

**A DESIGN FOR POLLUTION CONTROL IN A PROCESS INDUSTRY
(STACK GASES FROM COCA COLA NIG AS CASE STUDY)**

BY

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2001/11609EH**

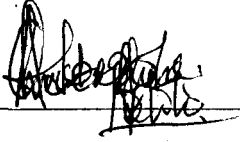
**DEPARTMENT OF CHEMICAL ENGINEERING
SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY
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**A PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENT FOR AWARD OF BACHELOR OF ENGINEERING
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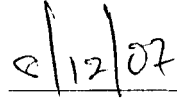
NOVEMBER 2007

DECLARATION

I declare that this project is my original work and has never to the best of my knowledge been submitted elsewhere.



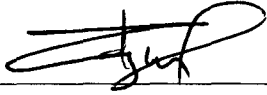
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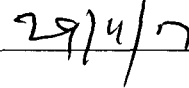
CERTIFICATION

I hereby certify that I supervised, read and approved this project work presented by **OKLOHO ADAKOLE CHRISTOPHER** (2001/11609EH) in partial fulfillment of the Bachelor of Chemical Engineering.



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DEDICATION

I dedicate this work to my fathers

Father you are the brain behind my existence and to you dada, you saw all the potential and talents stocked in me but did not live to see it all today, I still love you

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Navala, Lamai hillary, shoal, frank God will reward you guys for me. You all stood in the gap for me, you held the gates even though you had your own challenges to handle.

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MATERIAL BALANCE FOR THE PROCESS

ABSTRACT

With the high level of industrialization today, consumption and production activities produce waste as a by-product. This waste is accumulated as a stock of polluted material which has a negative effect upon the consumer and his environment. To eliminate this negative effect we consider two ways of reducing the stock of pollution, recycling and disposal. In many cases a decision must be made as to the resource allocation between the recycling of residues for reuse and the removal and disposal of polluted material. The latter, which reduces the negative effect of pollution is usually cheaper. The effect of pollution on human health and the ecosystem at large have to be considered to as not to alter the balance of the entire ecosystem.

CHAPTER 1

1.0 INTRODUCTION

1.1 THE NEED FOR THE STUDY

Pollution is the release of substance into the environment that are originally not present in the atmosphere (water, air and land) which could be harmful to living organisms.

The substances released are usually toxic. The most harmful released into the atmosphere by pollution are more 1 lead residues. The former is being alleviated by mandatory use of low sulphur fuel and the latter by elimination of tetraethyl lead from most gasoline and by use of catalytic converters

Water pollution due to discharge of toxic chemical waste is closely regulated by both environmental protection agency and federal water pollution act

Water pollution are usually soluble or insoluble particles and sometimes oil films on the surface of the water.

Air pollution are characterized by the discharge of gases to the air, fumes, smoke and particles that sometimes settle down on the vegetation around the vicinity of the industry where the discharge emanates from

On land pollution is usually the covering of the surface of the soil by toxic particles or liquids.

Pollution could be determined by comparing the released substance by some standard values.

Pollution sometimes are as a result of improper use of chemicals like fertilizers on the soil, use of pesticides to spray directly to the soil. Because of the toxicity and the need to make the environment friendly the need

1.2 SCOPE OF WORK

This project intend to cover the process that lead to the control of the discharge of flue gases to the atmosphere coca cola plc. The scope of the design of the pollution prevention plant is as follows:

1. Detail literature on the different method of process of treating sulphur dioxide
2. Material Balance across the plant
3. Energy Balance across the plant

1.3 AIM AND OBJECTIVE

Pollution can be a threat to humans, plants and animals alike. That has propelled me to reduce the discharge of flue gases to the atmosphere.

1.4 A DESING

A design is the act of working out the form of something as by making a sketch, or outline, or plan. It could be an artistic or a mathematical representation.

(word wed dictionary)

1.5 A PROCESS INDUSTRY

A process industry is an industry that has a well defined procedure from raw materials primarily used to the finished product. (CONDENSED CHEMICAL DICTIONARY)

They include industries like the beverage, brewery, refinery etc

In the process industry depending on the process, there are combinations of process which are either unit process or unit operations

1.6 processes in coca cola (NBC)

In coca cola plc, it is majorly by a beverage Industry, some other Process are carried out there as well. All the process leads to the final output which is the soft drink Examples of such processes are:-

- water treatment
- syrup mixing
- bottle washing
- Filling of bottles
- quality assurance test
- production of CO₂

The CO₂ that is used for the preservation of the soft drink is gotten from the burning of liquefied natural gas. From that process some effluent gases go into the atmosphere which results in pollution.

1.7 pollution in the plant

A number of pollution are observed in the plant such as noise as a result of the vibration from the machines, water pollution as a result of action like washing were the water that contains caustic soda is flushed into a near by stream and air pollution as a result of the burning of liquefied natural gas which leads to gases SO_2 H_2S , CO , NO , NO_2 , SO_3 and water vapor

1.8 PRODUCTS FROM COCA-COLA

- FANTA ORANGE
- Fanta apple
- Coke
- And CO_2

1.9 STACK GASES

Stack gas is anything that comes out of a burner stack in gaseous form. This is, however, not so simple as it sounds! Stack gas will contain water in vapors form when it is hot. This water will liquefy when the stack gas cools down, reducing the volume and producing condensate. Gas analyzers are used for many purposes, but the main reason is measurements in stack gas, and most definitions are made for this medium. Extractive methods measure the concentration of pollutants in dry stack gas, whilst in-site equipment tends to measure on a wet basis, including the volume of the water vapor at that temperature.

Stack gas consists mostly of nitrogen and carbon dioxide. When hot, water vapor must also be considered. There will also be some oxygen in there, but this should not be too much. All other components are, roughly speaking, pollutants. Stack gas should be sampled before any dilution has been carried out. It is possible to calculate the concentrations of the components before dilution, using the reference oxygen factor, but this will magnify errors and means that the true oxygen content of the stack gas cannot be ascertained.

<<http://www.habmigern2003.info/suggestions/Overview/Overview.html>>

1.10 ACKNOWLEDGEMENT

But gradually increasing populations and the proliferation of basic industrial processes saw the emergence of a civilization that began to have a much greater collective impact on its surroundings. It was to be expected that the beginnings of environmental awareness would occur in the more developed cultures, particularly in the densest urban centers. The first medium warranting official policy measures in the emerging western world would be the most basic: the air we breathe.

