MINIMIZATION OF H_2S GAS FLARED IN PETROLEUM INDUSTRY

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A RESEARCH PROJECT SUBMITTED TO CHEMICAL ENGINEERING DEPARTMENT SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY.

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING DEGREE IN CHEMICAL ENGINEERING.

MARCH, 2000

CERTIFICATION

his is to certify that this work "MINIMIZATION OF H_2S GAS FLARED IN ETROLEUM INDUSTRY" was carried out by **ABOLARIN ADEOLA** of the epartment of Chemical Engineering, School of Engineering and Engineering echnology, Federal University of Technology, Minna.

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ACKNOWLEDGEMENT

My sincere gratitude go to all that made the writing of this research work a success. Some of whom mentioning their contributions will make the writing of this research work pale into insignificance.

My thanks go to my supervisor, Mr. U. G. Akpan, for his kindness and understanding, criticism, patience and above all, for supplying the right antidote to tension. I am grateful.

My thanks to Anita for extending her hand and heart during the writing of this research work. The heart surely never forgets.

I will like to thank Bimbo Babalola for kicking the ball rolling. I do not forget easily. I am over whelmed!.

My thanks also go to the Okunbanjo's for their support both physically and spiritually. With all humility, I say thank you.

Special thanks to all staff and students of the Federal University of Technology, Minna. May God reward you all accordingly.

Worthy of mention are all my course mates, for giving the needed cup of garri when required. May you all never lack.

My sincere thanks to my parents, Mr. and Mrs. Abolarin, for footing the bill and for having such confidence in me. Mummy, Daddy, you are both parents in a million!

I will like to thank all my friends and well wishers. God bless you all.

This work will not be complete without thanking all my brothers, sisters, nephews and cousins. I am greatly flattered having you all.

My utmost thanks go to the Alpha and the Omega, the Almighty God, for being there for me to get here. To Him I give praise.

ABOLARIN .A.

MARCH 2000.

DEDICATION

This project is dedicated to the Glory of the Almighty God.

".... In vain the refining goes on..." Jer. 6:29 (RSV)

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ABSTRACT

This research work was focused on the minimization of flare gases in petroleum industry, with particular emphasis on the reduction of hydrogen sulphide (H_2S) in the flare, and the conversion of this acidic gas to a more useful form: SULPHUR. In a bide to achieve this set goal, the process of stripping hydrogen sulphide with Di-Ethanolamine (DEA) solution from refining off gases and the conversion to sulphur of hydrogen sulphide using Claus' process, was optimized. The combination of both processes from mathematical calculation achieved an optimum efficiency of 95 – 96%, and with stringent environmental laws, 99% efficiency could be achieved using multi – stage processes.

CHAPTER ONE

1.0 INTRODUCTION

Nigeria is the 8th world producer of crude oil, otherwise called "Black Gold" and has four large refineries processing over three hundred thousand barrels of crude oil daily[6]. Seventy percent of Nigeria's income comes from the sale of crude and petroleum products and until there are alternatives to her sources of revenue generation, nothing will be out of tune or place towards the maximization of her profit from petroleum.

In as much as maximization of profits serves as a lubricant to our wheels of development, the environment, man and the entire ecosystem deserves our attention. Nothing is ever complete or useful if it is done at the detriment of other God's given resources. The minimization of flares in our petroleum industries is a drive towards the tide of maximum profit but at a low (minimum) hazard to man and his environment. The flaring of the lower petroleum gases with sulphur and other trace gases constitute dangers to man's health and to the environment at large.

The minimization of flares in petroleum industries will put to rest the risk of diseases causing death in man like cancer, cough, asthma etc. and the damage done to the environment. Destruction of the Ozone layer is one of the highlights of global warming and if the combustion of petroleum products continues at this rate the danger will be better imagined than experienced. Not only that, Nigeria stands to gain more since the flared gases can be converted and use as feedstock for other petrochemical industries, thereby fetching the country more foreign exchange. The rate of pollution in our society will also be reduced drastically which will give justification to the tax-payers money spent on pollution control agencies spread across the country. It is of no interest to man that he is killed by his ardent pursuit to make money. Also of concern are the aquatic animals which have been bearing the brunt of man's inhumanity for long.

