another experiment to bend plastic manually and install it with the aluminum as in figure(2) , but this way also did not succeed, because of plate thickness of 4 mm, it was too difficult to bend it by hand, if this method had applied (bended it by hands) this led to the rupture and broken plastic.

3 - The experience of exposing plastics to heat, this method successfully without plastic broken, but the absence of considerable (big) heat machine for the length of 2m, has been exposing part and then part to heat and bend immediately after exposure to heat, but the output shape is not the shape of accurate cylinder.

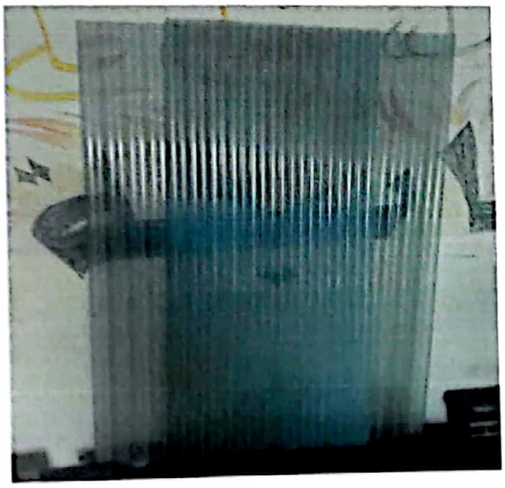


Fig(5.24a)

Fig(5.24.b)

C - The Selection of the Appropriate Type:

The lack of success on the test panels of the thickness of 4 mm, it was inspired to bring the 2-mm thick plastic panels and are bended manually and installed with special screws without the need for heat or hot air, this method was successful.



Fig(5.25)

5.5 Other Operations and Accessories

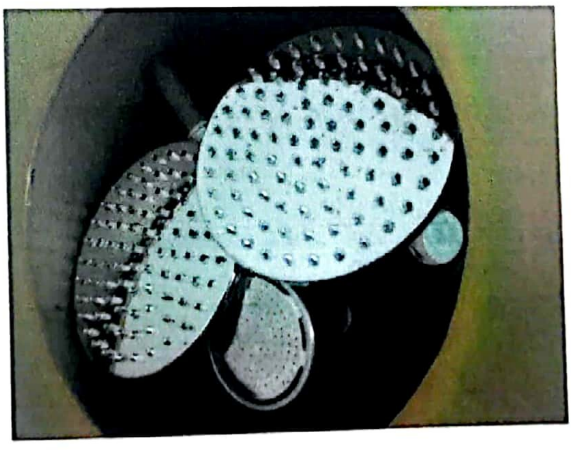
A - The welding of moffa of 3 "diameter at the water exit as in figure(2),and a nibble of 4" diameter at the entrance of the gas as in figure(1).

Fig(5.26a)

Fig(5.26.b)

B - The screws were 16 mm in diameter, to install flanges together by them.

C- Joining the distributors of water with T-pipes and other special parts.



Fig(5.27)

D- Casket was brought and placed at the link between Flanges to prevent leakage of gas through it.

Fig(5.28)

E- Kalkal were brought and placed between the plastic and iron sheets cylinders when joined together in order to prevent the leakage of gas or water.

Fig(5.29)

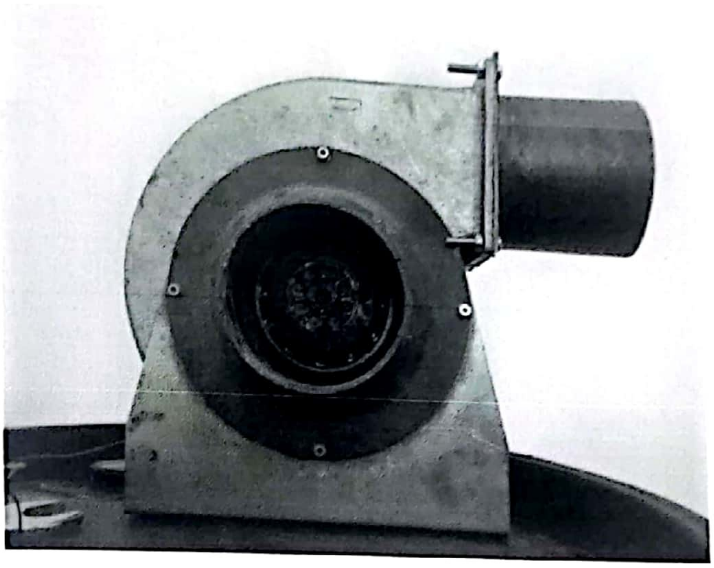
F- NH_3 Cylinder

It will be used instead of the pollutant gases that exhausted from the factory.

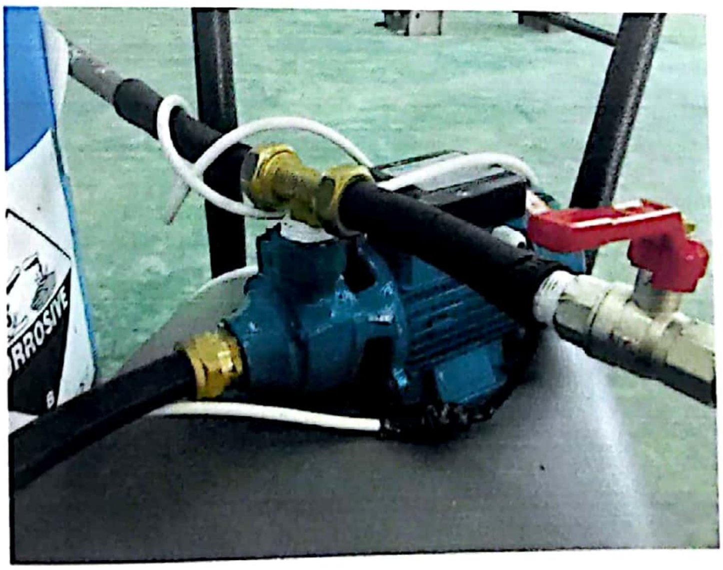
5.5.1 The Final Pieces before Final Building

5.5.2 Actuators Used in the Project

The actuators were brought according to the power calculations in the column design, and so, the fan and the pump were available locally, with flow rate 111 L/s and 110 L/s , respectively.

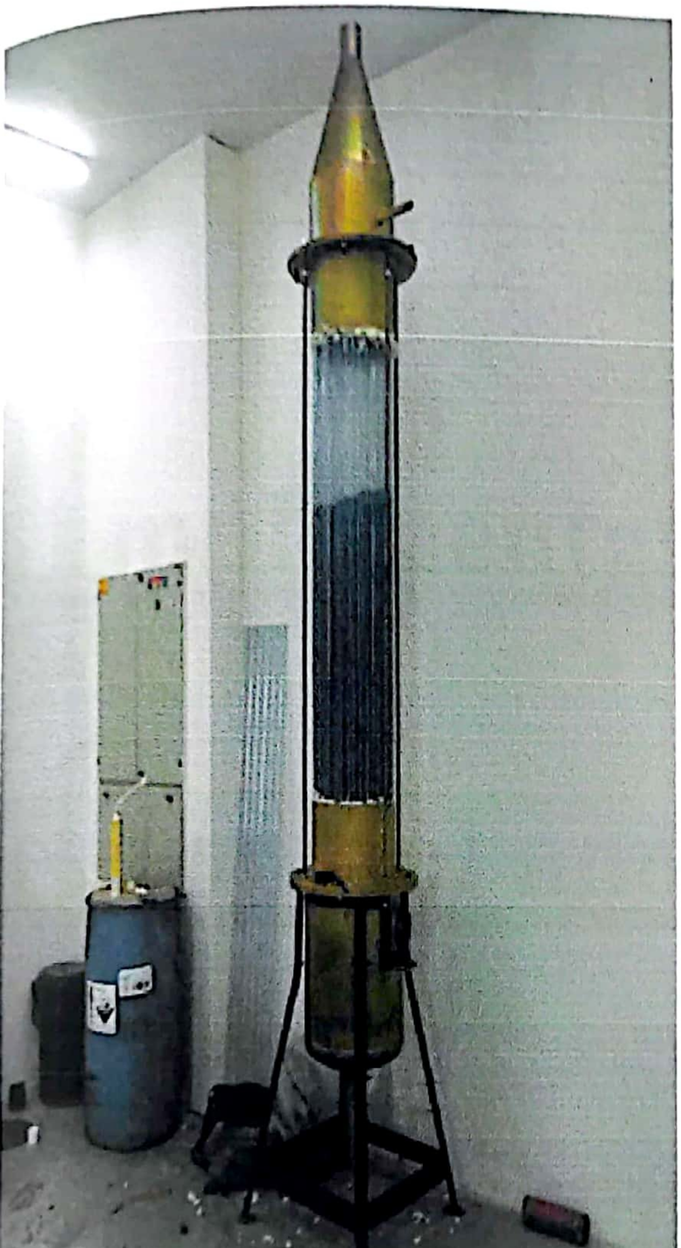


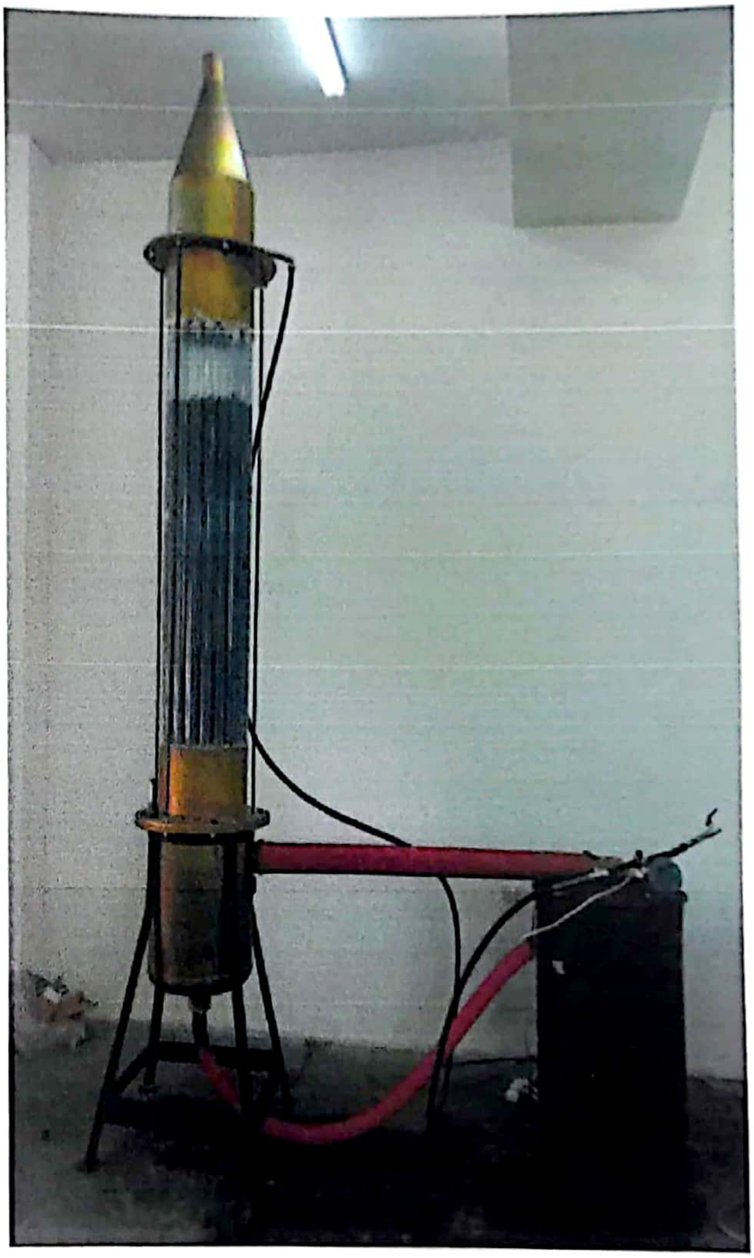
Fig(5.30): Fan



Fig(5.31) : Pump

5.5.3 The Final Shape of Building





Chapter Six

Implementation Of Control and Monitoring System

- Introduction.
- Required Sensors for Control and Monitoring System.
- Control and Monitoring Processes.
- Implementation of Control and Monitoring System.
- Control and Monitoring system in Eagleflex Company.

Chapter Six

Implementation of Control and Monitoring System

6.1 Introduction

This chapter discusses the control and monitoring system in this project. The main aim of this chapter is to show the way of thinking for building the control and monitoring system.

As the data collected from the factory by measuring the concentration of pollutants using measurement devices for gases; the results showed that the problem in the factory comes mainly from three gases which are NH_3, HCN, and VOCs and then the control and monitoring system will be based on them.

6.2 Required Sensors for Control and Monitoring System [14, 15]

Design of packed tower is based on NH_3 gas as explained in chapter five, so its concentration has to be measured at the entrance and the outlet of the tower to find out the system efficiency, and to compare it with the assumed efficiency. NH_3 gas concentration has to be detected using NH_3 gas sensors put at both sides of the tower, [see Appendix J].