<<http://www.habmigern2003.info/suggestions/Overview/Overview.html>>

CHAPTER 2

2.0 Literature review

2.1 POLLUTION

Pollution is the introduction of pollutants (whether chemical substances, or energy such as noise, heat, or light) into the environment to such a point that its effects become harmful to human health, other living organisms, or the environment.^[1]

2.2 TYPES OF POLLUTION

2.2.1 Air pollution

- Acid rain
- Air Quality Index Atmospheric dispersion modeling Chlorofluorocarbon
- Global dimming
 - Global warming
 - Haze
 - Indoor air quality
 - Ozone depletion
 - Particulate
- Smog

2.2.2 Water pollution

- **Eutrophication**
 - Hypoxia
 - Marine pollution
 - Ocean acidification
 - Oil spill
 - Ship pollution
 - Surface runoff
 - Thermal pollution
 - Wastewater
 - Waterborne diseases
 - Water quality
- **Water stagnation**

2.2.3 Land pollution

- **Bioremediation**
 - Herbicide
 - Pesticide

- Soil Guideline Values (SGVs)

2.2.4 Radioactive contamination

Actinides in the environment Fission product

- Nuclear fallout
- Plutonium in the environment
- Radiation poisoning
- radium in the environment
- Uranium in the environment

2.2.5 Other forms of pollution

- Invasive species
- Light pollution
- Noise pollution
- Radio spectrum pollution
- Visual pollution

2.3 POLLUTION CONTROL

Pollution control is a term used in environmental management. It means the control of emissions and effluents into air, water or soil. Without pollution controls the undesirable waste products from human consumption, industrial production, agricultural activities, mining, transportation and other sources will accumulate or disperse and degrade the natural environment. In the hierarchy of controls, pollution prevention and waste minimization are more desirable than pollution control

Pollution control is a measure taken to minimize or totally stop the discharge of harmful substances to the atmosphere.

This work is based on the control of the stack gases or effluent gases to the atmosphere; they are standard allowable Values Of these Individual gases in the atmosphere. And any quantity greater than these values causes a destabilization in the Ecosystem which results in air pollution. This then acts as a standard or a yard stick for pollution control. This actually is the removal or reduction of unwanted substances in the atmosphere

Table 1.0 Primary Components of Dry Air

Gas	% by Volume	% by Weight	Parts per Million (V)	Chemical Symbol
Nitrogen	78.08	75.47	780805	N ₂
Oxygen	20.95	23.20	209450	O ₂
Argon	0.93	1.28	9340	Ar
Carbon Dioxide	0.038	0.0590	380	CO ₂

2.4 PHILOSOPHY AND BACKGROUND

In as much as industrialization has made man a little bit more comfortable it has also not been without its negative effect. Industrial byproducts that are not well treated could cause a lot of harm to the environment and other inhabitants such as humans' animals and plants

Motor vehicle emissions are one of the leading causes of air pollution. China, United States, Russia, Mexico, and Japan are the world leaders in air pollution emissions; however, Canada is the number two country, ranked per capita. Principal stationary pollution sources include chemical plants, coal-fired power plants, oil refineries, petrochemical plants, nuclear waste disposal activity, incinerators, large livestock farms (dairy cows, pigs, poultry, etc.), PVC factories, metals production factories, plastics factories, and other heavy industry.

Why these countries are high ranked in air pollution is as a result of high level of industrialization.

2.5 LEGISLATIONS

While the level of technology and industrialization increases, a lot of research is been made to control or eradicate the emission of toxic materials into the atmosphere, To protect the environment from the adverse effects of pollution, many nations worldwide have enacted

legislation to regulate various types of pollution as well as to mitigate the adverse effects of pollution.

2.5.1 United States

The United States Environmental Protection Agency (EPA) established threshold standards for air pollutants to protect human health on January 1, 1970. One of the ratings chemicals are given is carcinogenicity. In addition to the classification "unknown", designated levels range from non-carcinogen, to likely and known carcinogen. Some scientists have said that the concentrations which most of these levels indicate are far too high and the exposure of people should be less. In 1999, the United States EPA replaced the Pollution Standards Index (PSI) with the Air Quality Index (AQI) to incorporate new PM2.5 and Ozone standards.

The United States Congress passed the Clean Air Act in 1963 to legislate the reduction of smog and atmospheric pollution in general. That legislation has subsequently been amended and extended in 1966, 1970, 1977 and 1990. Numerous state and local governments have enacted similar legislation either implementing or filling in locally important gaps in the national program. The national Clean Air Act and similar state legislative acts have led to the widespread use of atmospheric dispersion modeling in order to analyze the air quality impacts of proposed major actions.

Passage of the Clean Water Act amendments of 1977 required strict permitting for any contaminant discharge to navigable waters, and also required use of best management practices for a wide range of other water discharges including thermal pollution.

Passage of the Noise Control Act established mechanisms of setting emission standards for virtually every source of noise including motor vehicles, aircraft, certain types of HVAC equipment and major appliances. It also put local government on notice as to their responsibilities in land use planning to address noise mitigation. This noise regulation framework comprised a broad data base detailing the extent of noise health effects.

The state of California's Office of Environmental Health Hazard Assessment (OEHHA) has maintained an independent list of substances with product labeling requirements as part of Proposition 65 since 1986.

<<http://en.wikipedia.org/wiki/Portal:Ecology>>

2.5.2 The United Kingdom

In the 1840s, the United Kingdom brought onto the statute books legislation to control water pollution. It was extended to all rivers and coastal water by 1961. However, currently the clean up of historic contamination is controlled under a specific statutory scheme found in Part IIA of the Environmental Protection Act 1990 (Part IIA), as inserted by the Environment Act 1995, and other 'rules' found in regulations and statutory guidance. The Act came into force in England in April 2000.

Within the current regulatory framework, Pollution Prevention and Control (PPC) is a regime for controlling pollution from certain industrial activities. The regime introduces the concept of Best Available Techniques ("BAT") to environmental regulations. Operators must use the BAT to control pollution from their industrial activities to prevent, and where that is not practicable, to reduce to acceptable levels, pollution to air, land and water from industrial activities. The Best

Available Techniques also aim to balance the cost to the operator against benefits to the environment. The system of Pollution Prevention and Control is replacing that of Integrated Pollution Control (IPC) (which was established by the Environmental Protection Act 1990) and is taking effect between 2000 and 2007. The Pollution Prevention and Control regime implements the European Directive (EC/96/61) on integrated pollution prevention and control.

<<http://en.wikipedia.org/wiki/Portal:Ecology>>

2.5.3 China

China's rapid industrialization has substantially increased pollution. China has some relevant regulations: the 1979 Environmental Protection Law, which was largely modeled on U.S. legislation. But the environment continues to deteriorate. Twelve years after the law, only one Chinese city was making an effort to clean up its water discharges. This indicates that China is about 30 years behind the U.S. schedule of environmental regulation and 10 to 20 years behind Europe. In July 2007, it was reported that the World Bank reluctantly censored a report revealing that 750,000 people in China die every year as a result of pollution-related diseases. China's State Environment Protection Agency and the Health Ministry asked the World Bank to cut the calculations of premature deaths from the report fearing the revelation would provoke "social unrest".

