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PRODUCTION OF CARBON DISULFIDE BY CHARCOAL-SULFUR PROCESS

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ABSTRACT

Historical background of the production of Carbon Disulphide (CS_2) has been presented. Chemistry and physical properties of (CS_2) as well as its end uses and world producers have been also presented. All manufacturing processes for carbon disulphide have been discussed and compared.

The main objective behind this project is to describe, in detail, the process of (CS_2) production based on the reaction of Charcoal with Sulphur, that is the Retort Process. For this process, detailed theoretical and practical calculations have been done. Moreover, sample design calculations for some important equipments have been accomplished. These quipments are sulphur melting tank together with the agitator and molten sulphur pump, and condenser for Carbon Disulphidemic calculations performed in this work show that the manufacturing cost of (CS_2) is (3139 $) per ton. The economic study also shows that Breakeven point (QBE) and Payback- Period of the plant are (7.5t/day) and (5.3) years respectively.

It is suggested in this work that a Retort Process Plant of moderate capacity can be constructed in Libya to meet the demand for (CS_2) by different consumers.

The site preferred for the plant is that nearer to the big consumers of (CS_2) as well as that in districts where raw materials,mainly sulphur, are available.

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الملخص

تم عرض الخلفية التاريخية لإنتاج ثاني كبريتيد الكربون (CS_2). كما تم عرض الخواص الكيميائية والفيزيائية لـ (CS_2) واستخداماته النهائية والمنتجين العالميين. تمت مناقشة ومقارنة جميع عمليات التصنيع لثاني كبريتيد الكربون.

الهدف الرئيسي من هذا المشروع هو الوصف التفصيلي لعملية إنتاج (CS_2) المعتمدة على تفاعل الفحم مع الكبريت، وهي عملية المعوجة. ولهذه العملية، تم إجراء حسابات نظرية وعملية مفصلة. علاوة على ذلك، تم إنجاز حسابات تصميم العينات لبعض المعدات الهامة. هذه المعدات عبارة عن خزان لصهر الكبريت مع المحرض ومضخة الكبريت المنصهر ومكثف لحسابات ثنائي كبريتيد الكربون التي أجريت في هذا العمل تبين أن تكلفة تصنيع (CS_2) هي (3139 دولار) للطن الواحد. كما أظهرت الدراسة الاقتصادية أن نقطة التعادل (QBE) وفترة الاسترداد للمحطة تبلغ (7.5 طن/يوم) و(5.3) سنة على التوالي.

يُقترح في هذا العمل إنشاء محطة معالجة المياه العادمه ذات قدرة متوسطة في ليبيا لتلبية الطلب على (CS_2) من قبل مختلف المستهلكين.

الموقع المفضل للمصنع هو الأقرب إلى كبار المستهلكين لـ (CS_2) وكذلك في المناطق التي تتوافر فيها المواد الخام وخاصة الكبريت.

INTTIONROCUC

Electrothermal Process requires inexpensive source of electrical power .Methane Process requires a nearby source of methane. Moreover, each of these processes enable a higher output of carbon disulfide and are particularly wel suited for industrialized countries which have well-developed textile industries, etc, and therefore a large CS_2 demand .

In many other countries, such as Libya, textiles are not the main consumer of CS_2 therefore, retort (Charcoal-Sulphur) Process can be chosen with any capacity to mee present or future CS_2demand .

That capacities up to 5 to15 t/day are available by Retor Process. Therefore, in this search, retort (charcoal- Sulfur) process has been chosen[1].

1. RAW MATERIALS

The equation of the reaction is

$$C_{solid} + 2S_{vapor} \xrightarrow{800C^0} CS_{2(vapor)} \ (\Delta H = -2.8 kcal/kmol)$$

It is evident from the reaction equation that carbon and sulfur are the main raw materials of the process. One mole of carbon and two moles of sulfur are required to produce one mole of CS_2[1].

CHARCOAL

The requirements for charcoal quality are more exacting and have often led to a limited supply position within regional areas . Hardwood charcoal are preferred and must be prepared under carefully controlled conditions to avoid reducing their activity Charcoal from peat and soft wood are higher in ash lower in activity which reduces the productive capacity of the retort. The charcoal is usually preheated to remove moisture and to reduce volatile content before it is charged into the retort. The charcoal suitable for this process as a source for carbon should contain min 85%by weight of fixed carbon & max 2% by weight ash .other content are moisture and volatile matters[3].