Gas flaring, apart from being detrimental to the environment in the degradation of ambient air, has been seen to be a monumental waste of valuable resources. Not only that, gas flaring has been blamed for the acidification of soils and water, the corrosion of metal roofs and crop damages[1]. It also generates constant heat and it is a major partaker in the main greenhouse effect.

Time has therefore come (if not long over due) when one has to worry about the effects on the environment, one's health, wild life, plants, animals, buildings and cost, of the flared gases.

This work is therefore aimed at minimizing the flaring of sulphur as hydrogen sulphide during the refining of crude oil. This will be done by converting hydrogen sulphide to sulphur by the Claus's process.

Hydrogen sulphide is one of the gases flared on the course of crude refining, and this gas has dangerous effects on man (as toxic as HCN), plants (plant leaf symptoms, plant chlorosis, alteration of plant growth), animals (PH increase of water), buildings (acid rains), and the environment. It is therefore, important to either remove this dangerous gas or convert it to other useful components: sulphur.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 POLLUTION

According to Webster dictionary, pollution is defined as a process (means) by which water, land and air are made unhealthily impure.

Factory waste may pollute our rivers, earth-crust and the atmosphere.

2.1.1 AIR POLLUTION AND EFFECTS

For some four million (4,000,000) years,[7] from the earliest hominids to contemporary man, one human characteristic has remained unchanged and invariable - we have always produced garbage and litter. Even on our latest adventure into space, we have sent our debris ahead of us, and we have vented it on the surface and into the atmosphere of the new world where we have landed. Indeed, without such waste we should have little record of our evolutionary past, for it is from discarded tools, unscattered remains of meals, feaces, and similar artifacts or excrescences that we have been able to piece together something of our past cultural life.

With global erectus – sapiens populations totaling a million individuals[5], all in a hunting – gathering phase, such waste accumulated very slowly and quite locally. With a total world population now estimated at about more than three billion, the global pile of excrement increases at the rate of about 1½ million tons per day.[1]

Yet this is among the least of our problems. More and more of us now live in cities, and it has been calculated that the average city dweller produces 0.675 tons of garbage per year.[1] Also some of this garbage rises into the air in the form of solid pollutants. A global total of 14 million tons[1] of solid pollutants is now emitted unto the atmosphere annually. Some of these coat our buildings and soils our hands and clothes; while some are inhaled and deposited on the tissues of our lungs. This presents us with the problem, or rather the series of allied problems, now broadly described by the term "air pollution".

It is also now applied to situation where invisible particulate matter is present which produces some visible reaction. Schaefer (1969) remarks that particles with a cross section of less than 0.1γ are optically invisible, but such particulates may be a major source of air pollution. In the context of this research work, air pollution has been given a wider definition than is sometimes employed. It is taken here to include any atmospheric disturbance resulting from human activity which has a modifying effect on the role which air plays as an abiotic element of natural ecosystems.

Human beings receive their nutrient and energy requirements from food, water and air. Of the three, man cannot survive long without air. The intakes for an "Average" adult are listed below. The figures are approximate, and vary from individual to individual,

TABLE 1: AVERAGE AIR, FOOD AND WATER NEEDS OF AN ADULT.[7]

MATERIAL	AVERAGE DAILY INTAKE	AVERAGE INTAKE Kg/DAY
AIR	$20m^3$ [a]	24[b]
FOOD	1.5kg	1.5
WATER	1 Litre	1

[a] *This varies with the person and physical activity.*

[b] *Taking the density of air as 1.225 Kgm^{-3} at sea level (288k)*

but they indicate the significant position of air for man. Much of what is inhaled in is exhaled, but the lung tissue does come into contact with a large quantity of air daily. The absorption of material from the lungs into the blood stream is more effective (Perhaps by a factor of 2 to 5) than absorption from the alimentary tract. These facts emphasise the need for good quality air for healthy existence, and why the levels of air pollutants are required to be at least an order of magnitude less than in food and water.

Air pollution is not a new problem, but is one which many more people are aware of. The problem has grown however, as a result of the wide spread use of the internal combustion engine, and until recently a cheap fuel source, viz petroleum.