<<http://en.wikipedia.org/wiki/Portal:Ecology>>

2.6 WAYS OF CONTROLLING POLLUTION

- 1. Adsorption using Solid adsorbents**
- 2. catalyzed conversion of Impurities**
- 3. Membrane separation**
- 4. Liquid absorption**

(0digure 91)

2.7 POLLUTION CONTROL DEVICES

2.7.1 Dust collection systems

- Cyclones
- Electrostatic precipitators
- Bag houses

2.7.2 Scrubbers

- Baffle spray scrubber
- Cyclonic spray scrubber
- Ejector venturi scrubber
- Mechanically aided scrubber
- Spray tower
- Wet scrubber

2.7.3 Sewage treatment and Wastewater treatment

2.7.4 API oil-water separators

Sedimentation (water treatment)

2.7.5 Dissolved air flotation (DAF)

2.7.6 Activated sludge bio treaters

2.7.7 Bio filters

- Powdered activated carbon treatment

2.8 SOLVENTS FOR TREATING POLLUTION

- Water
- Solution of :-

- I. NH_4OH
- II. NaOH
- III. Na_2CO_3
- IV. Anime
- V. KMnO_4
- VI. $\text{Ca}(\text{OH})_2$ Odigurc (92)

2.9 EFFECTS OF POLLUTION

2.9.1 Human health

Adverse air quality can kill many organisms including humans. Ozone pollution can cause respiratory disease, cardiovascular disease, throat inflammation, chest pain, and congestion. Water pollution causes approximately 14,000 deaths per day, mostly due to contamination of drinking water by untreated sewage in developing countries. Oil spills can cause skin irritations and rashes. Noise pollution induces hearing loss, high blood pressure, stress, and sleep disturbance.

2.9.2 Ecosystems

- Sulfur dioxide and oxides of nitrogen can cause acid rain which reduces the pH value of soil.
- Soil can become infertile and unsuitable for plants. This will affect other organisms in the food web.
- Smog and haze can reduce the amount of sunlight received by plants to carry out photosynthesis.
- Invasive species can out compete native species and reduce biodiversity. Invasive plants can contribute debris and bio molecules (allopath) that can alter soil and chemical compositions of an environment, often reducing native species competitiveness.
- Biomagnifications describe a situation where toxins may be pass through trophic levels, becoming exponentially more concentrated in the process.

Chapter 3

3.0 METHODOLOGY

3.1 Alternative methods of controlling the pollution were examined and the most economical was selected. The methods that were examined are the:-

- Electro-catalytic oxidation (ECO).
- Alkaline absorption (MEA process via neutralization)
- Gas oxidation

The factors that were put under consideration were

- The number of equipment required for each of the process which had a direct link with cost.
- The degree of conversion for each of the process, which had to do with the efficiency of each of the process.
- Selectivity, which is the process that will convert all the gases without having to introduce a separate unit for the other gases in the process.

3.1.1 The electro-catalytic oxidation

The ECO process, treats flue gas in three steps to achieve multi-pollutant removal. First, a majority of the ash in the flue gas stream is removed in a conventional dry ESP.

Following the ESP is a barrier discharge reactor which oxidizes gaseous pollutants to higher oxides. For example, nitric oxide is reacted to form nitric acid, sulfur dioxide is converted to

sulfuric acid, and mercury oxidized to mercuric oxide. Products of the oxidation process are then captured in a wet electrostatic precipitator (WESP) that also collects fine particulate matter. Liquid effluent from the WESP may be treated to remove collected ash then delivered to a distillation system to produce concentrated sulfuric and nitric acids for sale. The ECO system is designed to be retrofit into the last fields of an existing ESP. It consumes about 5% of the electric utility's power output, and the concentrated sulfuric and nitric acids produced and captured in the WESP effluents are salable by-products, which may generate a profit on the power consumed. Oxidation of gaseous pollutants in the barrier discharge reactor is the heart of the ECO process. It is accomplished through generation of a non-thermal discharge or plasma. In a dielectric barrier discharge, energetic electrons are produced throughout the reactor without heating the gas stream to high temperatures, requiring considerably less energy than plasma discharges. Dielectric barrier discharges can be operated over a wide range of temperatures and pressures. (R. E. Burger pg 2-3)

3.1.2 Alkaline absorption (MEA process via neutralization)

A process for removing acid gases from a gas stream in which an acid-gas-containing gas stream in which the sum of the partial pressures of the acid gases does not exceed 1500 mbar is brought into contact with an aqueous absorbent in an absorption step at a total pressure of from 50 to 70 bar and an absorbent is used which consists of water, at least one tertiary alkanolamine and piperazine at a concentration of 15 to 40% by weight of the absorbent, an acid-gas-depleted gas stream and an acid-gas-loaded absorbent being obtained.

There are a number of alkaline solution that can be used, but monoethanolamine has the highest conversion, and it is the cheapest, but the process requires high pressure and a lot of equipment.

<http://www.freepatentsonline.com/REFEP1412056.html>

3.1.3 Gas oxidation (PEA process)

The PEA process is a two-step process, combining a small contact first stage with the nitric oxide process in the second stage polishing to nearly zero emissions in discharged gases from metallurgical plants. Conversion of metallurgical off-gases begins as SO₂-containing gases are generated by roasting or smelting sulfur bearing ores. These hot raw gases are first washed then cooled in tubular coolers. Wet electrostatic dust removal follows to remove acid mist and the last traces of the finest solids (especially arsenic). The now-optically clear gas enters a pre-dryer, where it is dried in two stages, first by 65-percent strong acid and then followed by 76-percent strong acid. The heat generated by water absorption is removed in an acid cooler, and the 65-percent produced acid is piped to the second stage, while the gases are fed to the drying tower, where high strength acid is required to condition the gas to the required dryness.

The SO₂ gas is then heated by countercurrent flow in the heat exchanger to ignition temperature by the hot SO₃ gas coming from the converter.

< <http://www.mercuryexposure.org/forum/index.php?&act>>

3.2 JUSTIFICATION

1. Performance of the ECO technology at the pilot scale shows its ability to remove NO_x, SO₂, Hg, air toxics and fine particulate matter from coal combustion produced flue gas.
2. ECO capital cost is estimated to be about 10-30% less than SCR based upon cost estimates developed for First Energy's R.E. Burger Generating Station.
3. ECO operating costs (including capital recovery) are estimated to be \$1,470/ton of NO_x removed, which is approximately two thirds the NO_x removal cost of SCR (\$2,200/ton).
4. No hazardous reagents or catalyst are required. ECO technology consumes electricity instead of reagents and may produce salable byproducts that recover the cost of electricity consumed. SO₂ and NO_x are converted directly into acids, and then collected by the wet precipitator, without the need to purchase, transport or handle reagents. Additionally, there are no scrubbing byproducts requiring landfill disposal.
5. The ECO system is designed to be retrofit into an existing ESP, requiring no additional space for catalysts and associated ductwork and structure.
6. In addition to reducing NO_x emissions, the ECO technology significantly reduces SO₂, PM_{2.5} and Hg emissions in an integrated system, thereby minimizing the need for additional capital investment in other pollution control equipment. The multi-pollutant control capability provides insurance against future regulatory requirements.
7. Flue gas remains above saturation. Acid mists can be removed without cooling flue gas below the saturation temperature of water so existing fans and stack can normally be used.