The sensing process of a sensor depends on the type of sensor and the manufacturing company of the sensor. almost all sensors have the same strategy in the sensing process, which is that the sensor would be at the place that the reading must be taken at, the reading is voltage output and needs a calibration process to become in the form of concentration output in part per million (ppm) according to the provided datasheets, this is shown in figure (6.1).

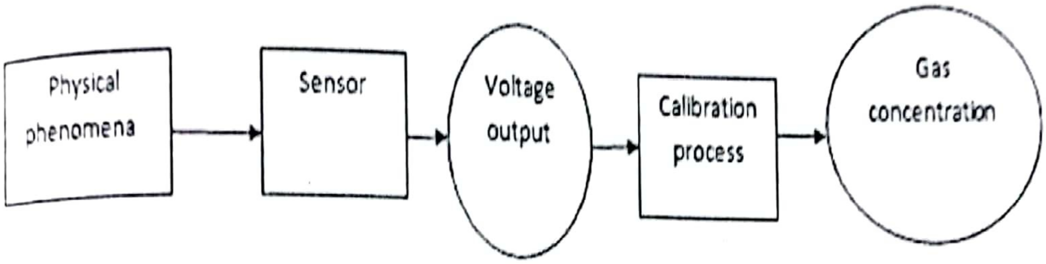


Figure 6.1: schematic flow diagram shows the sensing process.

6.3 Control and Monitoring Processes

This section discusses the main control and monitoring approaches and descriptions of the implemented control and monitoring system for this project. It is just ON\OFF control system has been implemented, and was preferred to be simple as much as can be done.

6.3.1 Control and Monitoring Approaches

There are many ways to control a system whatever its components, it mainly depends on the status of the input, the process, and the output, and can be achieved using one of the following:

1) PC computer and DAQ (data acquisition):
   This way is very complicated and advanced for using in this problem, since as said it is just on/off control.

2) PLC (Programmable Logic Controller):
   This way is much easier than the previous one, cheaper, has the ability to deal with analog and digital form of signals. But in the other hand there is a limitation for using PLC so it can't be used widely as the first one.

3) Microcontroller:
   This method is the suggested one to be used in the control an monitoring system that would be built in the next semester. It is chosen for many reasons; first of all it is the cost since it is very cheep, available and very accurate. Other reasons is that the PIC18F4550 series (the controller type that was

used) has gotten a good feature of accepting analog input such that it has an analog input pins, that to say it is not needed to convert the sensor reading into digital form to be an input for the microcontroller.

6.3.2 Description of Control and Monitoring Process

The suggested sensor to be used in the design of control system is NH3 sensor; the control and monitoring system block diagram is shown in the following figure. Each block has tacitly included components and is illustrated in the following points, assuming the NH_3 sensor is available although it was replaced by potentiometer in order to apply the idea of taking readings, display the results, and the sequence of operation under control and monitoring system.

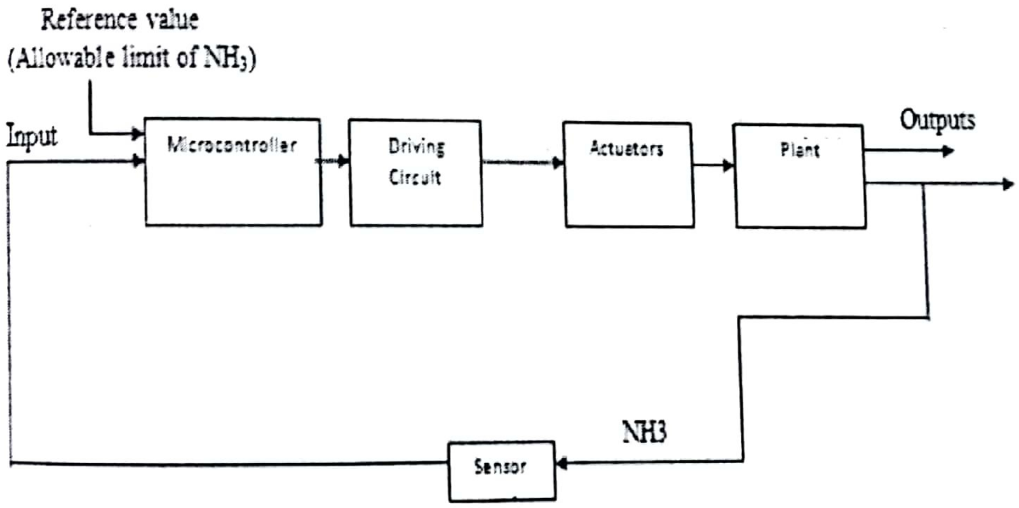


Figure 6.2: block diagram shows control system components.

1) Inputs include the following:

- Allowable limit of NH_3 gas in the atmosphere.
- The user input which is an ON\OFF switch turns the system either ON or OFF.
- The NH3 sensors readings at both sides of the tower.

2) Microcontroller: PIC18F4550 of 40 pins.

3) Driving circuits include the following:

- Four 12V relays for each output.
- Four optocouplers (4n25) switch between the microcontroller and the relays, since the microcontroller provides 5V output, and 12V input is required to operate the relays.
- Two contactors to operate the pump and the fan, the enable signals for each one come from relays.

4) Actuators are:

- Water pump.
- Fan.
- Electrical valves.

5) The Plant is the packed tower as whole.

6) Outputs include:

- Pump is ON\OFF.
- Fan is ON\OFF.
- Electrical valves ON\OFF.
- LCD screen displays the concentration of NH_3 at the inlet and outlet.

7) NH_3 gas sensors at the gas entrance and the gas outlet of the tower, to make a comparison between both concentrations and to obtain the system efficiency.

6.4 Building of Control and Monitoring System

The control and monitoring system method and components (hardware) are discussed at the previous section, in this section the processes sequence and the components connection will be discussed briefly.

6.4.1 Processes Sequence of Operation

Figure (6.3) illustrates the system operation flow chart; the sequence of operation is also highlighted in the following main points:

- The dominant input signal is a switch that can be turned ON and OFF manually by the user.
- If the switch turned ON, the pump starts working.
- After a delay of 10 seconds the fan goes ON also; this delay allows the water to flow through the tower before entering the gas stream, which guarantees washing the gas at the beginning of the process since the gas flow rate is higher the water flow rate.

- As the switch turned ON, the NH_3 sensors at the entrance (input) and the outlet (output) of the tower start taking readings within discrete time periods. As said before the NH_3 sensors were replaced by potentiometers and reading were taken assuming NH_3 sensors were available
- Sensors/Potentiometers readings are displayed at LCD screen of two lines, 16 characters each.
- The allowable value of NH_3 in (ppm) is installed within the microcontroller chip program, and it is also programmed to compare the output reading with the input one. Thus if the output signal is greater than the input signal, water make-up system works to replace the washing water with fresh water, if else then the absorption process works properly.
- If water make-up system starts working, the fan is turned OFF until the water is replaced, after that they starts working again automatically.
- Whenever the switch is turned OFF, the whole system components go OFF.

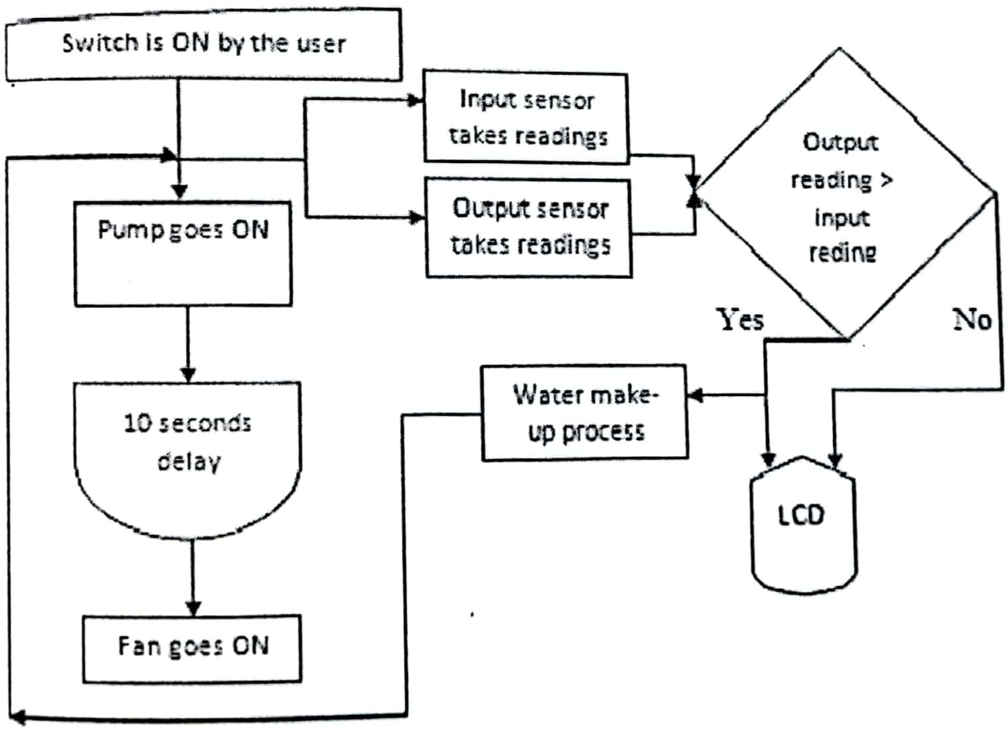


Figure (6.3): Illustration of Processes Flow Chart.

6.4.2 Implemented System Hardware Connection

Figure (6.4) illustrates the hardware connection circuit of control and monitoring system, implementing such a system is quite enough to perform the required process, it just needs to install a program to the microcontroller, and then the system operation follows the construction of the program.

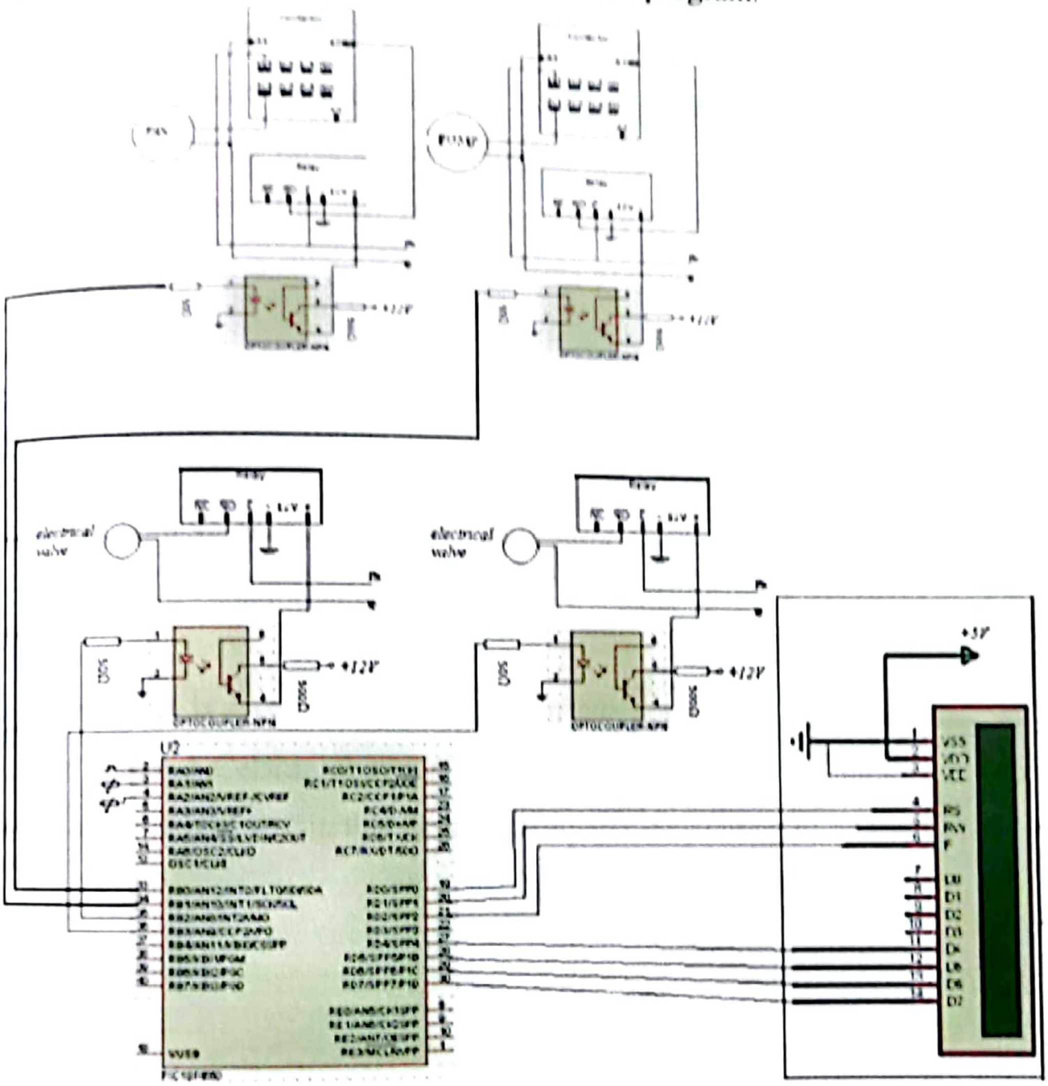


Figure (6.4): Control and Monitoring System Hardware Connection Circuit.