SULFUR

The raw sulfur is commercially pure grade in which carbon has been removed to minimize deposition of the carbon when sulphur is vaporize. Both underground sulfur and gas sulfur can be used with and gas sulfur can be used with the following typical analysis[3]**:**

a-Sulfur from underground deposits

Sulphur= 99%

Humidity=0.3%

Ash =0.25%

Hydrocarbon 1 1%

b-Gas sulfur

Sulfur =99.9%

Humidity Max 0.05%

Ash Max 0.1%

Hydrocarbons Max 0.2%

A- DESCRIPTION OF THE PROCESS

The technological stages of the process are:

1- The Sulfur Melting Stage

Sulfur is melted by using steam in ajacketed stirred tank. In this tank, the temperature of the molten sulfur is raised up to 150 ^{0}C and then it is transferred to the mixing tank by a centrifugal pump immersed in sulfur. The molten sulfur from mixing tank passes through the filter to the storage tank of pure sulphur .

2- Sulphur vaporizer and reactor (Reaction Stage)

Both, the sulfur vaporizer and the retort are placed in a firebrick-lined furnace heated by gasoil so that the temperature in the furnace is about (700-800) ^{0}C. Sulfur is vaporized in the vaporizer prior to entering the retort. Sulfur vapor at its boiling point (445) °C exists as a mixture of the molecular weight species (S-6&S-8) with only a minor fraction as S4 or S2.As the sulfur is superheated toward the reaction temperature, S-8 & S-6 species decomposes into the smaller weight species S-2. At 800°C sulfur vapor contains circa 97% of S-2 vapor by volume.

The sulfur vapor enters the retort at the bottom, passes through charcoal to produce CS_2 by the main reaction impurities in the charcoal mainly the volatile metters, product by-product gases, which may represent up to 3% of the sulfur fed into the plant.

3- Ureacted Sulfur Separation Stage

The reaction products containing CS_2 and by-products gases pass through sulfur separator (sulfur trap) to reduce elemental sulfur content in the gases. About 1% of the total sulfur entering the vaporizer is separated in this stage and returned to the retort .

4- Condensation Stage

The carbon disulfide is then condensed in the condenser using child water. The uncondensed gases are fed in to absorbers where counter currently flowing mineral oil removes the residual CS_2. The absorbed disulfide is freed from the mineral oil by stripping; the oil is returned to the absorbers for reuse and CS_2 is combined with portion from the condensing system. The condensed CS_2 passes to the daily production tank and then to the storage tank of raw CS_2. In these tanks, the product CS_2 is stored under water to minimize fire risk. The uncondensed gases containing mainly H_2S are directed to react with caustic soda to form sodium hydrogen sulfide*.

5- Purification Stage

In this stage, the raw carbon disulfide is distilled to remove the unreacted sulfur and the traces of hydrogen sulfide. Carbon disulfide of 99.99% purity passes to the storage tank of pure CS_2 and from this tank it is distributed to the consuming sections [9].

THEORETICAL MATERIAL BALANCE

The Reaction equation is:

$$C + 2S \rightarrow CS_2$$

Sulphur required to produce tons/day of CS_2 is:

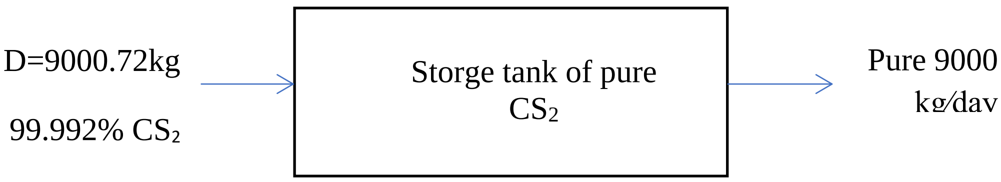
Carbon required to produce tons/day

Where

12, 64, 76 are molecular weights of C, S, CS_2 respectively

PRACTICAL MATERIAL BALANCE

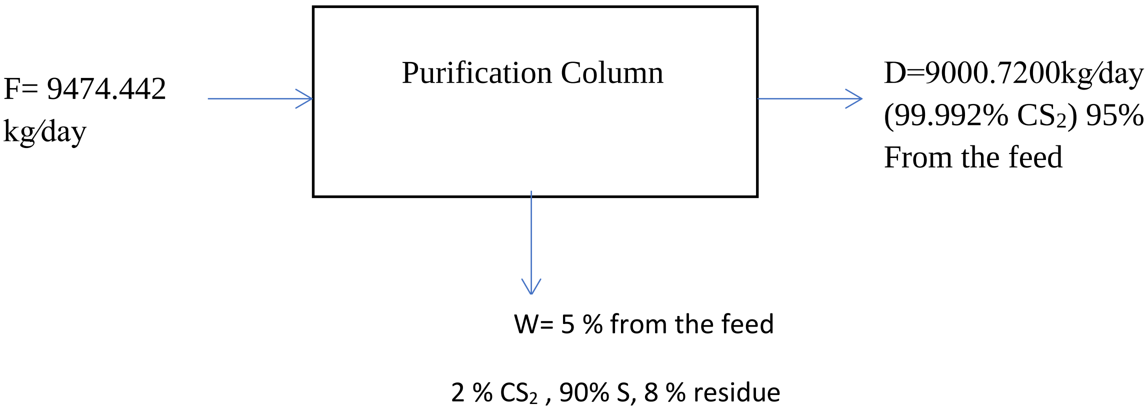
1.Material Balance Around Storage Tank of Pure CS_2



Weight of distillate = 9000.7200 kg/day

WEIGHT OF WATER = 9000.7200- 9000 = O.7200 kg/day

B- Material Balance Around Purification Column



F= 9474.442 kg/day

W = F – D = 9474.44 – 9000.7200 = 473.7219 kg / day

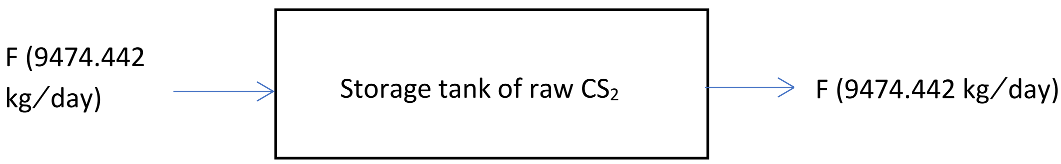
Waste composition:

Weight of CS_2 in W = 2 / 100 * 473.7219 = 9.474438 kg / day

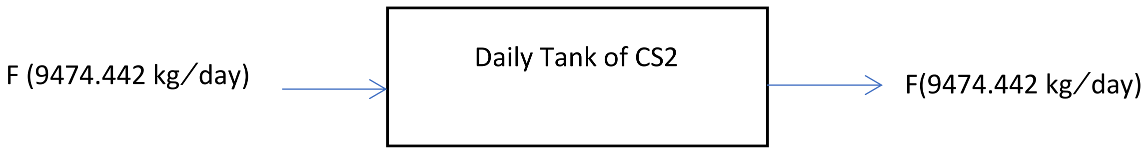
Weight of Sin W = 90/ 100 * 473.7219 = 426.34971 kg / day

Weight of residue in W = 8 / 100 * 473.7219 = 37.8977 kg / day

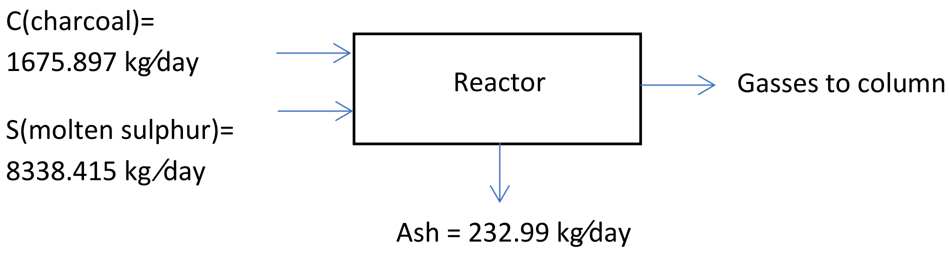
C- Material Balance Around storage tank of raw CS_2