TABLE II SOME EMISSIONS FROM SELECTED INDUSTRIES

INDUSTRY	POLLUTION
Chloro - alkali	Cl_2 Hg (Hg Cell only)
Copper Smelters	Particles, SO_2
Pulp and Paper (Kra ft)	Particles, SO_2, CO, H_2 S, CH_3 OH, $(CH_3)_2S$, $(C H_3)_2S_2$
Petroleum refining	$S0_2$, CO, hydrocarbons, nitrogen Oxides, aldehydes, NH_3
Portland Cement	Particles, $S0_2$, nitrogen oxides
Aluminium Production	Particles, gaseous and particulate, fluorides.

The general effect of this level of air pollution is summarized in an extract from the clean air act (88th congress, 1963), which states:

"... growth in the amount and complexity of air pollution brought about by urbanization, industrial development, and the increasing use of motor vehicles, has resulted in mounting dangers to the public health and welfare, including injury to agricultural crops and livestock, damage and deterioration of property, and hazards to air and ground transportation."[10]

Conclusively, air pollution causes green house effect, other meteorological effects, skin and lung cancer, scrotal cancer, emphysema, chronic bronchitis, diphtheria, pneumonia and the acidification of water and soil. Also added is noise pollution.

2.2 CHARACTERISTIC OF PETROLEUM GASES AND USES.

Depending on the origin, petroleum gases are divided into natural, casing head, and artificial ones.[4]

Natural gases are produced from independent fields, and casing head gases together with petroleum. At refineries, gas is obtained in primary distillation and in the secondary processing of petroleum. Gases of thermal and catalytic cracking contain a considerable amount of unsaturated hydrocarbons, while gases of catalytic reforming, hydrofining, and hydrocracking contain no unsaturated hydrocarbons.

The subsequent use of a gas depends on its composition. The gas of catalytic cracking rich in butylenes and isobutane is the best stock for catalytic alkylation plants.[4] Hydrogen, or more precisely a hydrogen containing gas with a volume fraction of hydrogen of 75% - 90%, is separated from the reforming gases. This gas is used for hydrogenation processes.

Many modern technological plants have units for the primary treatment of the gas. Here it is purified of hydrogen sulphide, and hydrocarbons with three or four carbon atoms are separated from it in the form of a liquid hydrocarbon fraction the - stabilizer overhead.

However, the gas is separated into individual hydrocarbons and narrow hydrocarbon fractions in specially built gas plants.

2.3 GAS FLARING

Flares are said to be operating at temperatures between 300 – 1400^{0}C which may be the case in the centre of the flame.[4]

Flaring of associated gases is a waste of a vital natural resources and is untenable in the long term. The issue could remain the most constraining factor for future oil growth, as international and national environmentalist press for reduce flaring.

Emissions from gas flaring are difficult to evaluate as only little is known about the flames temperature.

Refining processes in Nigeria datses back to the 1970's when little was known about the compositions and uses of the flared gases. Since then, with the processing of about 2 million barrels of crude a day,[6] the atmosphere and the entire ecosystem has suffered innumerable loss at the expense of crude refining. Consequently, more than 90% of the 2 million cubic feet of gas produced in Nigeria is flared.[6]

As of the year (1998), Nigeria gas reserves stands at about 1.3 million standard cubic feet (SCF). A daily production of 1.8 million cubic feet of gas production is flared. In energy terms, this 80% is equivalent to 257,000 barrels of oil production a day.[6] And by government regulations, this percentage of flared gas should be reduced to zero flare by the year 2008.

Gas flaring continued through the 1970's because of the out-dated and ancient refineries built in the 1960s when "black gold" was being explored in Nigeria. Not only that, little was known about the effect the effluents are having on the environment and man. Also, due to the cheapness of hydropower, the flared gases could not have a ready market at home. The component of the flared gases were not known and reserves stations were not built or developed.

Presently, some reputable companies are taking the bull by the horn, they are investing heavily in the gas (petroleum gas) sector. Companies like Mobil, the Escravoes, Chevron etc. are into gas sector development in Nigeria.

2.3.1 EFFECT OF GAS FLARING

As earlier mentioned, the effect of the flared gases on man, animals, plants and the environment is great and if something drastic is not done to arrest the situation, the environmental condition will be so much deteriorated.

The effect ranges from diseases causing death in man, poor yield in plants, dilapitation of man's habitat and the occurrence of the greenhouse effect, coupled with the antecedent of global warming.[7]

The generation of heat at flaring sites leads to the evaporation of water from sources close to the sites. The high infant mortality rate has been ascribed to the issue of air pollution which flaring from our refineries is boosting.