6.5 Control and Monitoring system in Eagleflex Company

6.5.1 Control System in Eagleflex Company

In Eagleflex factory all the industrial processes are based on PLC control system. when the temperature of the oven 185 C˚after 19 hours of baking process, the coils switched off and a valve is opened but the fan stills working. After 24 hours the packing process will be finished, the worker opens the oven gate slightly; the seven stages of baking process are programmed on the PLC control system of the oven.

6.5.2 Monitoring System in Eagleflex Company

Also there is a conditioning system to guarantee that the temperature within 23 and 25 degrees Celsius, that's because materials used in the industrial process must be kept and used within this range of temperature summer or winter.

6.5.3 Proposed Control and Monitoring System for Eagleflex Company

The project team proposes a control system for the factory; this system will base on using sensors in the factory for the polluted gases which will be distributed in the work site in some arrangement such that the process can be easily monitored and controlled.

For controlling the process in the factory there is a thinking of using sensors close to the nozzle in order to measure the gases concentrations, since there is an idea of closing the nozzle and using a plastic pipes instead of the existed tin pipe line, because of an important feature of gases which is the diffusion, this problem can cause a really serious problem effect the workers at the factory, because of the bad health effect of the produced gases of baking process. So that sensors can be connected to an alarm in order to monitor if there is diffusion of the gases.

Another control system can be suggested for the factory related to the water used in the gas treatment method there, and it is known that water can dissolve gases in it for a limit, and after this the reveres thing would happen such that the gas will take things from the water, thus to prevent this a sensor at the outlet of gas from the water full take readings in order to monitor the concentration of the gas (let it for example NH_3 gas) , if the concentration is increasing comparing with the inlet that's mean that there is a problem and the water must be changed so a clean water must be interred to the scrubber by opening an electrical valve and through that another valve must open to get rid of the dirty water.

Chapter Seven

Concluding Remarks, Recommendations and Future Work

- Concluding Remarks
- Recommendations
- Suggested Future Work

Chapter Seven

Concluding Remarks, Recommendations and Future Work

In this chapter, the main concluding remarks of building packed tower, and implementing control and monitoring system are previewed together. with suggested future work.

7.1 Concluding Remarks

The followings are the main concluding remarks:

- The baking of cut-off wheels results in main air pollution problem, and causes various environmental impacts due to the toxicity of the exhausted gases from the baking process.
- The exhausted gases from the baking of the cut-off wheels are identified to include at least VOC, HCN and NH_3. Their levels in the exhausted gases (referred to the allowable standard).
- The existing treatment process in the Eagleflex company seems to be useful in treating some of pollutant gases with low efficiency, that decreases with time; due to water saturation with pollutants.

- spectrophotometer device analysis indicated that pollutant content in water increases with time until approaching full saturation, and thus no further removal of gases.

- There is a need for installing an engineered absorption process; such as packed tower, for efficient gas treatment process.
- A practical packed tower is built, and is shown to be a practical method for treating the pollution problem.

7.2 Recommendations

For the improvement of the treating process in Eagleflex company, it is recommended that:

- Water duration cycle to be reduced in the range of five to seven days, and water replacement must be done with fresh water.
- It is recommended to Close the nozzle that collects the gases from the ovens, in order to prevent gases from diffusion out side the nozzle to the working environment.

- A monitoring system is recommended to be installed, so that it can release an alarm to the workers when the concentrations of gases have exceeded the allowable standards, and then operating a ventilation fan.
- The existing treatment process should be examined every period of time to make sure that no corrosion happened, and no leakage of water from pipes.

7.3 Suggested Future Work

The main project goals and activities have been achieved within the project period, and a complete packed tower has been built. a logistic problems and constraints were faced, thus in the following points a suggested and recommended future works are mentioned:

- It is recommended to perform detailed gas detection on real time operation in the factory for obtaining actual removal efficiency with time.
- Investigating a treatment method for the used water in the absorption process before discharging into surrounding system.
- Using the NH_3 gas cylinder instead of the exhausted gases from the oven, for the educational purposes.
- It is recommended to close the open nozzle in order to prevent the diffusion of gases into working environment.
- It is also recommended to use a more effective distributer in the built packed tower.
- Based on new data, other gases (other than NH_3) may be considered for packed tower design and for monitor/control system.
- It is recommended to obtain and install the gas sensor for monitor/control system.

References:

1) Robert E. Treybal, Mass-Transfer Operations, third edition.
2) Yunus A.Cengel, Introduction to Thermodynamics and Heat Transfer, University of Nevada Reno, The McGraw-Hill Companies, Inc, ©1997.
3) C. C. Lee and Shun Dar Lin, Handbook of Environmental Engineering Calculations, Second Edition, Published by McGraw-Hill Professional, © 2007.
4) David A. Dzombak, Rajat S. Ghosh, George M. Wong-Chong, Cyanide in Water and Soil: Chemistry, Risk, and Management, Published by CRC Press, 2006.
5) http://www.environment.gov.au/atmosphere/airquality/publications/standards.html.
6) http://www.wccoff.org/hydrogen%20sulfide%20gas%20fact%20sheet.pdf
7) http://www.nmenv.state.nm.us/aqb/projects/openburn/chem_info.html
8) http://www.epa.gov/iaq/voc.html
9) http://www.epa.gov/apti/bces/module4/absorption/absorption.htm
10) http://www.academicjournals.org/ERR
11) http://www.cgwheels.comn
12) http://www.betescrubbers.com/en/gas-scrubbers/packed-tower-scrubber.html
13) http://www.hygradeplastics.com/packed.html
14) http://www.alphasense.com/alphasense_sensors.html
15) http://www.nemototech.com/industrial/ntnh3.html
16) http://www.saskschools.ca/curr_content/chem30_05/6_redox/labs/electrochem_cells.htm
17) http://www.coheadquarters.com/colimits1.htm
18) http://www.atsdr.cdc.govl
19) http://www.ec.gc.ca/nopp/DOCS/consult/2-Methoxyethanol/en/rms5.cfm
20) www.engineeringtoolbox.com

Note: all of the web sites are in year 2009.

Appendices

- Appendix A.
- Appendix B.
- Appendix C.
- Appendix D.
- Appendix E.
- Appendix F.
- Appendix G.
- Appendix H.
- Appendix I.
- Appendix J.

Appendix

(A)

Health Effect

Table [2.1]

Air Pollutant	**Sources**	**Health Effect**
Sulfur dioxide (SO_2)	• combustion of sulfur containing fossil fuels • power plant • marine vessel • motor vehicle	High level • impairment of respiratory function • aggravate existing respiratory and cardiac illnesses • increased morbidity and mortality rates Low level • chronic respiratory diseases
Nitrogen Oxides (NOx)	• power plant • motor vehicle • fuel combustion • space heating	Long term exposure • lower resistance to respiratory infections • lung development impairment • aggravate existing chronic respiratory diseases
Volatile Organic Compounds (VOCs)	• building material • cleaning agent • cosmetics, wax	• toxicological effects on the central nervous system, liver, kidney and

	• carpet • furnishing • laser printer photocopier • printing materials • adhesive, sealant • paint varnish and solvent	blood • eye irritation: burning, dry, gritty; watery eyes • throat irritation: dry throat • respiratory problems

[1] http://www.cleanair.hk/eng/appendix_f.pdf

The World Health Organization has compiled the following international guidelines for airborne pollutants [1].

Pollutant	Guideline Value[μ g/m^3]	Averaging Time
Carbon Monoxide	**100 000**	**15 minutes**
	60 000	**30 minutes**
	30 000	**1 hour**
	10 000	**8 hours**
Lead	**0.5**	**1 year**
Nitrogen Dioxide	**200**	**1 hour**
	40	**1 year**
Ozone	**120**	**8 hours**
Sulphur Dioxide	**500**	**10 minutes**
	125	**24 hours**
	50	**1 year**

[1] http://www.wunderground.com/health/pollutionfaq.asp#intst

Appendix

(B)

The Oven

Oven No.	Height(cm)		Length(cm)		Depth (cm)		Inner volume (m^3)
	Outer	Inner	Outer	Inner	Outer	Inner	
1	200	186	190	133	140	120	2.9
2	242	186	185	135	154	133	3.4
3	242	186	185	135	154	133	3.4
4	242	186	185	135	154	133	3.4

Table (3.1) : the outer and inner dimensions of the ovens

The Volume of Ovens

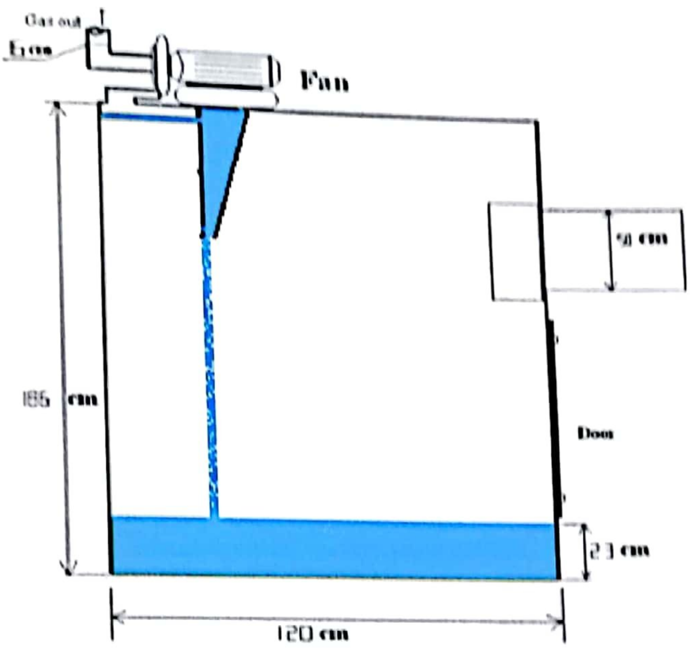
Oven NO.	Internal volume(m3)	Volume of fibers(m3)	Empty volume
1	2.9885	0.988	2
2	3.402	0.59126	2.81074
3	2.9885	0.59126	2.39724
4	3.402	0.9238	2.4782

Appendix

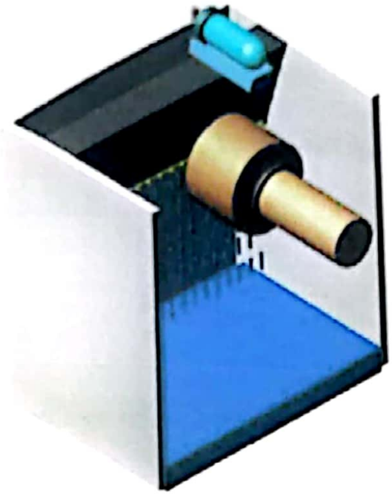
(C)

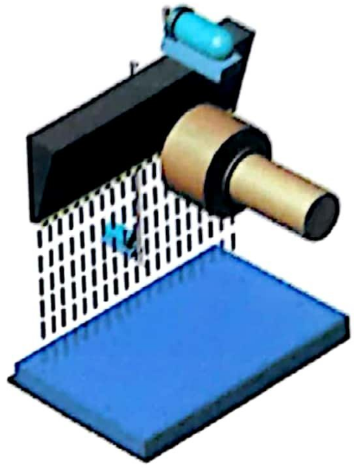
The Waterfall

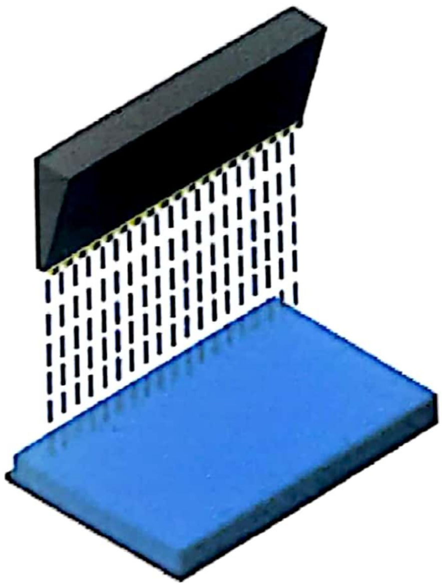
Dimension of Waterfall scrubber

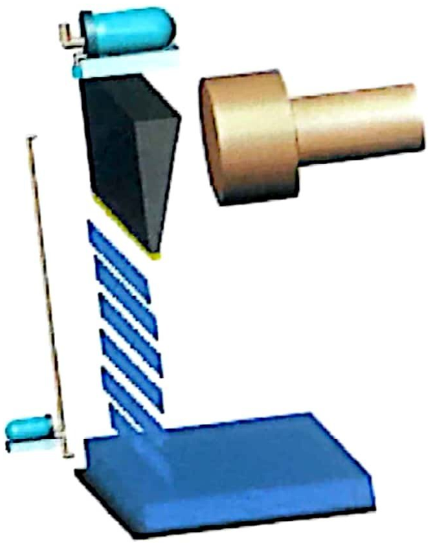


Sketches for waterfall scrubber (existing treatment process)