8. No makeup water is needed. The flue gas stream provides moisture necessary to form acids and maintain wetted precipitator plates.(R. E. Burger 8)

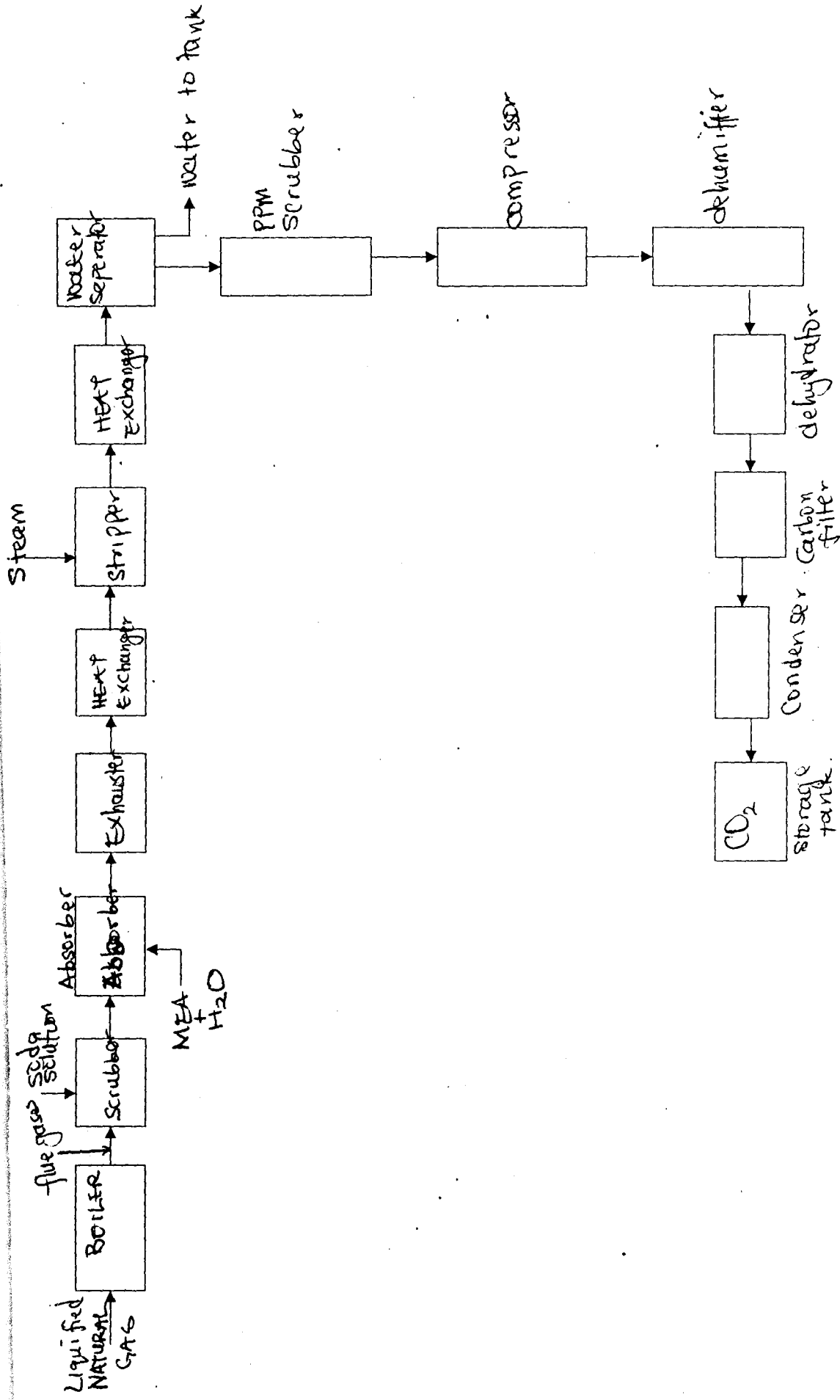
Table 3.0

Table showing the composition of stack gases generated

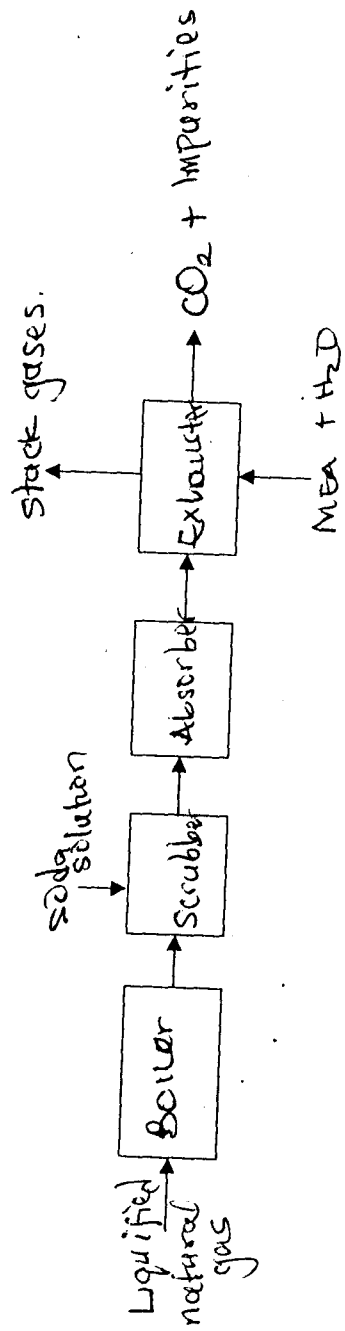
Gases	Composition %
N ₂	78.86
CO ₂	13.58
H ₂ O	8.18
O ₂	3.54
Ar	0.87
NO	0.50
CO	0.37
SO ₂	0.05
H ₂	0.04

Table showing the composition gases in the atmosphere (WHO)

Gas	% by Volume
Nitrogen	78.08
Oxygen	20.95
Argon	0.93
Carbon Dioxide	0.038



FLOW SHEET FOR PRODUCTION OF CO₂

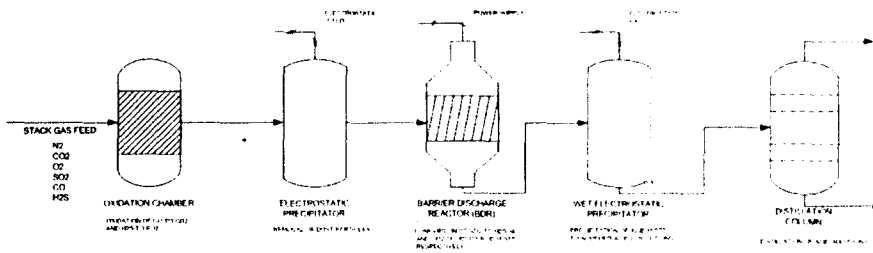


FLOW SHEET SHOWING THE GENERATION OF STACK GASES.