Finally, according to analysis, tens of thousands of naira are being thrown into the dust-bin during flaring which affects our economy adversely.

2.4 SULPHUR

Sulphur occurs, mainly in combined form, to the extent of about 340 ppm in the crustal rocks of the earth.[8] It is the sixteenth element in order of abundance, closely following barium (390 ppm) and strontium (384 ppm), and being about twice as abundant as the next element carbon (180 ppm). Earlier estimates placed its global abundance in the range 300 – 1000 ppm.[8] Sulphur is widely distributed in nature but only rarely is it sufficiently concentrated to justify economic mining. Its ubiquity is probably related to its occurrence in nature in both inorganic and organic compounds, and to the fact that it can occur in at least five oxidation states: - 2 (sulphides, H_2S, and organosulphur compounds), - 1 (disulphides, $S^2{}_2$-), 0 (elemental S), + 4 (SO_2), and + 6 (sulphates).[8]

The three most important sources are:

1. Elemental sulphur in the caprock salt domes in the U.S.A. and mexico, and the sedimentary evaporite deposits in south – eastern poland;

2. H_2S in natural gas and crude oil, and organo sulphur compounds in tar sands, oil shales, and coal,

3. Pyrites (FeS_2) and other metal – sulphide minerals.

2.5 HYDRIDES OF SULPHUR (SULPHANES)

Hydrogen sulphide is the only thermodynamically stable sulphane; it occurs widely in nature as a result of volcanic or bacteria action and is, indeed, a prime source of elemental sulphur.[8] It has been known since earliest times and its classical chemistry has been extensively studied since the seventeenth century. H_2S is a foul smelling, very poisonous gas familiar to us. Its smell is noticeable at 0.02 ppm[8] but the gas tends to anaesthetize the olfactory senses and the intensity of the smell is therefore a dangerously unreliable guide to its concentration.[8] H_2S causes irritation at 5 ppm, head aches and nausea at 10 ppm, and immediate paralysis and death at 100 ppm; it is therefore as toxic and as dangerous as HCN.[8]

TABLE III SOME MOLECULAR AND PHYSICAL PROPERTIES OF H_2S[8].

Distance (S – H)/pm	133.6 (g)	Density (s)/g cm $^{-3}$	1.12 (-85.6^0)
Angle H – S – H	92.1^0 (g)	Density (l)/gcm $^{-3}$	0.993 (-85.6^0)
MP/^{0}C	- 85.6	Viscosity/centipose	0.547 (-82^0)
BP/^{0}C	- 60.3	Dielectric Constant $\in$	8.99 (-78^0)
Critical Temp./^{0}C	100.4	Electrical Conductivity/ohm^{-1}cm^{-1}	3.7 x 10^{-11}
Critical Press./atm	8.4		
ΔHf^0/Kjmol $^{-1}$	20.1 (g)		

2.6 SOUR CRUDE OIL: COMPOSITION

Sulphur content and API gravity are the two properties which have the greatest influence on the value of crude oil.[9] The sulphur content is expressed as percent sulphur by weignt and varies from less than 0.1% to greater than 5%[9]. Although the term "sour" crude initially had reference to those crude containing dissolved hydrogen sulphide independent of total sulphur content, it has come to mean any crude oil with a sulphur content high enough to require special processing. There is no sharp dividing line between sour and sweet crudes, but 0.5% sulphur content is used as the criterian.[9] Both Nigeria crude oils 0.24 and 0.16 weight percent sulphur respectively are considered as sweet crudes.

2.7 SOUR CRUDE OFF GASES

These are composed of hydrogen sulphide, hydrogen and saturated light hydrocarbons (methane, ethane, propane, iso and normal butane, pentane) and the chief ingredient is hydrogen which occupies 60 –90 vol. % of feed.[9]

In normal operation, the following compositions are dominant in refinery off – gases flared.