D- Material Balance Around Daily Tank of CS_2



E- Material Balance On Reactor



$$\rho = \frac{P1 * Mwt * Y}{R * T * Z}$$

[6]

Where

: densityρ

z: compressibility factor

P: absolute pressure of the gas

Mwt:Molcular weight

R: Ideal gas constant

T: Temprature (K^0)

Y: mole fraction or volume fraction

N.B Z=1 for all gases because the pressure is about (1atm), i.e. the reduced

Pressure is very low [4]

R = 8312 $Pa.m^3/Kmol.\ K$

P = 102991 N/m^2

Gases out from the reaction:

25%by – pr0duced gases [3]

75% CS_2

Composition of by-product gases:

H_2S 75%vol, CO_3 % vol

COS 10%vol , CO_2 3% vol

N_2 5%vol , CH_4 1% vol , H_2 3%vol

Tota volume of produced gases= 2649.259 m3 ⁄ day

Tota weight of by - produced gases= 261.65 kg ⁄ day

According to the reaction's equations of by-product gases, we can calc amounts of sulphur, carbon, and other components used:

Hence, the total amount of sulphr is

7587.36 kg/day for the main reaction

241.32 kg/day for by-product reactions

426.349 kg/day for in the waste of purification

Total = 8255.03042 kg ⁄ day

The amount of sulphur seperator in the separated forms 1% wt from the amount of sulphur going to the reactor.

: Hence, the amount of sulphur going to reactor = 8338.415 kg ⁄ day

Amount of sulphur separated in the separator = 8338.415 -8255.0304 =83.3846 kg ⁄ day

F- Material Balance of Sulphur Melting, Mixing & Filtratio

The raw sulphurfed to melter contains the following impurities:

Ash content 0.08%

Bituminous 0.2%

Total 0.28%

Raw sulphur fed to the melter = 8361.828 kg ⁄ day

G- Specific Consumptions of Raw Materials

a. SULPHUR

The specific consumption = 0.929 kg ⁄ kg of CS_2

Conversion = 90.89 % kg ⁄ day

b. CHARCOAL

The consumption of charcoal for the main reaction= 1422.632 kg⁄ day

Total = C for the main reaction + C for by products

Total = 1422.632 + 1.8810 = 1424.513 kg ⁄ day

But carbon forms 85% wt (fixed carbon) from the carbon

Amount of charcoal required = 1675.897 kg⁄ day

amount of charcoal without volatile matters

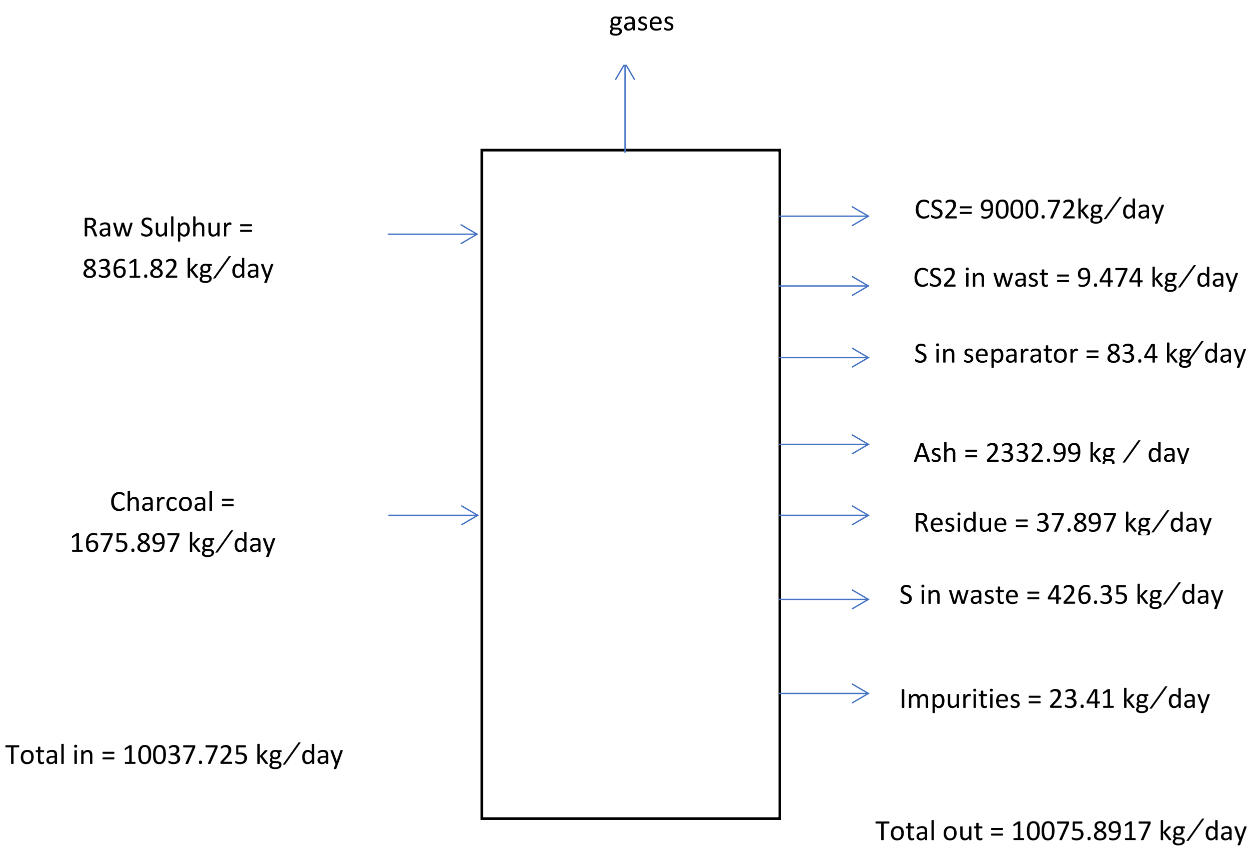
= 1675.85 – (H_2 + O_2 + N_2)

= 1675.85 -18.44 = 1657.45 kg⁄ day

Specific consumption = 0.186211 kg⁄kg CS_2

OVERALL MATERIAL BALANCE

BY – product = 261.65 kg ⁄ day



DESIGN OF PUMP

Pumps are used to transfer fluids from one location to another. The pump accomplishes this transfer by increasing the pressure of the fluid and thereby, supplying the driving force necessary for flow. Power must be delivered to the pump from some outside source. Thus electrical or steam pump. Part of this mechanical energy is added to fluid as work energy, and the rest is lost as friction due to inefficiency of the pump and drive.

Although the basic operating principles of gas pumps and Liquid pumps physical properties of gases and liquid. In general, pumps used for transferring moving parts are necessary for gas pumps because of the lower viscosity of gases and the greater ten dency for the occurrence of leaks.

The different types of pumps commonly employed in industrial operation can be classified as follows:

1. Reciprocating or positive _displacement pumps with value action: piston pumps, diaphragm pumps, plunger pumps.

2. Rotary positive _displacement pumps with no value action:

gear pumps, lobe pumps, screw pumps, eccentric _cam pumps, metering pumps.

3. Rotary centrifugal pumps with no value action: open impeller, closed impeller, volute pumps, turbine pumps.

4.Air-displacement systems: air lifts, acid eggs or blow cases, jet pumps, barometric legs [4].

The Centrifugal Pumps

Generally speaking, the centrifugal pump has these characteristics:

1. Wide capacity, pressure, and fluid characteristics range.

2 Easily adapted to direct motor, V-belt or other drive.

3Relatively small ground area requirements.

4Relatively low cost.

5.Difficult to obtain very low flows at moderate to high pressures.

6Develops turbulent conditions in fluids.