Appendix

(D)

Measuring pollutant gas concentration and charts

(1)

Table of percentage of gases for non working condition

TIME: 11:15 AM
PRESSURE: 1 atm

TEMP. 16 C°

TRAIL / GAS NO.	1	2	3	4	5
CO	0	0	0	0	0
H_2S	0	0	0	0	0
O_2	20.9	20.9	20.9	20.9	20.9
LEL	0	0	0	0	0
VOC	1	1	1	1	1
NO_2	0.2	0.1	0.1	0.1	0.1
NH_3	0	0	1	1	2
SO_2	0	0	0.1	0.1	0.1
HCN	0	0	0	0	0
O_3	0	0	0	0.01	0

Trail	Gas measurement from Oven3(ppm)@140C°					Gas measurement from Nozzle(ppm)@23C°							
Gas	1	2	3	4	Avg	1	2	3	4	5	6	7	Avg
CO	1	3	3	2	3	2	4	5	5	4	4	4	4
H_2S	0	0	0	0	0	0	0	0	0	0	0	0	0
O_2	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
VOC	15	20	22	18	18.75	30	35	37	38	27	29	32	32.5
NO_2	0.2	0.1	0.1	0.1	0.125	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.114
NH_3	46	63	73	72	63.5	57	114	62	72	53	73	65	70.85
SO_2	0	0	0	0	0	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0	0	0	0	0	0
O_3	0	0	0	0	0	0	0	0	0	0	0	0	0

Trail	Gas measurement from Oven2 door(ppm)@185C°						Gas measurement from Waterfall [scrubber] (ppm)@16C°						
Gas	1	2	3	4	5	Avg	1	2	3	4	5	6	Avg
CO	55	57	80	137	133	92.4	0	0	0	0	0	0	0
H_2S	0	0	0	0	0	0	0	0	0	0	0	0	0
O_2	19.7	20.5	20.3	20.3	20.2	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
LEL %	4	4	6	6	7	5.4	0	0	0	0	0	0	0
VOC	404	398	550	728	215	459	10	10	10	10	10	11	10.2
NO_2	5.1	3.2	1.4	1.5	0.9	2.42	0.2	0.1	0.1	0.1	0.1	0	0.1
NH_3	200	200	200	200	200	200	44	42	42	40	40	40	41.3
SO_2	0.2	0.6	0.7	0.6	0.9	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HCN	10	14	11	12	10	11.4	0	0	0	0	0	0	0
O_3	0	0	0	0	0	0	0	0	0	0	0	0	0

Trail / Gas	Gas measurement from the outlet of waterfall(ppm)@185C°					
	1	2	3	4	5	Avg
CO	1	1	1	1	1	1
H_2S	0	0	0	0	1	0.2
O_2	20.9	20.9	20.9	20.9	20.9	20.9
LEL%	0	0	0	0	0	0
VOC	17	18	18	18	18	17.8
NO_2	0	0.1	0.1	0	0	0.4
NH_3	181	162	143	128	114	145.6
SO_2	0.2	0.2	0.1	0.1	0.2	0.16
HCN	1	0	0	0	0	0.2
O_3	0	0	0	0	0	0

Trail / Gas	Gas measurement (ppm)					
	Non-working	Oven3@ 140C°	Nozzle	Oven2@ 185 C°	Waterfall	Outlet
CO	0	3	4	92.4	0	1
H_2S	0	0	0	0	0	0.2
O_2	20.9	20.9	20.9	20.2	20.9	20.9
LEL%	0	0	0	5.4	0	0
VOC	1	18.75	32.5	459	10.2	17.8
NO_2	0.12	0.125	0.114	2.42	0.1	0.4
NH_3	0.8	63.5	70.85	200	41.3	145.6
SO_2	0.06	0	0	0.6	0.1	0.16
HCN	0	0	0	11.4	0	0.2
O_3	0.002	0	0	0	0	0

(2)

Trail / Gas	Gas measurement concentration (ppm) from: The **Oven.**										
	Temperature: 15 C°				Pressure: atm.				Time:10:45 AM		
	1	2	3	4	5	6	7	8	9	10	Avg.
CO	58	58	66	64	64	70	69	72	73	63	65.7
H_2S	0	0	0	0	0	0	0	0	0	0	0
O_2	20.2	20.2	20.2	20.2	20.1	20.1	20.1	20.1	20.1	20	20.13
LEL%	6	7	7	6	7	7	7	8	7	8	7
VOC	422	631	761	727	918	712	812	665	668	667	698.3
NO_2	2.4	2.1	1.8	1.6	1.7	1.5	1.3	1.1	1	2.3	1.68
NH_3	200	200	200	200	200	200	200	200	200	200	200
SO_2	0.4	0.5	0.7	0.8	0.9	1.1	1.1	1.2	1.3	1.1	0.91
HCN	8	9	10	10	11	12	12	13	12	13	11
O_3	0	0	0	0	0	0	0	0	0	0	0

Trail / Gas	Gas measurement concentration (ppm) from: Inside the input **nozzle,** that enters the waterfall.							
	Temperature: 15 C°			Pressure: atm.		Time:10:55 AM		
	1	2	3	4	5	6	7	Avg.
CO	0	2	3	2	0	0	0	1
H_2S	0	0	0	0	0	0	0	0
O_2	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
LEL%	0	0	0	0	0	0	0	0
VOC	15	46	45	24	17	35	32	30.57
NO_2	0	0.3	0.2	0	0	0	0	0.07143
NH_3	59	66	67	50	57	70	73	63.143
SO_2	0.7	0.1	0.2	0.2	0.2	0.2	0.2	0.257
HCN	1	1	1	1	1	1	2	1.143
O_3	0	0	0	0	0	0	0	0

Trail / Gas	Gas measurement concentration (ppm) from: **Outlet from waterfall.**										
	Temperature: 23 C°				Pressure: atm.				Time:11:00 AM		
	1	2	3	4	5	6	7	8	9	10	Avg.
CO	0	0	0	0	0	0	2	2	2	3	0.9
H_2S	0	0	0	0	0	0	0	0	0	0	0
O_2	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
LEL%	0	0	0	0	0	0	0	0	0	0	0
VOC	23	23	22	22	22	15	16	17	19	21	20.0
NO_2	0.3	0.2	0.2	0.2	0.1	0.6	0.7	0.6	0.4	0.3	0.36
NH_3	67	68	68	67	69	62	66	70	76	79	69.2
SO_2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.23
HCN	1	1	1	1	1	2	2	2	2	2	1.5
O_3	0	0	0	0	0	0	0	0	0	0	0

Trail Gas	Average Gas measurement concentration (ppm) from the three main locations: nozzle, waterfall and outlet. The water cycle is from 8th- January due to 10th-Fabuary			
	The Oven	The Nozzle	The Outlet	Efficiency % between the Nozzle & outlet
CO	65.7	1	0.9	10%
H_2S	0	0	0	*
O_2	20.13	20.9	20.9	0**
LEL%	7	0	0	*
VOC	698.3	30.57	20.0	34.57%
NO_2	1.68	0.07143	0.36	403.99% ***
NH_3	200	63.143	69.2	9.59% ***
SO_2	0.91	0.257	0.23	10.5%
HCN	11	1.143	1.5	31.23% ***
O_3	0	0	0	*

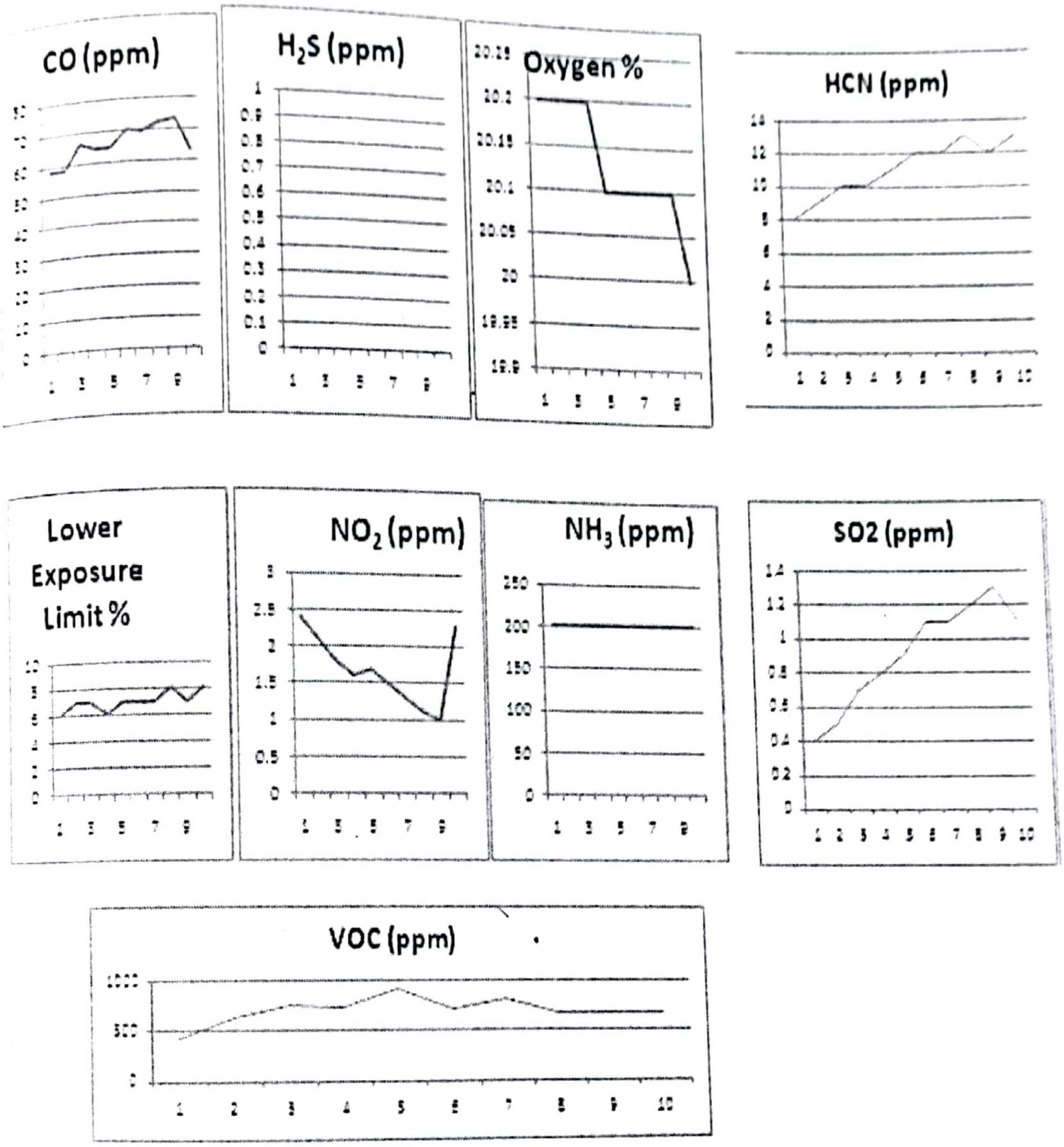
* : Not measured at either in the inlet or outlet of the waterfall.