H_2 (hydrogen)	-	63 – 73 mol. %
CH_4 (methane)	-	11 – 15 mol. %
C_2H_6 (ethane)	-	6 – 8 mol. %

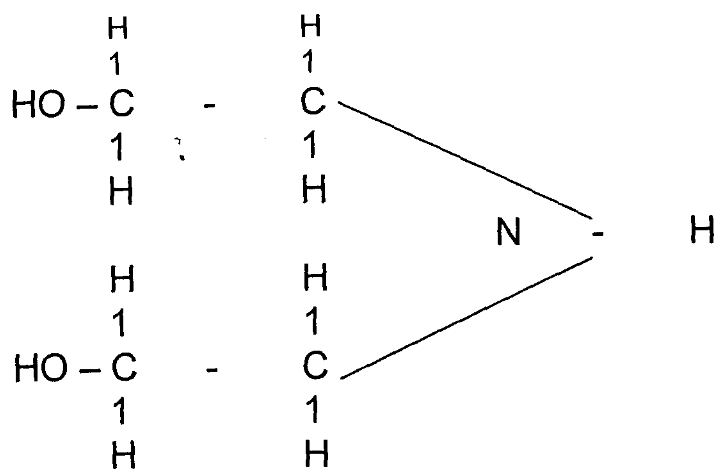
Most of the hydrogen sulphide in the off – gases is formed by conversion of sulphur compounds in hydro treating and cracking and also the crude oil contains small amounts of hydrogen sulphide.[9]

2.8 STRIPPING OF H_2S FROM OFF - GASES

Hydrogen sulphide and other acid gases from sour refinery gases and liquified petroleum gases (LPG) are removed by using Di – Ethanol amine (DEA) solution, which is regenerated by heating to temperature above its solution.

2.8.1 DEA SOLUTION

20 weight percent diethanolamine (DEA) aqueous solution is employed as the absorbent. Pure DEA is a white crystalline below 28^0 and is a colourless liquid above 28^0C. Structural formula is presented below:. [9]



Di – ethanol – amine

2.8.2 BASIC CHEMISTRY

The operation of the process is based upon the equilibrium reaction between DEA and the acid gas H_2S. The principal reactions are represented by the following equations, in which R represents the group of (- CH_2 – CH_2 0H).[9]

H_2S reacts with DEA to form amine hydro-sulphide according to the overall reaction and an intermediate product of this reaction is amine sulphide as shown below.

$$\underset{\text{(DEA)}}{2R_2NH} \quad + \quad H_2S \rightleftharpoons \underset{\text{(Amine Sulphide)}}{(R_2\,NH_2)_2\,S} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$(R_2\,NH_2)_2\,S \quad + \quad H_2S \rightleftharpoons \underset{\text{(Amine hydrosulphide)}}{2(R_2\,NH_2\,HS)} \quad \ldots\ldots\ldots\ldots \quad (2)$$

The equilibrium of the above reactions lies at the right hand side of the equations at lower temperature and higher pressure the reaction is reversed, resulting in the removal of H_2S from the DEA solution.[9]

2.9 CONVERSION OF H_2S TO S USING CLAUS PROCESS

Separation of gas (H_2S) by absorption in ethanol amine and then converting it to sulphur by a process first developed by C. F. Claus in Germany about 1880.[8] In this process one – third of the H_2S is burned to produce SO_2, water vapour, and sulphur vapour; the SO_2 then reacts with the remaining H_2S in the presence of oxide catalyst such as Fe_2O_3 or Al_2O_3 to produce more water and sulphur vapour.

2.9.1 EQUATIONS OF REACTION

$$H_2S + \tfrac{1}{2}O_2 \xrightarrow[\text{Combustion}]{\text{Low Temp.}} \tfrac{1}{8} S_8 + H_2O \quad \ldots\ldots (3)$$

$$H_2S + 1\tfrac{1}{2} O_2 \longrightarrow SO_2 + H_2O \quad \ldots\ldots (4)$$

$$2H_2S + SO_2 \xrightarrow[\text{Catalyst } 300^{0}C]{\text{Oxide}} \tfrac{3}{8} S_8 + 2H_2O \quad \ldots\ldots (5)$$

Multiple reactors achieve 95 – 96% conversion and recovery.[8] The stringent air pollution legislation has now pushed this to 99%.[8]

Much has been said but the target is to minimize the flared gases to avail the environment and man of the dangerous effects emanating from flaring.

The liquefied natural gas (LNG) and the liquefied petroleum gas (LPG) have garner awareness and interest but the uncondensable gases from refining also needs our attention towards its reduction.

The need for this study cannot be over emphasized as the nation marches boldly into the new millenium with her eyes glued to a vision of 2010.