Flow sheet showing the control of the stack gases

PROCESS FLOW DIAGRAM FOR THE ECO PROCESS

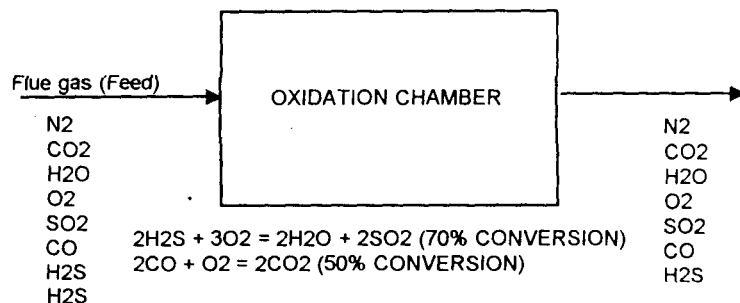
Wednesday, November 28, 2007



MATERIAL BALANCE FOR THE ECO PROCESS
BASIS: 100kg/hr of Flue Gas

UNIT 1 - OXIDATION CHAMBER

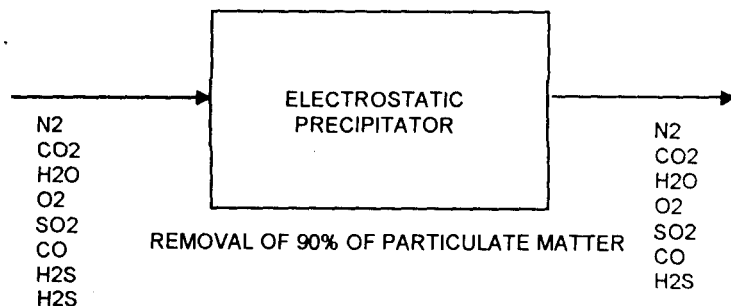
TAKING MATERIAL BALANCE ABOUT THE OXIDATION CHAMBER



components	mol wt (kg/kgmol)	moles (kgmol/hr)	IN			OUT			
			mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass
N2	28.01	2.55672	0.70968	71.61360	71.61740	2.55672	0.70969	71.61360	71.61740
CO2	44.01	0.30220	0.08388	13.30000	13.30070	0.30226	0.08390	13.30228	13.30298
H2O	18.02	0.62431	0.17329	11.25000	11.25060	0.62439	0.17332	11.25159	11.25219
O2	32.00	0.11906	0.03305	3.81000	3.81020	0.11890	0.03301	3.80493	3.80513
SO2	64.06	0.00012	0.00003	0.00750	0.00750	0.00021	0.00006	0.01316	0.01316
CO	28.01	0.00010	0.00003	0.00290	0.00290	0.00005	0.00001	0.00145	0.00145
H2S	34.08	0.00013	0.00004	0.00430	0.00430	0.00004	0.00001	0.00129	0.00129
FLY ASH	-	-	-	0.00640	0.00640	-	-	0.00640	0.00640
TOTAL		3.60264	1.00000	99.99470	100.00000	3.60257	1.00000	99.99470	100.00000

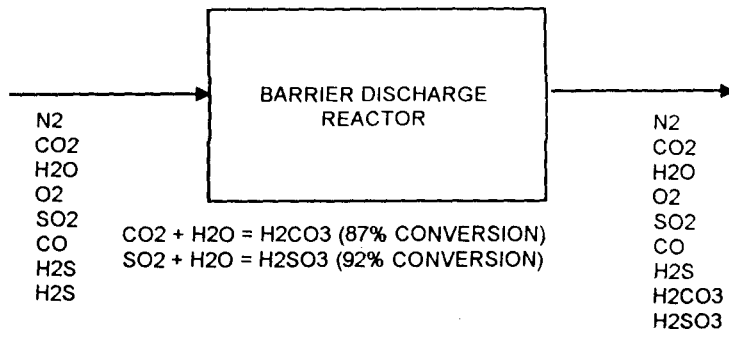
UNIT 2 - ELECTROSTATIC PRECIPITATOR

TAKING MATERIAL BALANCE ABOUT THE ELECTROSTATIC PRECIPITATOR



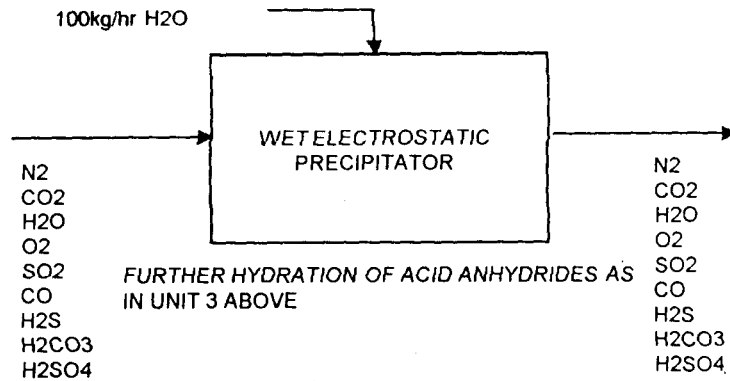
components	mol wt (kg/kgmol)	moles (kgmol/hr)	IN			OUT			
			mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass
N2	28.01	2.55672	0.70969	71.61360	71.61740	2.55672	0.70969	71.61360	71.61740
CO2	44.01	0.30226	0.08390	13.30228	13.30298	0.30226	0.08390	13.30228	13.30298
H2O	18.02	0.62439	0.17332	11.25159	11.25219	0.62439	0.17332	11.25159	11.25219
O2	32.00	0.11890	0.03301	3.80493	3.80513	0.11890	0.03301	3.80493	3.80513
SO2	64.06	0.00021	0.00006	0.01316	0.01316	0.00021	0.00006	0.01316	0.01316
CO	28.01	0.00005	0.00001	0.00145	0.00145	0.00005	0.00001	0.00145	0.00145
H2S	34.08	0.00004	0.00001	0.00129	0.00129	0.00004	0.00001	0.00129	0.00129
FLY ASH	-	-	-	0.00640	0.00640	-	-	0.00064	0.00064
TOTAL		3.60257	1.00000	99.99470	100.00000	3.60257	1.00000	99.99470	100.00000