** : No reduction as the percentage in fresh air is normal.

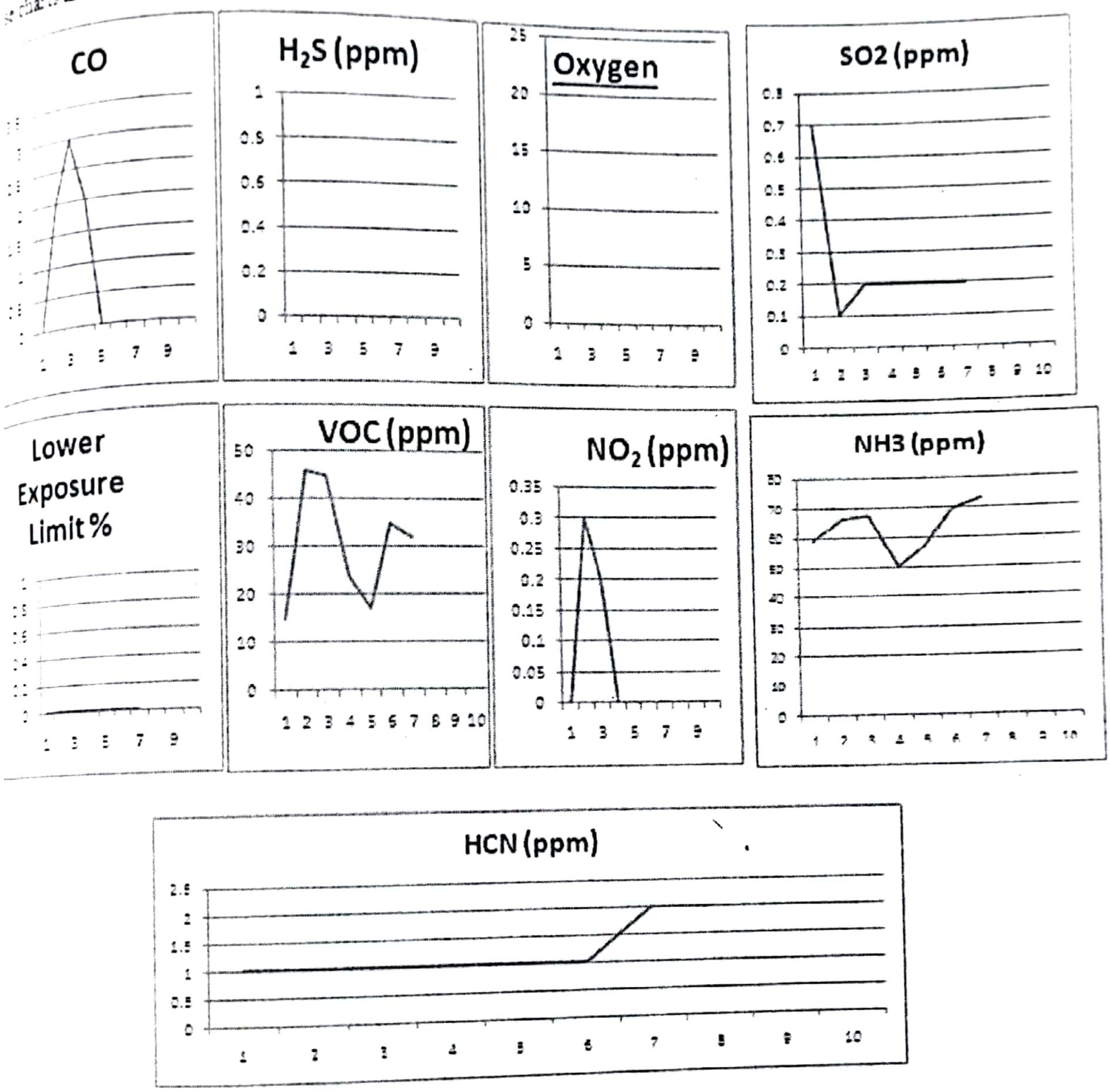
***: Means that the percentage of gas has increased not reduced, and this is related to the large duration cycle of the used water in the cleaning process.

(3)

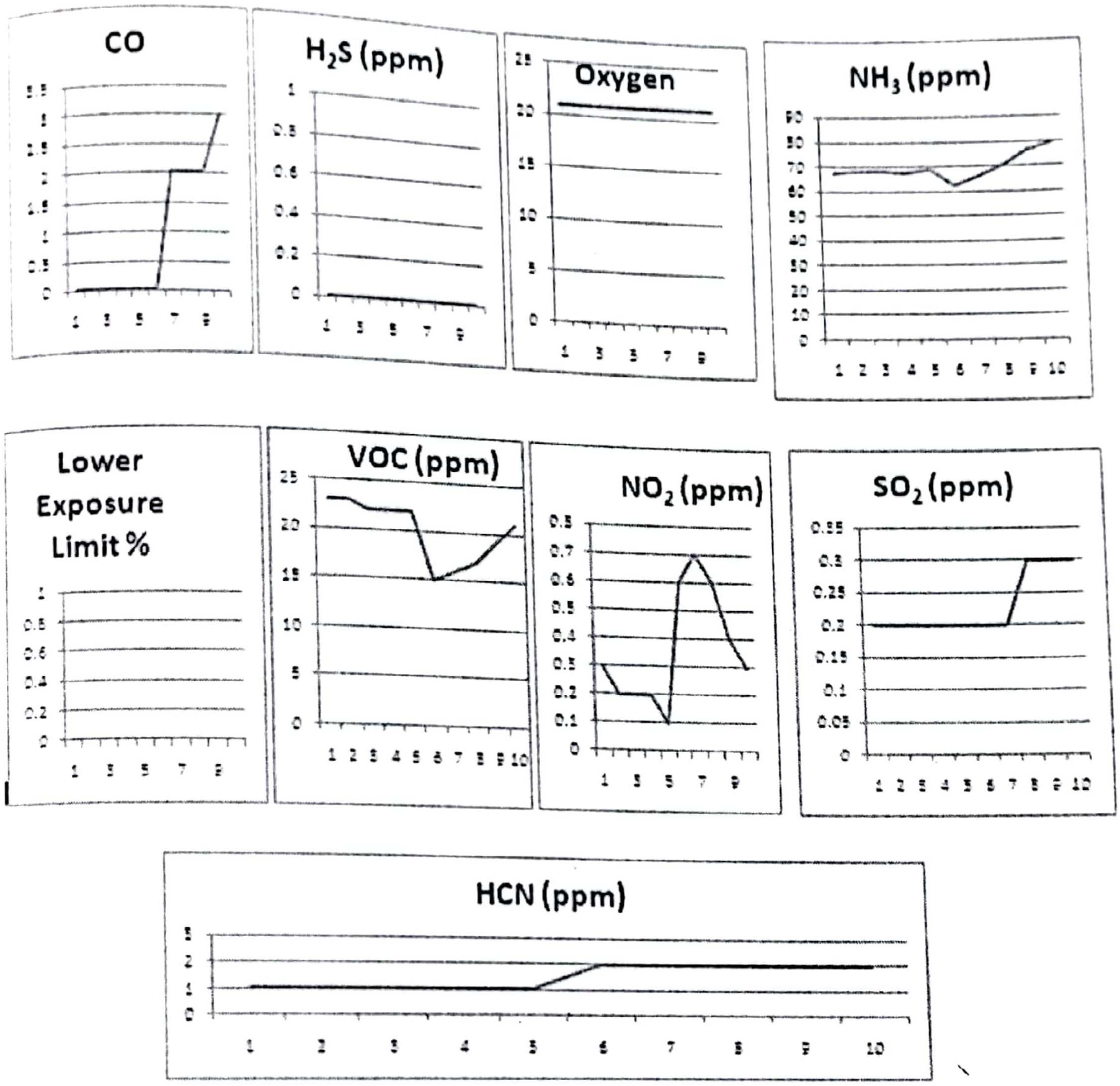
Data from the **Oven**: Concentration of gas (ppm) vs. Time (*10 s)



se charts are for gas concentration from the Nozzle.



These data charts are taken from the outlet



Appendix

(E)

Flow and Density Measurements

(1)

Nylon Bag #	L (m)	R (m)	Time (sec)	W1 (gr)	W2 (gr)	V (m^3)	Q (m^3/s)	Avg.
1@inlet	1.27	0.16	20	42	43	0.1026	0.0051	0.0078
2@inlet	1.75	0.16	15.86	50	52	0.1407	0.0089	
3@inlet	1.79	0.16	15	49	51	0.1440	0.0096	
4@outlet	1.32	0.16	2.01	42	43	0.1062	0.0528	0.0525
5@outlet	1.30	0.16	2	41	42	0.108	0.0522	

$V=\pi r^2 * L$

$Q=v/t$

L: Length of the cylindrical bag.

R: Radius of the cylindrical bag.

W1: Weight of the Nylon bag before filling.

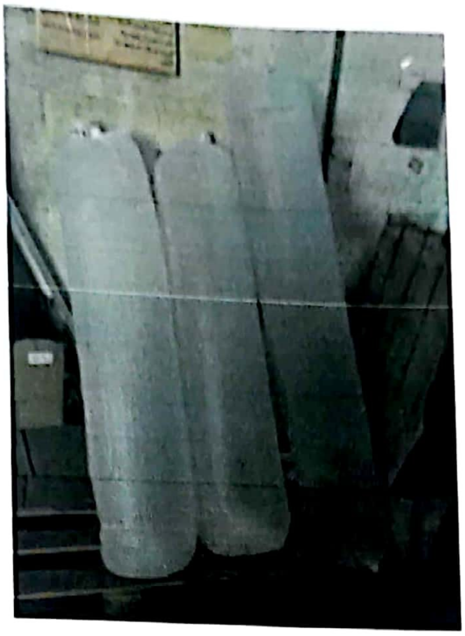
W2: Weight of the Nylon bag after filling.

V: Volume of the bag.

Q: gas flow rate.

The average gas flow rate at the inlet is 0.007867 m^3/s

The average gas flow rate at the oulet is 0.0525 m^3/s



Nylon Bag

(2)

Nylon Bag #	L (m)	Contour (m)	Time (sec)	W1 (gr)	W2 (gr)	V (m^3)	Q (m^3/s)	ρ (g/m^3)
1@inlet	1.76	0.75	8.59	19	40	0.07878	0.00917	266.5
2@inlet	1.76	0.75	9	20	40	0.07878	0.00875	253.87
3@inlet	1.76	0.75	6.9	1030	1052	0.07878	0.0114	279.25
Avg.							0.00977	266.54

Resident time calculations:

S = vol. vol. displacement

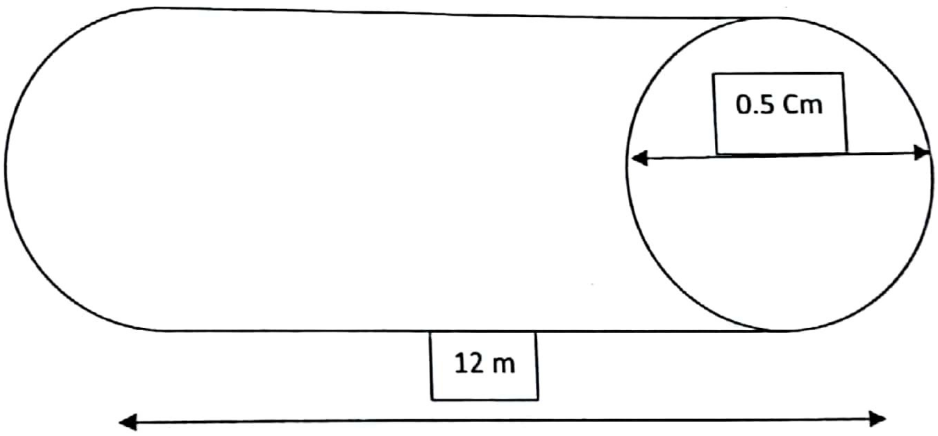
$V = \pi\ 4 * 0.5^2 * 12 = 2.3562\ m^3$

$V_d = 0.0075 \rightarrow s = 314.16$ sec One oven

$V_d = 0.015 \rightarrow s = 157.08$ sec Two Ovens

$V_d = 0.0225 \rightarrow s = 104.72$ sec Three Ovens

$V_d = 0.03 \rightarrow s = 78.54$ sec Four Ovens



Appendix

(F)

Water Sample Test

After tacking the polluted water from the water flow, which the gas has been cleaned by, and with duration of 10 days of cleaning the results of the pollutant gases were as follow:

Note: (these results were taken at energy and environment research unit -ppu-):

The PH scale of the polluted water was 9.3, which indicates that the water has base effect,

But for the clean water that was taken from the unit at the same temperature and same device has a scale of PH=8.2

NO_3: Solvent gas in the polluted water is very large; as it has been indicated as 1.1gr/l

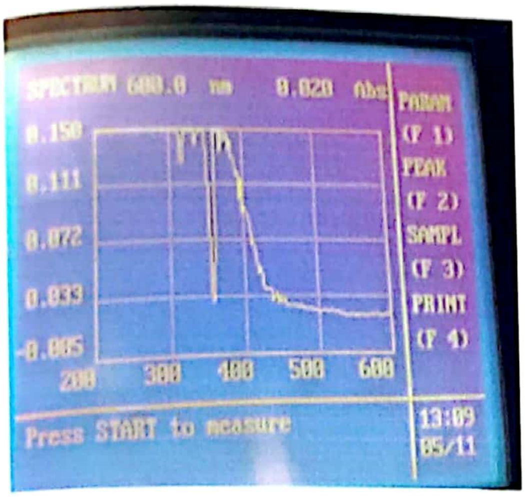
SO_4 : it has been indicated that the polluted water has got 450mg/l of so_4 and the following procedure was followed in measuring its percentage:

1- 10 ml of fresh water mixed with 1 cm^3 of polluted water.
2- Then 10 drops of SO_4^{-1} has been added.

then one spoon of SO_4^{-2} has been added

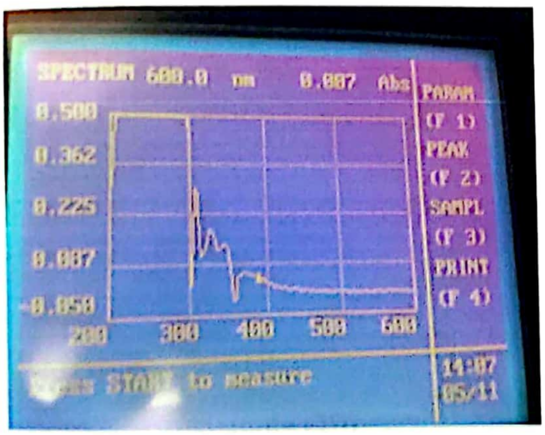
water samples analysis

Fresh water



Sample (2)