The major reason for carrying-out this study is to minimize flaring and its effects on man, plants, animals and the environment in general.

CHAPTER THREE

3.0 EXPERIMENTAL

3.1 RESEARCH METHODOLOGY

3.1.1 SOURCE OF DATA COLLECTION

3.1.2 PRIMARY SOURCES

These includes activities that brings a personal contact with problems under study.

It involves personal interview of workers working with the existing system at the refineries.

3.1.3 SECONDARY SOURCES

The entire data obtained from the secondary source is from Kaduna Refinery and Petrochemical Company (KRPC) in Kaduna.

3.2 LIMITATION OF EXPERIMENTAL

The limitations of this research work includes the following:

i. Breakdown of the refineries across the country which disturbs the collection of samples for analysis.

ii. Lack of proper record keeping in refineries.

iii. Financial constraints which necessitate the concentration of study to a single location and

iv. The importation of fuel from outside the country.

CHAPTER FOUR

4.0 RESULT

PRODUCTS	CRUDE SOURCE			
	AFRICAN	SOUTH EAST ASIAN	MEXICAN	MIDDLE EAST
Dry gas & C_4, wt %	6.2	7.4	10.5	9.2
C5 – 193^0c, naptha, wt %	18.5	20.4	21.4	17.4
Gravity, ^{0}API	56.1	62.3	54.9	58.3
Sulphur, wt %	0.1	0.2	0.9	0.5
193^0c +, gas oil, wt %	65.3	54.5	33.0	48.5
Gravity, ^{0}AP1	22.4	34.9	20.5	25.3
Sulphur, wt %	0.59	0.42	4.26	2.28
Coke, wt %	10.0	17.7	35.1	24.9
Ni + V, ppm (weight)	500	249	25.92	361
Sulphur, wt %	1.1	0.8	6.4	5.1

BASIS: 100 percent weight as 100kg.

4.1 CHEMISTRY OF REACTION

At temperature of 193^0C + the African crude source has a sulphur content of 0.59% by weight. Hydrogenation reaction occurs between sulphur and hydrogen at temperature above 200^0C;

$$\underset{(1-x)}{H_2} + \underset{(1-x)}{{}^1/_8\, S_8} \longrightarrow \underset{x}{H_2S}$$

1 mole l mole 1 mole

But the sulphur content is:

0.59% of 100kg

=> <u>0.59</u> x 100kg

100

=> 0.59 kg

.: (1 – x) = 0.59 kg

x = 1 – 0.59

x = 0.41kg

REACTANTS	MOLE	kg
HYDROGEN (H_2)	1	0.59
SULPHUR (S)	1	0.59
PRODUCT		
HYDROGEN SULPHIDE (H_2S)	1	0.41

4.2 AFTER TREATMENT

The use of multiple Claus process achieves 95 – 96% conversion and recovery bu the stringent air pollution legislation has now pushed this to 99%

SUBSTANCE	RECOVERY AND CONVENSION
HYDROGEN SULPHIDE (H_2S)	99% of 0.41kg ⇨ $\frac{99}{100}$ x 0.41kg => 0.4059kg

Amount of H_2S left after treatment

= Amount of H_2S in feed – Amount of H_2S treated

= 0.41kg – 0.4059kg

= 0.0041kg (Amount of H_2S left in the off gases).

CHAPTER FIVE

5.0 DISCUSSION OF RESULT

The African crude source was taken due to the peculiarity of this work, which was carried out in an African country (Nigeria). The averages of the African crude source was as made available in the table of result.

Taking a basis of 100% wt (percent weight) as 100kg and at temperature of 193^{0}C and above, it can be seen that the sulphur content of the African crude source has a sulphur content of 0.59% by weight.

During hydrocatalytic cracking of crude oil, hydrogenation reaction occurs between sulphur and hydrogen at temperature above 200^{0}C. It was discovered by calculation, that for every 100kg of flared gases, 0.59kg of sulphur and 0.41kg of hydrogen sulphide were produced and flared into the atmosphere. From texts, 0.59% wt of sulphur in a crude is high enough to make it a sour crude source.

By inference, Nigeria treats an average of 200 million barrels of crude daily (31.8 million M^3). This from calculation gives an average of 0.82 million (0.41% of 200 million) of hydrogen sulphide produced daily and directly flared into the atmosphere.