UNIT 3 - BARRIER DISCHARGE REACTOR
TAKING MATERIAL BALANCE ABOUT THE BDR



components	IN					OUT				
	mol wt (kg/kgmol)	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	
N2	28.01	2.55672	0.70969	71.61360	71.62152	2.55672	0.765640	71.61360	71.62595	
CO2	44.01	0.30226	0.08390	13.30228	13.30375	0.03929	0.011767	1.72930	1.72959	
H2O	18.02	0.62439	0.17332	11.25159	11.25284	0.36124	0.108179	6.50960	6.51072	
O2	32.00	0.11890	0.03301	3.80493	3.80535	0.11881	0.035579	3.80191	3.80256	
SO2	64.06	0.00021	0.00006	0.01316	0.01316	0.00002	0.000005	0.00105	0.00105	
CO	28.01	0.00005	0.00001	0.00145	0.00145	0.00005	0.000016	0.00145	0.00145	
H2S	34.08	0.00004	0.00001	0.00129	0.00129	0.00004	0.000011	0.00129	0.00129	
FLY ASH	-	-	-	0.00064	0.00064	-	-	0.00064	0.00064	
H2CO3	62.02	0.00000	0.00000	0.00000	0.00000	0.26296	0.078747	16.30841	16.31122	
H2SO3	82.08	0.00000	0.00000	0.00000	0.00000	0.00019	0.000057	0.01551	0.01551	
TOTAL		3.60257	1.00000	99.98894	100.00000	3.33932	1.000000	99.98276	100.00000	

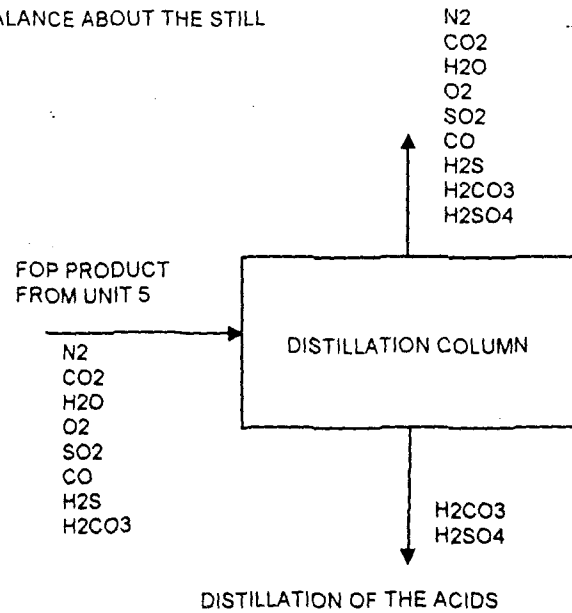
UNIT 4 - WET ELECTROSTATIC PRECIPITATOR
TAKING MATERIAL BALANCE ABOUT THE WESP



components	IN					OUT			
	mol wt (kg/kgmol)	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass
N2	28.010	2.55672	0.28764	71.61360	35.80989	2.556715	0.288748	71.61360	35.81000
CO2	44.010	0.03929	0.00442	1.72930	0.86472	0.005108	0.000577	0.22481	0.11241
H2O	18.020	5.91063	0.66496	106.50960	53.25939	5.876432	0.663666	105.89331	52.95139
O2	32.000	0.11881	0.01337	3.80191	1.90112	0.118802	0.013417	3.80167	1.90100
SO2	64.060	0.00002	0.00000	0.00105	0.00053	0.000001	0.000000	0.00008	0.00004
CO	28.010	0.00005	0.00001	0.00145	0.00073	0.000052	0.000006	0.00145	0.00073
H2S	34.080	0.00004	0.00000	0.00129	0.00065	0.000038	0.000004	0.00129	0.00065
FLY ASH	-	-	-	0.00064	0.00032	-	-	0.00064	0.00032
H2CO3	62.018	0.26296	0.02958	16.30841	8.15491	0.297148	0.033559	18.42851	9.21508
H2SO3	82.080	0.00019	0.00002	0.01551	0.00776	0.000204	0.000023	0.01675	0.00838
TOTAL		8.88871	1.00000	199.98276	100.00000	8.854501	1.000000	199.98211	100.00000

UNIT 5 - DISTILLATION COLUMN

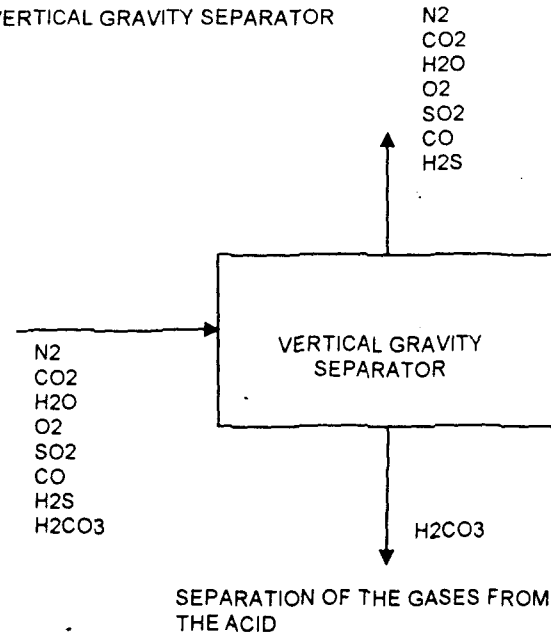
TAKING MATERIAL BALANCE ABOUT THE STILL



components	IN					TOP PRODUCT				BOTTOM PRODUCT			
	mol wt (kg/kgmol)	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass
N2	28.010	2.556715	0.28875	71.61360	35.81000	2.556715	0.28875	71.61360	35.81312	0.00000	0.00000	0.00000	0.00000
CO2	44.010	0.005108	0.00058	0.22481	0.11241	0.005108	0.00058	0.22481	0.11242	0.00000	0.00000	0.00000	0.00000
H2O	18.020	5.876432	0.66367	105.89331	52.95139	5.876432	0.66368	105.89331	52.95600	0.00000	0.00000	0.00000	0.00000
O2	32.000	0.118802	0.01342	3.80167	1.90100	0.118802	0.01342	3.80167	1.90117	0.00000	0.00000	0.00000	0.00000
SO2	64.060	0.000001	0.00000	0.00008	0.00004	0.000001	0.00000	0.00008	0.00004	0.00000	0.00000	0.00000	0.00000
CO	28.010	0.000052	0.00001	0.00145	0.00073	0.000052	0.00001	0.00145	0.00073	0.00000	0.00000	0.00000	0.00000
H2S	34.080	0.000038	0.00000	0.00129	0.00065	0.000038	0.00000	0.00129	0.00065	0.00000	0.00000	0.00000	0.00000
FLY ASH	-	-	-	0.00064	0.00032	-	-	0.00000	0.00000	-	-	0.00064	0.03680
H2CO3	62.018	0.297148	0.03356	18.42851	9.21508	0.297148	0.03356	18.42851	9.21588	0.00000	0.00000	0.00000	0.00000
H2SO3	82.080	0.000204	0.00002	0.01675	0.00838	0.000000	0.00000	0.00000	0.00000	0.00020	1.00000	0.01675	0.96320
TOTAL		8.854501	1.00000	199.98211	100.00000	8.854297	1.00000	199.96472	100.00000	0.00020	1.00000	0.01739	1.00000