Sample (1)

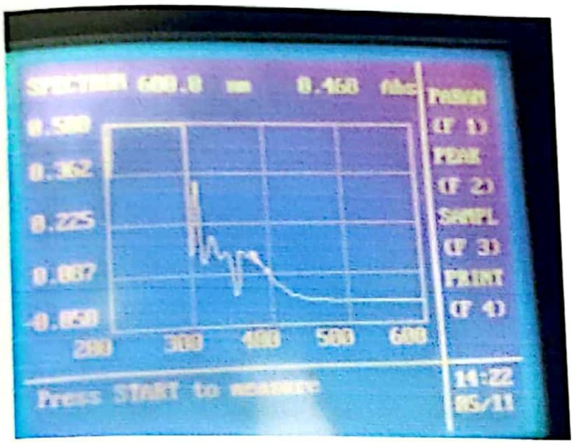


Sample (4)

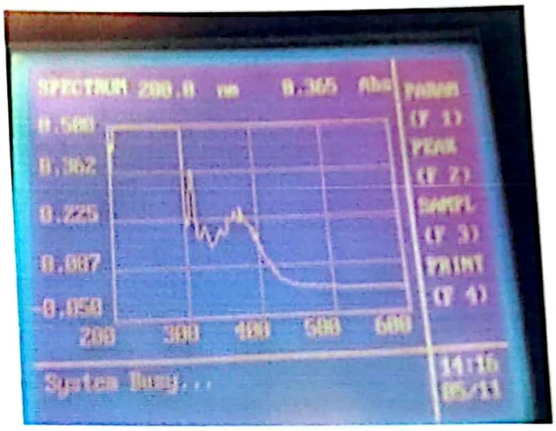
Sample (3)

Sample (6)

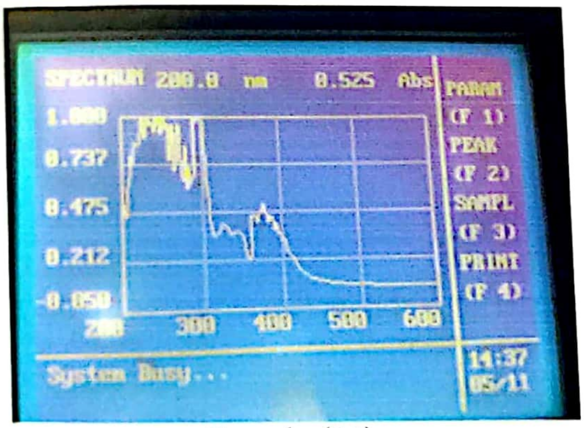
Sample (5)



Sample (8)

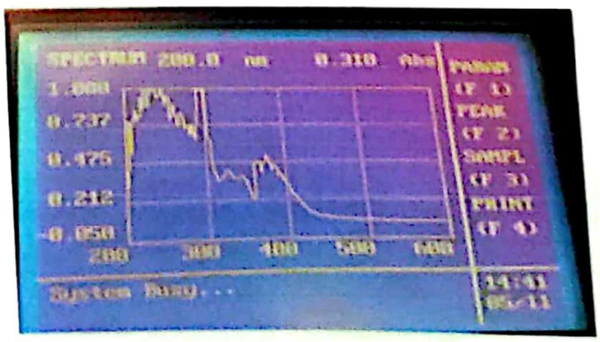


Sample (7)



Sample (10)

Sample (9)




SPECTRUM 200.0 nm 0.500 Abs
PARAM
(F 1)
PEAK
(F 2)
SAMPL
(F 3)
PRINT
(F 4)
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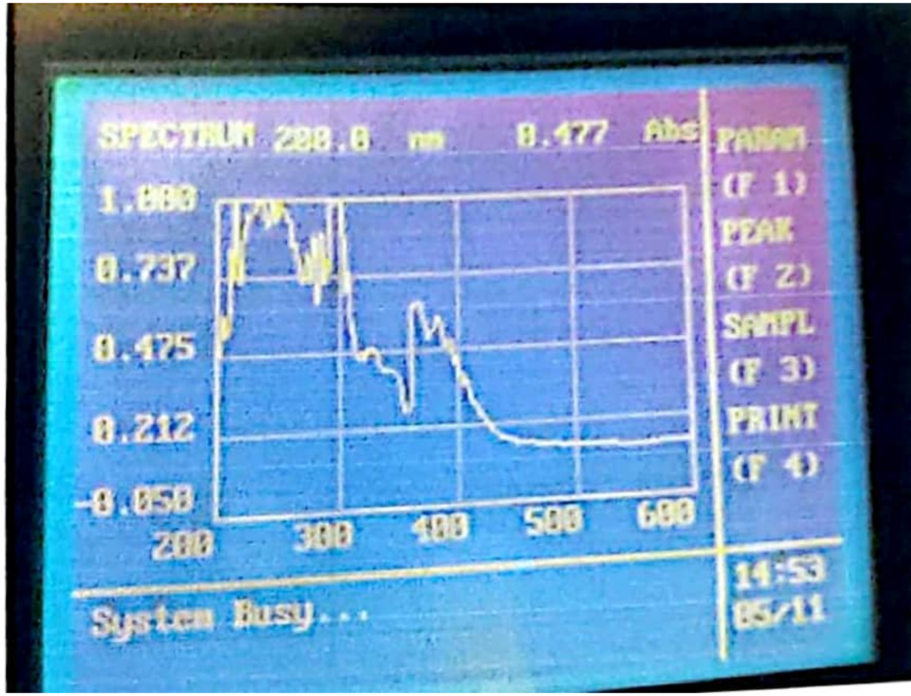
0.475
0.212
-0.050
200
300
400
500
600
14:56
05/11
System Busy...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(F 4)
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200
300
400
500
600
14:53
05/11
System Busy...

Appendix

(G)

Gases Properties and Allowable cocentration

Gases Properties

Gas	Molecular weight	Critical points	Boiling point (1.013 bar)	Gas density (1.013 bar)
Dry air	28.95 g/mol	1)-140.5 °C 2)37.71 bar	-194.5 °C	1.202 kg/m^3
CO	28.01 g/mol	1)-140.3 °C 2)34.987 bar 3) 301 kg/m^3	-191.6 °C	4.355 kg/m^3
NO_2	46.05/mol	1)157.8°C 2)101.32 bar	21.1 °C	3.4 kg/m^3
SO2	64.06 g/mol	1)157.6 °C 2) 78.84 bar	-10.1 °C	3.049 kg/m^3
H2S	34.08 g/mol	1) 100 °C 2)89.37 bar	-60.2 °C	1.93 kg/m^3
HCN	27.03 g/mol	-	26°C	0.94 kg/m^3
NH3	17.03 g/mol	1)132.4°C 2)112.8 bar	-33.5 °C	0.86 kg/m^3
VOC (CH4)	16.043g/mol	1) -82.7 °C 2) 45.96 bar	-161.6 °C	1.819 kg/m^3

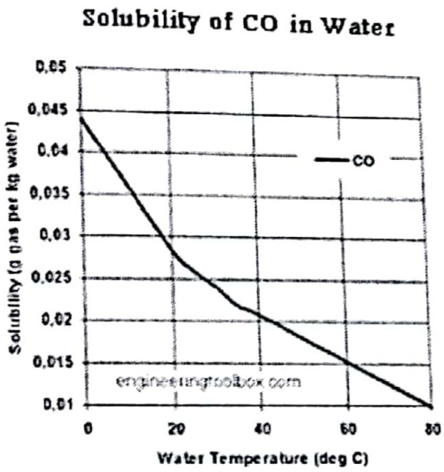
http://encyclopedia.airliquide.com/encyclopedia.asp

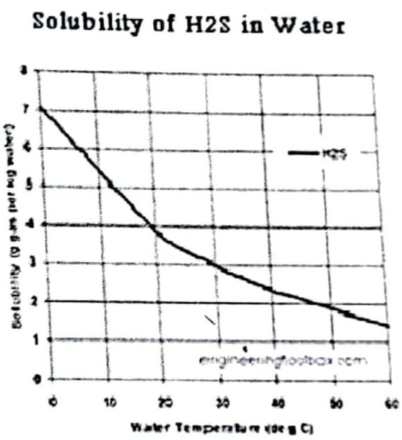
Solubility of gases in water (*)

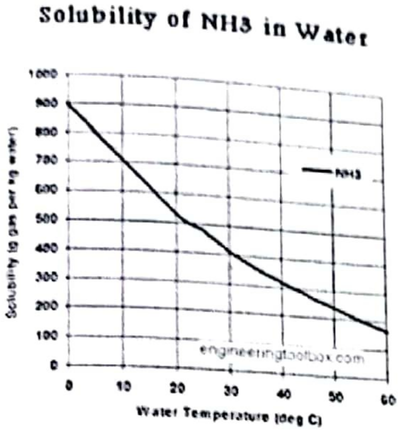
Gas	Solubility g/l
NH3	654.94
SO2	228.0426
H2S	7.1
O3	0.64
O2	0.06
CO	0.04398
CH4	0.03865
NO2	REACTS
HCN	Not Available

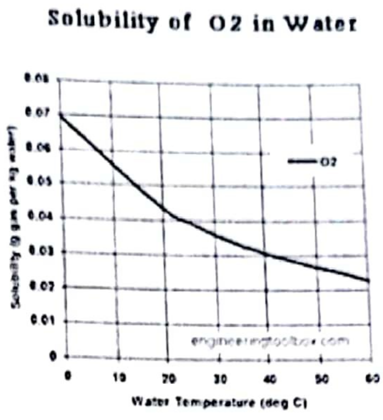
(*)http://encyclopedia.airliquide.com/encyclopedia.asp

Solubility Carves

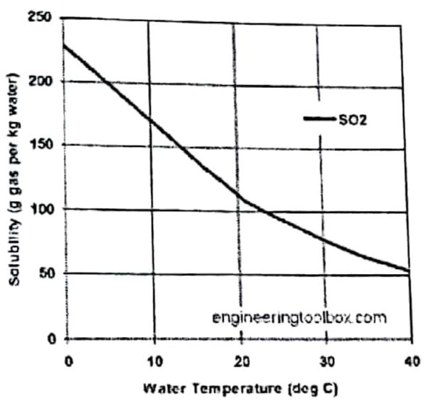








Solubility SO_2 in Water



Henry's Law Constant

Henry's law can be put into mathematical terms (at constant temperature) as

$$p = k_{\mathrm{H}}\, c$$

where p is the partial pressure of the solute, c is the concentration of the solute and k_{H} is a constant with the dimensions of pressure divided by concentration.[1] The constant, known as the Henry's law constant, depends on the solute, the solvent and the temperature.

Some values for k_{H} for gases dissolved in water at 298 kelvins include:

Gas	k_{H}	units	Ref.
CO	1052.63	L·atm/mol	1
H_2S	515	L·atm/mol	2
O_2	4.3×10^4	L·atm/mol	2
NO_2	1.0×10^{-2}	mol/atm	3
NH_3	0.764	----------	2
SO_2	38	L·atm/mol	2
HCN	0.122	L·atm/mol	4
O_3	5×10^3	L·atm/mol	2

[1] http://en.wikipedia.org/wiki/Henry%27s_law

[2] **Page 334**
Handbook of Environmental Engineering Calculations
By C. C. Lee, Shun Dar Lin
Edition: 2, illustrated, revised
Published by McGraw-Hill Professional, 2007
ISBN 0071475834, 9780071475839
1772 pages
[3] http://www.isws.illinois.edu/nitro/terms.asp?lpg=glossary&lsec=&term=NSpecies

[4] page 60

Cyanide in Water and Soil: Chemistry, Risk, and Management
By David A. Dzombak, Rajat S. Ghosh, George M. Wong-Chong
Edition: illustrated
Published by CRC Press, 2006
ISBN 1566706661, 9781566706667
602 pages

Gases Allowable

Gas	Allowable ppm	Average (Minutes)	Allowable ppm	Average (Hours)	Allowable ppm	Average year	Ref.
CO	35	60	9	8	0.2	1	1
NO_2	5	15	25	8	0.053	1	2
SO2	0.2	10	2	8	0.03	1	2
H2S	10	10	20	8	0.23	1	2
HCN	4.7	15	10	8	0.2	1	2
NH3	35	15	25	8	1-5 ppb	1	2
VOC	5	10	25	8	0.35	1	3