Early usage of Claus process achieved 95 – 96% conversion of H_2S to sulphur and the recovery of the converted sulphur. The stringent air pollution legislation has pushed for a change and with the use of this multiple Claus process (multi – stage process), 99% of conversion and recovery can be achieved. The efficiency of the Claus process has been increased by 3% which is a major landmark in air pollution control.
Simply put, for every 100kg of sample treated, it contains 0.41kg of H_2S and after processing only a meagre 0.0041kg of H_2S finds their way into the atmosphere i.e. 0.4059kg was recovered after treatment.

5.1 SOURCES OF ERROR

The source(s) of error can be classified into two:

i. Technical Error and

ii. Equipment Error

The technical error emanates from the haphazard way the refinery functions, for the situation on ground is a far cry from normal.

The equipment error comprises of leakages of gas from reactors which makes the process unsteady and the use of anti-foam reagents, which is further promoted by the following causes;

a. Contamination of DEA solution by surface active agents which tend to concentrate in the surface layer, these causing a decrease in surface tension.

b. The presence of fine solids such as Iron sulphide

c. The presence of dissolved organic acids and/or hydrocarbons.

d. Contamination by valve greases on a soap base

e. Make-up water contaminated with dissolved material

f. HCN, if present in the feed gas, which may form complex iron salts.

5.2 SAFETY AND ECONOMY

Due to the poisonous nature of hydrogen sulphide all workers working in and around the sulphur plant should be well enlightened and protected. Protective materials like the nose mask to forestall the inhaling of the gas, protective leather (more rubber – like) clothing to protect the skin since the gas is acidic and the use of hand – gloves should be enouraged.

Safety valves and gas concentration indicators are also necessary and important.

Though the use of multiple Claus process and the treatment of the foaming tendency of DEA solution can be quite expensive, the fact remains that man and his environment is of the highest priority and their safety a dominant factor.

CHAPTER SIX

6.0 CONCLUSION

Hydrogen sulphide is a foul smelling, very poisonous gas familiar to us. Its smell is noticeable at 0.02 ppm but the gas tends to anaesthetize the olfactory senses, causes irritation, headaches and nausea and causes immediate paralysis and death at 100 ppm. It is known to be as toxic and as dangerous as HCN.

In every 100kg of sample of off gases 0.41kg H_2S is found to exist and this is considerably high. The whole lot of this is ejected into the atmosphere at a very high temperature (1000 – 1100^{0}C) as flares. This exposes man to all the dangers affiliated to H_2S in an uncontrolled state in the atmosphere. The accumulation of H_2S in the atmosphere over a long period of time can be as fatal as the exposure of man to nuclear radiation.

The use of multiple Claus process will not only strip H_2S from the off – gases in refineries but will as well convert it to a more useful and usable form i.e. sulphur. Sulphur is one of the four basic raw materials of the chemical industry (the other three being coal, limestone, and salt). It is used in religious ceremony, for purification of containers, for bleaching, in warfare, medicine, rubber vulcanizing, insecticides, dyes, fungicides and in pharmaceuticals.

The use of multiple Claus process also improves by 3% in efficiency, on the early process of a single process. The multiple process gives 99% recovery and conversion which is an up-date on the old system which gives a paltry 95 – 96% recovery and conversion.

Conclusively, every 100kg of sample flared has 0.41kg of H_2S which after processing (using multiple Claus process) leaves 0.0041kg to be flared and o.4059kg recovered and converted to sulphur.

CHAPTER SEVEN

7.0 RECOMMENDATIONS

With the investigations and the results gathered, the following recommendations can be made.

i. The single stage system should be changed and the multiple stage process implemented.

ii. Proper and adequate lagging should be carried out on all vessels used in the process.

iii. Immediate market should be found for the end product (sulphur) since this process will increase production.

iv. All units down in the process should be reactivated by making funds available and

v. Competent and skilful workers should be employed to further give credence to specialization.

Although the implementation of this process is an added cost but it is in the right direction. Man and his safety should be our major watchword. No amount of money is greater than life.

In no distance future, with the start of a smelting company in Akwa-Ibom State and the rejuvenation of the Ajaokuta Steel Company in Kogi State, the cost dominant factor of material (Steel) will be a thing of the past.

Finally, the sourcing for locally made raw materials will go a long way to reduce cost and improve the economy of this findings, giving more time and money.

TEXT

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