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REMOTION OF HYDROGEN SULFIDE IN ABSORPTION COLUMN

F. G. M. Porto[1+]
M. L. Begnini[2]
e J. R. D. Finzer[3]

[1,2,3]*University of Uberaba, Chemical Engineering - Uberaba, Minas Gerais, Brazil*

(+ Corresponding author)

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ABSTRACT

Some physical, chemical or electrochemical phenomena that cause the decomposition of a material, usually metallic, they can be defined as corrosion. Analyzing the adverse means and determining its characteristics, several efficient methods can be developed to prevent it, consisting in one of them the absorption of the oxidizing agent. This technique is based on significantly reduce the concentration of the compound. As the hydrogen sulfide corrosive substance, its excessive presence in gas streams intensifies the deterioration of equipment during the contact. The objective was to absorb hydrogen sulfide from biogas. The absorption study was conducted by applying a 5% sodium hydroxide solution. The device designed consisted of a cylindrical packing column, bearing a gas inlet and a distributor at the bottom, which further supports the packing, and a liquid inlet and distributor at the top. The treated gas is released from the top of the column, and the liquid is discharged at the bottom, containing hydrogen sulfide absorbed in the form of salts. In the design, the biogas flow was $15 m^3/h$ with 3% mole hydrogen sulfide and the tower was package with Rasching rings of 1.5 inches. The calculations performed have enabled the design of an absorption column 0.10 m in diameter and 3.00 m height of the packing, causing a loss in pressure of 0.5 cm water/m column.

Contribution/ Originality:

This study contributes in the existing literature to use biogas for energy use and to perform an absorption column design to avoid corrosion by hydrogen sulfide gas. The project was developed for application in a unit installed in a farm in the city of Uberaba in Brazil.

1. INTRODUCTION

Some physical, chemical or electrochemical phenomena that cause the decomposition of a material, usually metallic, can be defined as corrosion. Considering then the corrosion as a spontaneous process, it is often possible to notice the transformation of some material, usually metal, so that affect their performance and endurance, causing problems in use. Research involving corrosive processes are on the rise, since many problems with equipment and facilities are granted to this cause. Some environmental conditions significantly influence the corrosion, such as temperature and pressure. Therefore, knowing the aggressive means and characteristics that cause damage to the

† Corresponding author

materials it is necessary to develop methods which are effective to combat corrosion, as well as the nature of the material to be protected from the corrosive environment. The cost and time for applying the selected method must also be taken into account (Frauches-Santos *et al.*, 2014).

One way to prevent corrosion is the technical absorption of corrosive agent. Known to be a biggest operations in chemical engineering, the absorption is characterized by the transport of substance of a component present in the gas phase to the liquid phase, which occurs because the appropriate properties of a particular solvent, which is then able to solubilize one or more compounds of interest. In this process, the gas molecules are distributed within the liquid, and the movement in the opposite direction is negligible. This operation can be divided into two principal groups: where only one physical processes occur and another in which chemical reactions are part of the process (Leite *et al.*, 2005).

Absorption via chemical reaction has high industrial application, prevailing in the removal of acid gases, inert mixtures and hydrocarbons in gas streams. When applied, this method increases the mass transfer efficiency due to the presence of the reagents. Changing the operating parameters (pressure, temperature, flow) also strictly influences the reaction rate. As hydrogen sulfide (H_2S) is a highly oxidizing agent, present in excess of that substance in gas streams of industrial processes can generate a deterioration of certain equipment corrosion. To mitigate this problem, one may use the absorption of gases so that the concentration of (H_2S) is less than the regulated. In this case, using a caustic solution capable of reacting with the acid through acid-base reaction is an alternative, since the products will be generated soluble salts in the liquid stream. This method has been very effective in industries processing gases containing hydrogen sulfide (Sinnott *et al.*, 2005).

This work aims to scale a gas absorption column with chemical reaction using a caustic solution for the removal of this hydrogen sulfide into biogas that will be used to production of electric energy.

2. THEORY, CALCULATION AND MATERIALS

The equipment used in the gas absorbed consists of a cylindrical column or tower, equipped with a gas inlet and a distributor at the bottom, which also supports the packing, and a liquid inlet and a distributor at the top. The gas, after absorption of solutes, is discharged at the top of the column and the liquid containing the solute that has been absorbed is discharged into the bottom of the column. The equipment is called packed column or tower (tower) Packing, as shown in Figure 2.