UNIT 6 - VERTICAL GRAVITY SEPARATOR

TAKING MATERIAL BALANCE ABOUT THE VERTICAL GRAVITY SEPARATOR



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components	IN					TOP PRODUCT				BOTTOM PRODUCT			
	mol wt (kg/kgmol)	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass	moles (kgmol/hr)	mol fraction	mass (kg/hr)	% mass
N2	28.01	2.556715	0.28875	71.61360	35.81312	2.556715	0.29878	71.61360	39.44866	0.00000	0.00000	0.00000	0.00000
CO2	44.01	0.005108	0.00058	0.22481	0.11242	0.005108	0.00060	0.22481	0.12384	0.00000	0.00000	0.00000	0.00000
H2O	18.02	5.876432	0.66368	105.89331	52.95600	5.876432	0.68673	105.89331	58.33178	0.00000	0.00000	0.00000	0.00000
O2	32	0.118802	0.01342	3.80167	1.90117	0.118802	0.01388	3.80167	2.09416	0.00000	0.00000	0.00000	0.00000
SO2	64.06	0.000001	0.00000	0.00008	0.00004	0.000001	0.00000	0.00008	0.00005	0.00000	0.00000	0.00000	0.00000
CO	28.01	0.000052	0.00001	0.00145	0.00073	0.000052	0.00001	0.00145	0.00080	0.00000	0.00000	0.00000	0.00000
H2S	34.08	0.000038	0.00000	0.00129	0.00065	0.000038	0.00000	0.00129	0.00071	0.00000	0.00000	0.00000	0.00000
FLY ASH	-	-	-	0.00000	0.00000	-	-	0.00000	0.00000	-	-	0.00000	0.00000
H2CO3	62.018	0.297148	0.03356	18.42851	9.21588	0.000000	0.00000	0.00000	0.00000	0.29715	1.00000	18.42851	100.00000
H2SO3	82.08	0.000000	0.00000	0.00000	0.00000	0.000000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TOTAL		8.854297	1.00000	199.96472	100.00000	8.557149	1.00000	181.53621	100.00000	0.29715	1.00000	18.42851	100.00000

ENERGY BALANCE FOR THE ECO PROCESS

TABLE OF THERMODYNAMIC PROPERTIES FOR THE COMPONENTS

COMPONENT	Cp (KJ/kg K)	DHf (KJ/mol)	A	B	C	D
N2	1.0300	0.0000	13.320	3.22E-02	1.53E-05	8.77E-09
CO2	0.8340	-383.5090	15.200	6.23E-02	8.97E-06	9.88E-09
H2O	1.9300	-285.5000	18.297	4.72E-01	-1.34E-03	1.31E-06
O2	0.9191	0.0000	24.300	5.20E-02	-1.24E-05	2.54E-09
SO2	0.6400	-296.8400	38.910	3.90E-02	-3.10E-05	8.61E-09
CO	1.0200	-110.5250	32.240	1.53E-02	8.77E-05	1.33E-08
H2S	1.0200	-20.6300	13.623	8.97E-02	9.88E-05	1.52E-09
FLY ASH	-	-	-	-	-	-
H2CO3	1.0500	-275.2000	11.520	1.24E-02	2.54E-05	2.43E-09
H2SO3	1.4200	-814.0000	47.210	1.34E-02	1.31E-04	3.89E-08

UNIT 1- OXIDATION CHAMBER

TAKING ENTHALPY BALANCE ABOUT THE OXIDATION CHAM

Tref = 298

T1 = 305

T2 = 352

P=101.3kPa

components	mol wt (kg/kgmol)	IN		OUT	
		moles(kmol/hr)	Enthalpy (kJ/hr)	moles(kmol/hr)	Enthalpy (kJ/hr)
N2	28.010	2.55672	441.57825	2.55672	3551.36588
CO2	44.010	0.30220	74.21271	0.30226	715.76897
H2O	18.020	0.62431	327.55508	0.62439	2542.91948
O2	32.000	0.11906	32.43550	0.11890	256.65289
SO2	64.060	0.00012	0.03942	0.00021	0.60012
CO	28.010	0.00010	0.03275	0.00005	0.12555
H2S	34.080	0.00013	0.04388	0.00004	0.10813
FLY ASH	-	-	-	-	-
TOTAL		3.60264	875.89760	3.60257	7067.54103

UNIT 2- ELECTROSTATIC PRECIPITATOR

TAKING ENTHALPY BALANCE ABOUT THE ELECTROSTATIC PRECIPITATOR

Tref = 298

T1 = 352

T2 = 352

P=101.3kPa

components	mol wt (kg/kgmol)	IN		OUT	
		moles(kmol/hr)	Enthalpy (kJ/hr)	moles(kmol/hr)	Enthalpy (kJ/hr)
N2	28.010	2.55672	3551.36588	2.55672	3551.36588
CO2	44.010	0.30226	715.76897	0.30226	715.76897
H2O	18.020	0.62439	2542.91948	0.62439	2542.91948
O2	32.000	0.11890	256.65289	0.11890	256.65289
SO2	64.060	0.00021	0.60012	0.00021	0.60012
CO	28.010	0.00005	0.12555	0.00005	0.12555
H2S	34.080	0.00004	0.10813	0.00004	0.10813
FLY ASH	-	-	-	-	-
TOTAL		3.60257	7067.54103	3.60257	7067.54103

UNIT 3- BARRIER DISCHARGE REACTOR

TAKING ENTHALPY BALANCE ABOUT THE BARRIER DISCHARGE REACTOR

components	mol wt (kg/kgmol)	T1 = 352		T2 = 430		P=300.6kPa
		IN	moles(kmol/hr)	OUT	moles(kmol/hr)	
N2	28.010	2.55672	3551.36588	2.55672	9295.74818	
CO2	44.010	0.30226	715.76897	0.03929	190.24782	
H2O	18.020	0.62439	2542.91948	0.36124	3534.09057	
O2	32.000	0.11890	256.65289	0.11881	653.81436	
SO2	64.060	0.00021	0.60012	0.00002	0.10225	
CO	28.010	0.00005	0.12555	0.00005	0.34317	
H2S	34.080	0.00004	0.10813	0.00004	0.29768	
FLY ASH	-	-	-	-	-	
H2CO3	62.018	0.00000	0.00000	0.26296	751.72746	
H2SO3	82.080	0.00000	0.00000	0.00019	1.94041	
TOTAL		3.60257	7067.54103	3.33932	14428.31192	

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UNIT 4 - WET ELECTROSTATIC PRECIPITATOR