[1[http://www.coheadquarters.com/colimits1.htm

[2]http://www.atsdr.cdc.govl

[3]http://www.ec.gc.ca/nopp/DOCS/consult/2-Methoxyethanol/en/rms5.cfm

VOC Types

http://www.tpub.com/content/altfuels08/5364/53640050.htm

Types of VOC Air Releases

VOC Type	Process Source	Emission Type	Quantifiable
Methane	Anaerobic Digestion	Fugitive	No
Acetaldehyde	Fermentation/Product Storage/Boiler	Vent/Fugitive	Yes
Acetic Acid	Fermentation	Fugitive	No
Formic Acid	Fermentation	Fugitive	No
Propionic Acid	Fermentation	Fugitive	No
Formaldehyde	Boiler	Vent	Yes
2-Furfural	Pretreatment	Fugitive	No
Ethyl Alcohol	Fermentation/Product Storage	Vent/Fugitive	Yes
Isopropyl Alcohol	Fermentation/Product Storage	Fugitive	No
N-butyl Alcohol	Fermentation/Product Storage	Fugitive	No
N-propyl Alcohol	Fermentation/Product Storage	Fugitive	No
S-butyl Alcohol	Fermentation/Product Storage	Fugitive	No
Isobutyl Alcohol	Fermentation/Product Storage	Fugitive	No

Gas Constant

Substance	Formula	Molar mass (kg/kmol)	R (gas constant) (KJ/Kg)
Carbon monoxide	CO	28.011	0.2968
Hydrogen Sulfide	H_2S	34.08	0.029
Oxygen	O_2	32	0.2598
Volatile Organic Compounds	VOC(CH_4)	16	0.5182
Nitrogen Dioxide	NO_2	46.05	0.18054
Ammonia	NH_3	17.03	0.4882
Sulfur Dioxide	SO_2		0.1298
Hydrocyanic Acid	HCN	27.017	0.3077
Air	---	28.97	0.287

$R = R_u / M$, R_u=8.314 kJ/Kmol.K universal gas constant, M is the molar mass

PPM = (mg/m^3) *(22.4/ molecular weight)

Appendix

(I)

Needed Data for Packed Tower

Type Of Packing materials

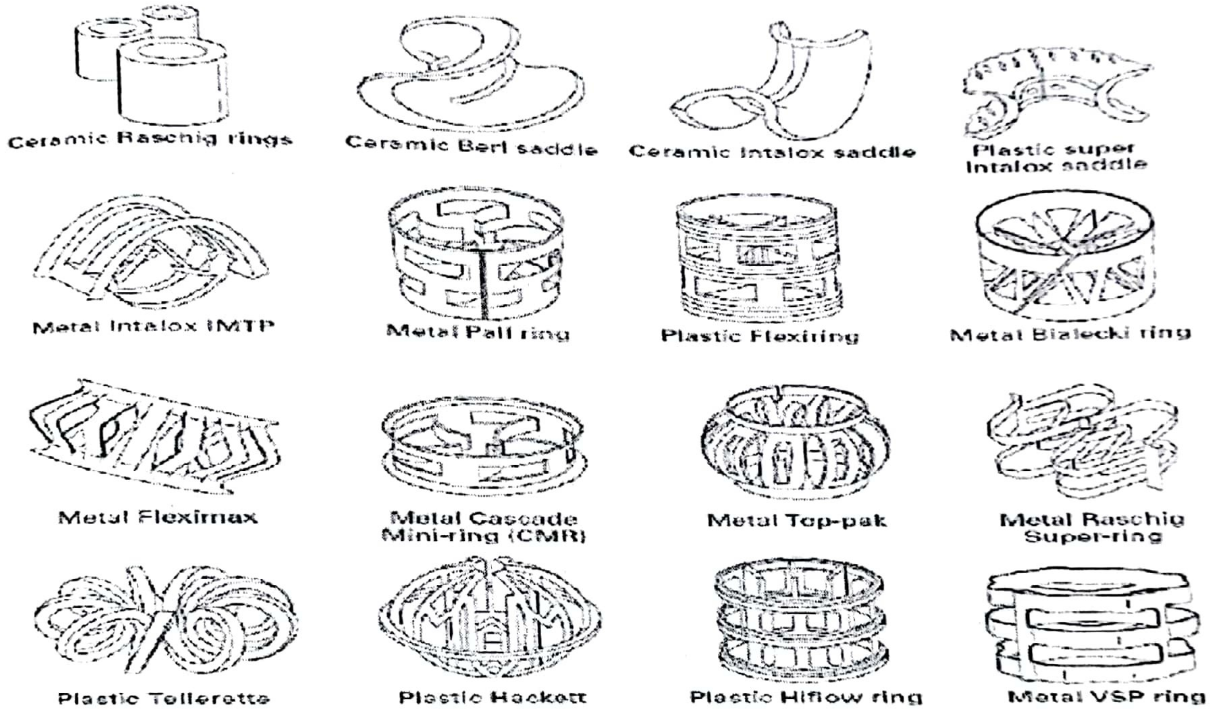


Table1: Types of packing materials:

No.	Paking type	Application features
1.	Raschig Rings	• Earliest type. • Usually cheaper per unit cost. • Available in widest variety of materials. • Very sound structurally. • Usually packed by dumping wet or dry, with larger 4-6-inch sizes sometimes hand stacked. • Wall thickness varies between manufacturers. • Available surface changes with wall thickness. • Produce considerable side thrust on tower. • Usually has more internal liquid channeling, and directs more liquid to walls of tower. • Low efficiency.
2.	Berl Saddles	• More efficient than Raschig Rings in most applications. • More costly. • Packing nests together and creates "tight" spots in bed which promotes channeling but not as much as Raschig rings. • Do not produce as much side thrust. • Has lower HTU and unit pressure drops with higher flooding point than Raschig rings. • Easier to break in bed than Raschig rings.
3.	Intalox Saddles' and Other Saddle-Designs	• One of most efficient packings, but more costly. • Very little tendency or ability to nest and block areas of bed. • Gives fairly uniform bed. • Higher flooding limits and lower pressure drop than Raschig rings or Berl saddles. • Lower HTU values for most common systems. • Easier to break in bed than Raschig rings, as ceramic.
4.	Pall Rings	• Lower pressure drop (less than half) than Raschig rings. • Lower HTU (in some systems also lower than Berl saddles). • Higher flooding limit. • Good liquid distribution. • High capacity.

		• Considerable side thrust on column wall.
5.	Metal Intalox Hy-Pak Chempak	• Available in metal, plastic and ceramic. • High efficiency. • Low pressure drop. • reportedly good for distillations
6.	Spiral Rings	• Usually installed as stacked. • Taking advantage of internal whirl of gas-liquid and offering extra contact surface over Raschig ring. • Lessing rings or cross partition rings. • Available in single, double and triple internal spiral designs. • Higher pressure drop. • Wide variety of performance data not available
7.	Lessing Rings	• Not much performance data available. • In general slightly better than Raschig ring. • Pressure drop slightly higher. • High side wall thrust
8.	Cross-Partition Rings	• Usually used stacked, and as first layers on support grids for smaller packing above. • Pressure drop relatively low. • Channeling reduced for comparative stacked packings. • No side wall thrust.
9.	Grid Tile	• Available with plain side and bottom or serrated sides and drip-point bottom. • Used stacked only. • Also used as support layer for dumped packings. • Self supporting. • No side thrust. • Pressure drop lower than most dumped packings and some stacked. • Lower than some ¼ inch x 1 inch and ¼ inch x 2-inch wood grids, but greater than larger wood grids. • Some HTU values compare with those using 1 - inch Raschig rings
10.	Teller Rosette (Tellerette)	• Available in plastic. • Lower pressure drop and HTU values. • Higher flooding limits than Raschig rings or Berl saddles.

		• Very low unit weight. • Llow side thrust.
11.	Spraypak	• Compared more with tray type performance than other packing materials. • Usually used in large diameter towers above about 24-inch dia, but smaller to 10-inch dia available. • Metal only.
12.	Panapak	• Available in metal only. • Compared more with tray type performance than other packing materials. • About Same HETP as Spraypak for available data. • Used in towers 24 inches and larger. • Shows some performance advantage over bubble cap trays up to 75 psia in fractionation service, but reduced advantages above this pressure or in vacuum service.
13.	Stedman Packing	• Available in metal only. • Usually used in batch and continuous distillation in small diameter columns not exceeding 24-inches dia. • High fractionation ability per unit height. • Best suited for laboratory work. • Conical and triangular types available. • Not much industrial **data** available
14.	Sulzer, Flexipac, and Similar	• High efficiency. • Generally low pressure drop. • Well suited for distillation of clean systems. • Very low HETP.
15.	Goodloe Packing and Wire Mesh Packing	• Available in metal and plastic. • Used in large and small towers for distillation, absorption, scrubbing, liquid extraction. • High efficiency. • Low HETP. • Low pressure drop. • Limited data available.
16.	Cannon Packing	• Available in metal only. • Low pressure drop. • Low HETP. • Flooding limit probably higher than Raschig rings.

		• Not much literature data available. • Used mostly in small laboratory or semi-plant studies.
17.	Wood Grids	• Very low pressure drop. • Low efficiency of contact. • High HETP or HTU. • Best used in atmospheric towers of square or rectangular shape. • Very low cost.
18.	Dowpac FN-90	• Plastic packing of very low pressure drop (just greater than wood slats). • Transfer Coefficients about same as 2-inch Raschig rings. • Most useful applications in gas cooling systems or biological trickling filters.
19.	Poly Grid	• Plastic packing of very low pressure drop. • Developed for water-air cooling tower applications.

Table 2: Data for some types of packing materials. [2]

No	Packing type	material	Size (in)	Weight (lb/ft³)	Surface area, a ft²/ft³ packing volume	Void fraction (%)	Packing factor F (ft²/ft³)
1.	Rasching ring	Ceramic and porcelain	½ 1 1 ½ 2 3	52 44 42 38 34	114 58 36 28 19	65 70 72 75 77	580 155 95 65 37
		steel	½-1/32 1-1/32 2-1/16	77 40 38	128 63 31	84 92 92	300 115 57
2.	Berl saddles	ceramic	¼ ½ 2	55 54 48 38	274 155 79 32	63 64 68 75	900 240 110 45
3.	Intalox saddles	plastic	1 2 3	6 3.75 3.25	63 33 27	91 93 94	30 20 15
		ceramic	¼ ½ 1 2	54 45 44 42	300 190 78 36	75 78 77 79	725 200 98 40
4.	Pall rings	Plastic	5/8 1 2	7 5.5 4.5	104 63 31	87 90 92	97 52 25
		metal	5/8-0.018 thick 1 ½ - 0.03 thick	38 24	104 39	93 95	73 28
5.	Tellerettes	----------	1 2 3	7.5 3.9 5	55 38 30	87 93 92	40 20 15

[2]: Joseph and Beachler 1981.

Table 3: Equilibrium data table.

X	Y
0	0
0.017469	0.013335
0.021137	0.01605
0.0529	0.04324
0.074114	0.06292
0.09553	0.086425
0.1082	0.10144
0.15875	0.1875

Table 4: Some calculations.

x	y	y*	$(1-y^*)_{*lm}$	$(y-y^*)$	F(y)
0	$7.08*10^{-6}$	0	0.99	$7.08*10^{-6}$	$139*10^{3}$
$1.071*10^{-6}$	$1.77*10^{-5}$	$1.1*10^{-6}$	0.993	$1.66*10^{-5}$	$59.8*10^{3}$
$2.139*10^{-6}$	$2.83*10^{-5}$	$2.15*10^{-6}$	0.994	$2.615*10^{-5}$	$38.01*10^{3}$
$3.212*10^{-6}$	$3.894*10^{-5}$	$3.2*10^{-6}$	0.997	$3.574*10^{-5}$	$27.8*10^{3}$
$4.281*10^{-6}$	$4.956*10^{-5}$	$4.25*10^{-6}$	0.997	$4.531*10^{-5}$	$22.01*10^{3}$
$5.35*10^{-6}$	$6.018*10^{-5}$	$5.32*10^{-6}$	0.996	$5.486*10^{-5}$	$18.16*10^{3}$
$6.42*10^{-6}$	$7.08*10^{-5}$	$6.41*10^{-6}$	0.996	$6.439*10^{-5}$	$15.47*10^{3}$

Henry constant for NH_3 = 0.7614 =H

$(1-y)_{*lm} = (y-y^*)*\ln([1-y^*]/[1-y]$

$f(y) = (1-y)_{*lm}/[(1-y)*(y-y^*)]$

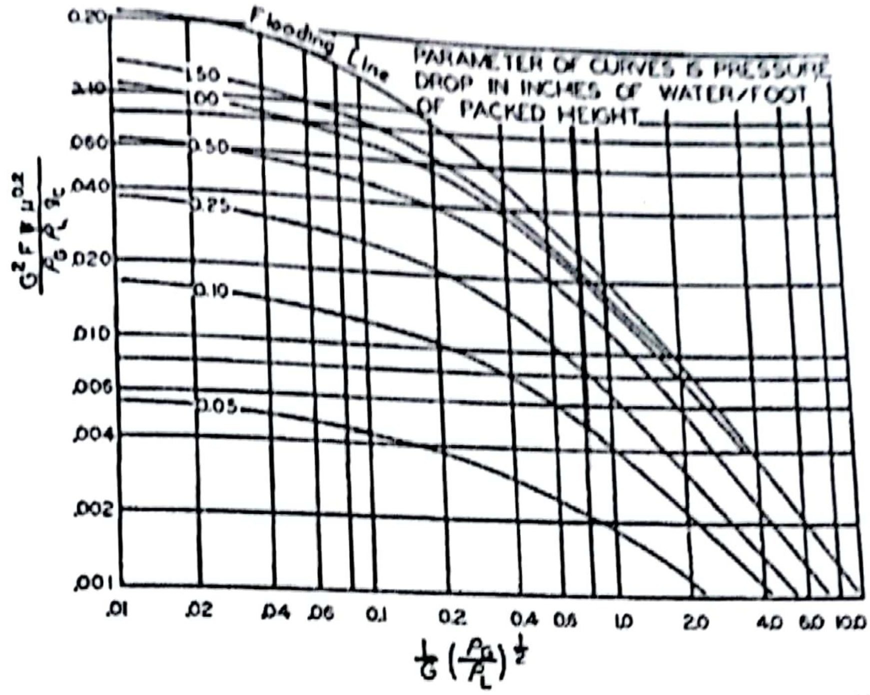


Figure 1: Flooding and pressure drop curve of packed tower [1].