7.Turbine type:(a) offers very high heads at low flows, ((b) self –priming, (c) limited to very clean, non – abrasive fluids with limited physical

properties, clearances can be problem on assembly and maintenance

Estimation Of Pipe Diameter Required

Optimum velocity for liquid=2.4 m/s

Assume mass flow rate = 7590 kg/h

$Q = \frac{G}{\rho}$

Where

G = mass flow rate, kg⁄s

ρ =density of sulfur, kg⁄m3

Q =volumetric flow rate, m3/s

$Q=\frac{2.108}{1780}$ =0.000118 m3⁄s

$A=\frac{Q}{U}$

Where

A=Area of pipe, m2

U=Velocity, m⁄s

$A = \frac{0.0018}{2.4}$ = 0.00075

$di = \frac{\sqrt{4A}}{\pi}$

di = inside diameter of pipe line, m

di = 0.0174m

the optimum diameter for the flow can be calculated using the following equation for carbonate steel pipe

d optimum = 282 G 0.52 ρ − 0.37

= 26.06 mm

This result agrees well with that obtained above [4].

The nearest standared size of pipe = 38.1 mm

Estimation Of Pump Power
Mass flow rate = 7590 kg⁄h

Head = 30 m

Density of sulfur at 150 co = 1780 kg⁄m3 [2]

Capacity = 0.00118m3 ⁄ s

From fig η =36% [7]

Power required = GHg = 2.108 (30)(9.81)= 620.38 W [8]

Where : g is acceleration

Power must be supplied = $\frac{1}{\eta}$ G H g

= 1721.5 W =1.7215 KW

Power required with safety factor

β =1.2 [8]

Power required, P = 1.2 x 1.907 =2.06 KW

CONCLUSIONS AND RECOMMENDATIONS

In this work, physical and chemical properties, specifications, producers and end uses of Carbon Disulfide (CS_2) have been presented. Moreover, all manufacturing processes for carbon disulfide have been discussed and compared .

Comparison of the manufacturing methods shows that Electrothermal Process requires inexpensive source of electrical power. Methane Process requires a nearby source of methane. Moreover, each of these processes enable a higher output of Carbon disulfide and are particularly well suited for industrialized countries which have well-devolved textile industries, etc, and therefore a large CS_2demand.

On the other hand, capacities up to 5 to 15 t/day are available by Charcoal- Sulphur (Retort) Process. In Libya, as in many other countries, textiles are not the main consumer of CS_2, therefore, Retort process can be chosen with any capacity to meet the present and future CS_2 demand.

With this objective in mind, the main concern of this search has been to describe in detail, the process of CS_2 production based on the Retort Process. The capacity of the plant chosen is 9 tons/day. Typical technological calculations for this plant have been made. Moreover, sample design calculations for some important equipments have been accomplished .

Economic calculations performed in this work show that the manufacturing cost of (CS_2) is (3139.9 $) per ton. The economic study also shows that Breakeven point (QBE) and Payback-Period of the plant are (7.5 t/day) and (5.3) years respectively.

Although the values of cost, QBE and Payback - Period

mentioned above are approximately calculated using practical assumptions, data and procedures available in the literature, nevertheless, they are encouraging. Therefore, we recommend that a Retort Process Plant of moderate capacity can be constructed in Libya to meet the Present and future CS_2demand by different consumers .

The site preferred for the plant is that nearer to the big consumers of (CS_2) as well as that in districts where raw materials, mainly sulphur, are available.

REFERENCES

1.Kirk - Othmer Encyclopedia of Chemical engineering Volume 4, Second Edition .

2.(Ulmann's Encyclopedia of Industrial chemistry, Volume A 2 (1994 .

3.Rayon state Co. Hidiyah, Iraq .Practical Data

4.COULSON, J. M. and RICHARDSON, J.F .

5. Chemical Engineering, Volume6, Pergam Press (1984) HOLMAN, J.

6- Heat Transfer, Seventh Edition in SI Units .PERRY, R.H. CHILTON, C.H .Perry's Chemical Engineers Handbook Sixth Edition. McGraw-Hill, 1984 .

7- Max S.Peters Klaus D. Timmerhaus Plant Design and Economics for Chemical Engineers, T Edition

8- PAVLOV, K.F and OTHERS Processes & Equipments of Chemical Engineering. Solved

Problems and Typical Design Calculation .Chemistry.Moscow

9- BLANK,T.L.and TARQUIN,J.A Engineering Economy, McGraw-Hill, Industrial Engineering Series .

10- WARRENL, M, JULIAN, S and PETER, H Unit Operation of Chemical Engineering . Fifith Edition