TAKING ENTHALPY BALANCE ABOUT THE BARRIER DISCHARGE REACTOR

components	mol wt (kg/kgmol)	T1 = 430		T2 = 363		P=1030kPa
		IN	moles(kmol/hr)	OUT	moles(kmol/hr)	
N2	28.010	2.55672	9295.74818	2.556715	4316.46228	
CO2	44.010	0.03929	190.24782	0.005108	10.37460	
H2O	18.020	5.91063	3534.09057	5.876432	27168.28186	
O2	32.000	0.11881	653.81436	0.118802	310.55792	
SO2	64.060	0.00002	0.10225	0.000001	0.00377	
CO	28.010	0.00005	0.34317	0.000052	0.15947	
H2S	34.080	0.00004	0.29768	0.000038	0.13322	
FLY ASH	-	-	-	-	-	
H2CO3	62.018	0.26296	751.72746	0.297148	439.16016	
H2SO3	82.080	0.00019	1.94041	0.000204	1.06094	
TOTAL		8.88871	14428.31192	8.854501	32246.19423	

UNIT 5 - DISTILLATION COLUMN

TAKING ENTHALPY BALANCE ABOUT THE DISTILLATION COLUMN

Tref = 298

T1 = 363

T2top = 384

T2bottom = 340

P=1030kPa

IN

OUT

TOP

BOTTOM

components	mol wt (kg/kgmol)	moles(kmol/hr)	Enthalpy (kJ/hr)	moles(kmol/hr)	Enthalpy (kJ/hr)	moles(kmol/hr)	Enthalpy (kJ/hr)
N2	28.010	2.55672	4316.46228	2.55672	5817.47169	0.00000	0.00000
CO2	44.010	0.00511	10.37460	0.00511	16.65132	0.00000	0.00000
H2O	18.020	5.87643	27168.28186	5.87643	38266.85199	0.00000	0.00000
O2	32.000	0.11880	310.55792	0.11880	415.64109	0.00000	0.00000
SO2	64.060	0.00000	0.00377	0.00000	0.00553	0.00000	0.00000
CO	28.010	0.00005	0.15947	0.00005	0.21479	0.00000	0.00000
H2S	34.080	0.00004	0.13322	0.00004	0.18170	0.00000	0.00000
FLY ASH	-	-	-	-	-	-	-
H2CO3	62.018	0.29715	439.16016	0.29715	481.17497	0.00000	0.00000
H2SO3	82.080	0.00020	1.06094	0.00000	0.00000	0.00020	0.56694
TOTAL		8.85450	32246.19423	8.85430	44998.19309	0.00020	0.56694

Chapter 4

4.0 DISCUSSION OF RESULT

The total amount of stack gases from the plant was calculated and it was observed that the output was reduced compared to the inputs shown in the tables below

TABLE 4.1

TABLE SHOWING THE COMPOSITION OF GASES FROM THE ABSORBER

components	mol wt (kg/kgmol)	moles (kgmol/hr)	IN		% mass
			mol fraction	mass (kg/hr)	
N2	28.01	2.55672	0.70968	71.61360	71.61740
CO2	44.01	0.30220	0.08388	13.30000	13.30070
H2O	18.02	0.62431	0.17329	11.25000	11.25060
O2	32.00	0.11906	0.03305	3.81000	3.81020
SO2	64.06	0.00012	0.00003	0.00750	0.00750
CO	28.01	0.00010	0.00003	0.00290	0.00290
H2S	34.08	0.00013	0.00004	0.00430	0.00430
FLY ASH	-	-	-	0.00640	0.00640
TOTAL		3.60264	1.00000	99.99470	100.00000

TABLE 4.2

TABLE SHOWING THE COMPOSITION OF STACK GASES AFTER DESIGN

moles (kgmol/hr)	TOP PRODUCT			moles (kgmol/hr)	BOTTOM PRODUCT		
	mol fraction	mass (kg/hr)	% mass		mol fraction	mass (kg/hr)	% mass
2.556715	0.298781	71.61360	39.448658	0.000000	0.000000	0.000000	
0.005108	0.000597	0.22481	0.123837	0.000000	0.000000	0.000000	
5.876432	0.686728	105.89331	58.331785	0.000000	0.000000	0.000000	
0.118802	0.013883	3.80167	2.094165	0.000000	0.000000	0.000000	
0.000001	0.000000	0.00008	0.000046	0.000000	0.000000	0.000000	
0.000052	0.000006	0.00145	0.000799	0.000000	0.000000	0.000000	
0.000038	0.000004	0.00129	0.000711	0.000000	0.000000	0.000000	
-	-	0.00000	0.000000	-	-	0.000000	
0.000000	0.000000	0.00000	0.000000	0.2971477	1.000000	18.428505	100.000000
0.000000	0.000000	0.00000	0.000000	0.000000	0.000000	0.000000	
8.557149	1.000000	181.53621	100.000000	0.2971477	1.000000	18.428505	100.000000

All the gases were hydrolyzed and turned into acids that can be collected in tank and be used for other commercial purposes.

4.2 DESIGN REQUIREMENT AND CRITERIA

It is required that the process is designed that will be reducing the effect of stack gases in the atmosphere. This design is limited to the control of stack gases to the atmosphere from a process plant that reclaims CO₂ and let other gases into the atmosphere.

The equipment required is expected to be as cheap as possible, and a simple design that will still handle the stack gases with a very high conversion. Some factors to look out for in the selection of equipments includes:-

- The ability to withstand corrosion
- The ability to withstand pressure
- Ability to withstand high temperature
- High level of stability (so that reaction does not occur with the vessel)

4.2 General Design Considerations

Generally in construction the aim is to put up something that is standard and will be able to

4.3 Process Design Development

The process design is from the already existing plant that produces co2 for beverage and the need arises for a solution to control an effect of the process that is unfriendly to the environment which is pollution

4.6 Software Use in Process Design

The software's that were used in the design includes:-

- Microsoft office Visio.
- Microsoft office excel

CHAPTER 5

5.0 CONCLUSION

In the design of the process economy as well as environmental factors were put into consideration. The design was made to make the environment less prone to air pollution from the process industry, by further conversion of the stack gases.

5.1 ENVIRONMENTAL AND ECONOMIC IMPACT

The design if properly implemented or incorporated into the plant will greatly reduce the discharge of stack gases to the atmosphere around the plant which in turn leaving the environment in a less polluted state.

The plant and animals in the surrounding will have no threat to their lives as a result air pollution.

The cost of treating the soil should in case it wants to be used for farming will be eradicated since that will have to a continuous exercise and the yield of the farm product cannot be guaranteed, but with the implementation of the design that automatically is being taken of.

5.2 RECOMMENDATION

There other processes that generate a lot of gases to the atmosphere that the scope of this work does not cover, so it is recommended that research should be carried out. Also that models and designs can be made to cover the aspects of pollution that this work does not cover.

It also recommended that soft ware should be designed to automatically determine the composition of gases from the plant that pollute the atmosphere and as the are generated only required quantity of adsorbents should be used so as to minimize the quantity of absorbent or adsorbents that are used in the pollution control process. It is also recommended that plants with higher conversion rates are designed so as to minimize the cost of designing processes for the control of pollution which is an additional cost to the design of the main plant for the production of the desired product.

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