x	y	y*	(1-y)*lm	y-y*)(	F(y)
0	7.07*10^-6	0	0.99	7.07*10^-6	140*10^3
4.233*10^-7	1.76*10^-5	0.55*10^-6	0.993	1.705*10^-5	58.24*10^3
*10^-7 8.535	2.83*10^-5	1.075*10^-6	0.999	2.723*10^-5	36.68*10^3
1.279*10^-6	3.89*10^-5	*10^-6 1.6	0.997	3.73*10^-5	26.73*10^3
1.705*10^-6	4.95*10^-5	2.125*10^-6	0.997	4.737*10^-5	21.05*10^3
2.135*10^-6	6.017*10^-5	*10^-6 2.66	0.999	5.751*10^-5	17.37*10^3
*10^-6 2.562	7.08*10^-5	*10^-6 3.205	0.999	6.76*10^-5	14.78*10^3

Appendix

(J)

NH_3 Gas Sensor

1) **Electrochemical NH3 Gas Sensor (NEMOTO NT-NH3)**

Specifications NT-NH3

- Detectable gas: Ammonia
- Detection range: 0 – 100 ppm
- Maximum range (short periods) 200 ppm
- Output current: 40 +/- 12 nA/ppm
- Reproducibility: +/- 10%
- Zero in clean air: <+/-10ppm.
- Output drift in air: < 2%/month.
- Response time ($T_{90\%}$): < 90 seconds.
- Temperature drift (zero) <15ppm (-20to +50°C).
- Expected lifetime >2 years.

Operating conditions:

- Operating temperature: -40°C to + 40°C.
- Humidity range (constant) 15-90% RH.
- Humidity range (intermittent) 0-99%% RH.
- Pressure: 0.9 – 1.1 atm.
- Recommended resistor: 10 ohms.
- Bias voltage: Not required.

- Recommended Storage temp 0-20°C.
- Storage time 6 months.

2) **Semiconductor NH_3 sensor (TGS 826)**

- **The Calibration Process:**

The figure below represents typical sensitivity characteristics; all data having been gathered at standard test conditions (see reverse side of this sheet). The Y-axis is indicated as sensor resistance ratio (Rs/Ro) which is defined as follows:

Rs = Sensor resistance of displayed gases at various concentrations

Ro = Sensor resistance at 50ppm of ammonia.

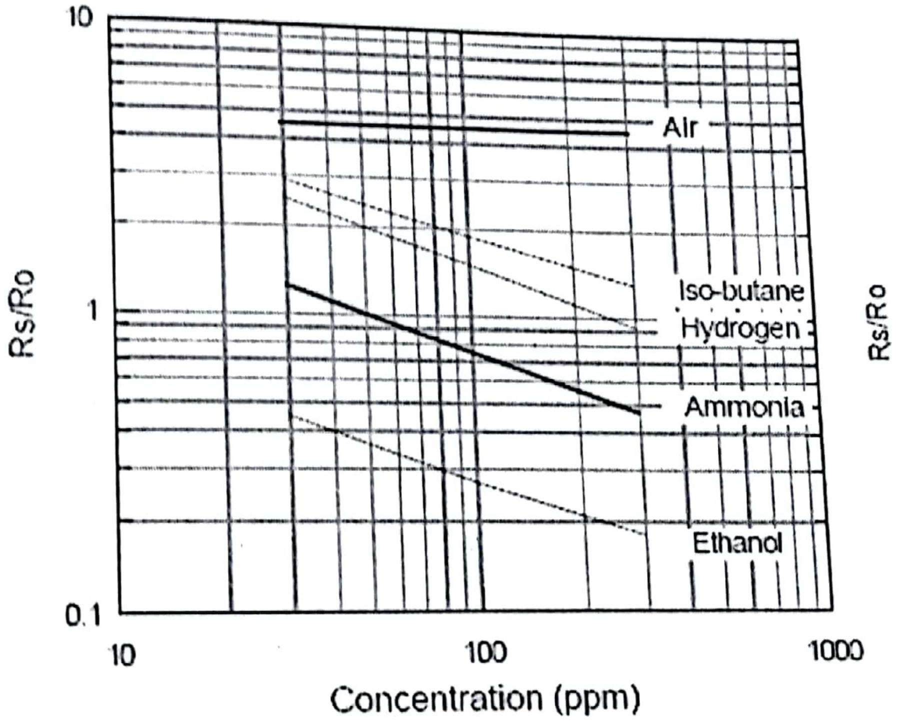


Figure H.1: Sensitivity characteristics.

Temperature/Humidity Dependency:

The figure below represents typical temperature and humidity dependence characteristics. Again, the Y-axis is indicated as sensor resistance ratio (Rs/Ro), defined as follows;

Rs = sensor resistance at 50 ppm of ammonia at various temperature/humidity.

Ro = Sensor resistance at 50ppm of ammonia at 20°C and 65% R.H.

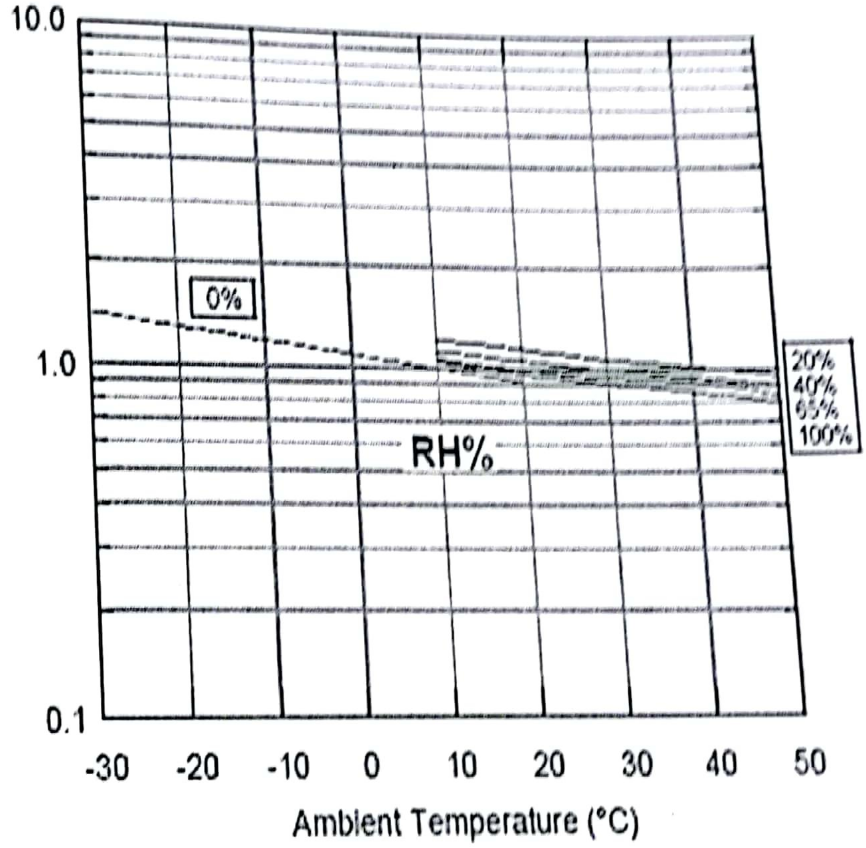


Figure H.2: temperature and humidity characteristics.

3- Anemometer code

```
#include <p18f4550.h>
#include <adc.h>
#include <delays.h>
#include "gamelcd.h"

#pragma config FOSC=INTOSC_HS
#pragma config WDT=OFF
#pragma config LVP=OFF
#pragma config DEBUG=ON
#pragma config PWRT=OFF

int volt, Q, S;
Void main (void)
{
Lcd_init();
TRISA=0b11111111;
TRISD=0b00000000;
ADCON1=0x00;

OpenADC(ADC_FOSC_64 & ADC_RIGHT_JUST & ADC_2_TAD,
ADC_CH0 & ADC_INT_OFF & ADC_REF_VDD_VSS, 00);

while (1)
        {
SetChanADC(ADC_CH0);
ConvertADC();
 While(BusyADC());
volt=ReadADC();
PROTC=volt;
```

```
PROTD =ReadADC();

            S=1.9661*volt+1.9294;
            Q=S/ 1000;
//transmit(volt);

Delay10KTCYX(100);
Delay10KTCYX(100);
Lcd_gotoyx(1,1);

Lcd_putrs("speed=");
Lcd_gotoyx(1,8);
Lcd_puti(s);
Lcd_gotoyx(1,12);
Lcd_putrs("m/s");

Lcd_gotoyx(2,1);
Lcd_putrs("Flow=");
Lcd_gotoyx(2,8);
Lcd_puti(Q);
Lcd_gotoyx(2,12);
Lcd_putrs("m3/s");

            }//While
}//main
```

3) More Specifications:

Model number			TGS 826	
Target gases			Ammonia	
Typical detection range			30 ~ 300 ppm	
Standard circuit conditions	Heater Voltage	V_H	5.0±0.2V DC/AC	
	Circuit voltage	V_C	Max. 24V (DC only)	Ps ≤ 15mW
	Load resistance	R_L	Variable	Ps ≤ 15mW
Electrical characteristics under standard test conditions	Heater resistance	R_H	30±3Ω at room temp.	
	Heater current	I_H	167mA	
	Heater power consumption	P_H	833mW	V_H = 5.0V DC
	Sensor resistance	Rs	20~100kΩ in 50ppm ammonia	
	Sensitivity (change ratio of Rs)		0.55 ± 0.15	Rs (150ppm) / Rs (50ppm)
Standard test conditions	Test gas conditions		Ammonia in air at 20±2°C, 65±5%RH	
	Circuit conditions		Vc = 5.0±0.01V DC V_H = 5.0±0.05V DC R_L = 33kΩ±1%	
	Conditioning period before test		7 days	

Sensor Resistance (Rs) is calculated by the following formula:

$$Rs = \left(\frac{Vc}{VRl} - 1\right) * Rl$$

Power dissipation across sensor electrodes (Ps) is calculated by the following formula:

$$Ps = \frac{Vc^2 \times Rs}{(Rs + R_L)^2}$$

TGS 826 Pre-Sorted Groupings

The TGS 826 sensor has a wide specification range in terms of its rated value in 50ppm of NH_3 and sensor resistance ratio (Rs in 150ppm of NH_3 / Rs in 50ppm of NH_3). To facilitate usage of this sensor, TGS 826 is shipped in pre-sorted groupings of 20 pieces per bag, with each bag marked with one of the following group numbers which indicate a more narrow range within the specification.

Please be advised that the sensor is produced to meet the overall specification range--production of specific groupings within the spec cannot be done. As a result, if a user requests a specific group(s), the sensor can be made available at an additional charge, but no guarantee can be offered as to availability for shipment. The minimum delivery time for special group selection should be considered at 8 weeks minimum.

Group #	Rs in 50ppm of NH_3 (kΩ)			Rs (in 150ppm of NH_3) / Rs (in 50ppm of NH_3)		
1-A	20 ~ 30			0.4 ~ 0.5		
1-B	20 ~ 30				0.5 ~ 0.6	
1-C	20 ~ 30					0.6 ~ 0.7
2-A		30 ~ 40		0.4 ~ 0.5		
2-B		30 ~ 40			0.5 ~ 0.6	
2-C		30 ~ 40				0.6 ~ 0.7
3-A			40 ~ 53	0.4 ~ 0.5		
3-B			40 ~ 53		0.5 ~ 0.6	
3-C			40 ~ 53			0.6 ~ 0.7
4-A	53 ~ 70			0.4 ~ 0.5		
4-B	53 ~ 70				0.5 ~ 0.6	
4-C	53 ~ 70					0.6 ~ 0.7
5-A		70 ~ 85		0.4 ~ 0.5		
5-B		70 ~ 85			0.5 ~ 0.6	
5-C		70 ~ 85				0.6 ~ 0.7
6-A			85 ~ 100	0.4 ~ 0.5		
6-B			85 ~ 100		0.5 ~ 0.6	
6-C			85 ~ 100			0.6 ~ 0.7