In packed columns, the flood point (flooding point) corresponds to the condition when the liquid occupies the entire cross-sectional area of the column. The gas flow must be optimized, but approaches 50% corresponding to the flooding condition (Mccabe *et al.*, 2005).

Figure 1 enables to obtain the pressure loss in packing in inches water/ft packing; μ_0 is the gas superficial velocity in ft/s; is the liquid viscosity in centistokes; Gx and Gy correspond to liquid and gas flows, respectively, and are measured in kg/m^2.s; ρy and ρx is the density in kg/m^3, and Cs is quantified by Equation 1, FP is a pressure loss factor which depends on the geometry and characteristics of the filling (Mccabe *et al.*, 2005).

$$C_S = u_0 \cdot \sqrt{\frac{\rho_y}{\rho_x - \rho_y}} \quad (1)$$

The cross-sectional area of the column can be calculated with Equation 2, being S the cross-sectional area of the column; W and Gy operation, the mass rate and gas flow, respectively, see details of the absorption tower in Figure 2.

$$S = \frac{W}{G_{y\,\text{operação}}} \quad (2)$$

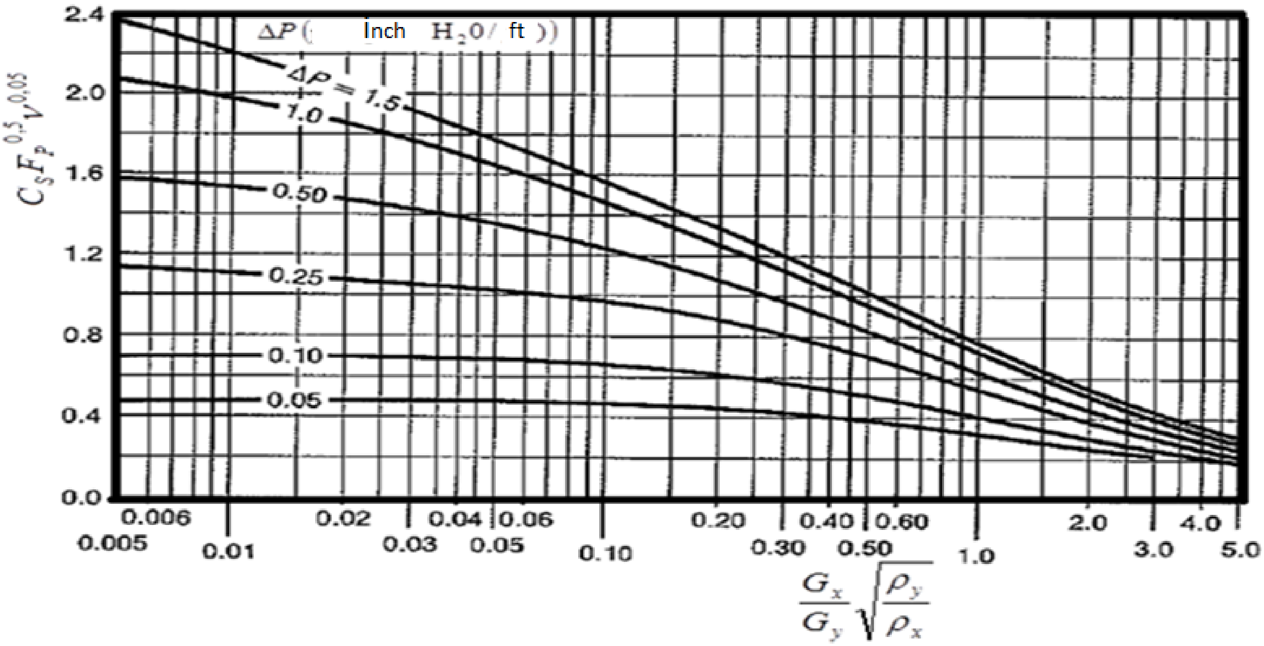

Figure-1. Correlation to widespread flooding and loss of pressure in columns.

Source: Mccabe *et al.* (2005)

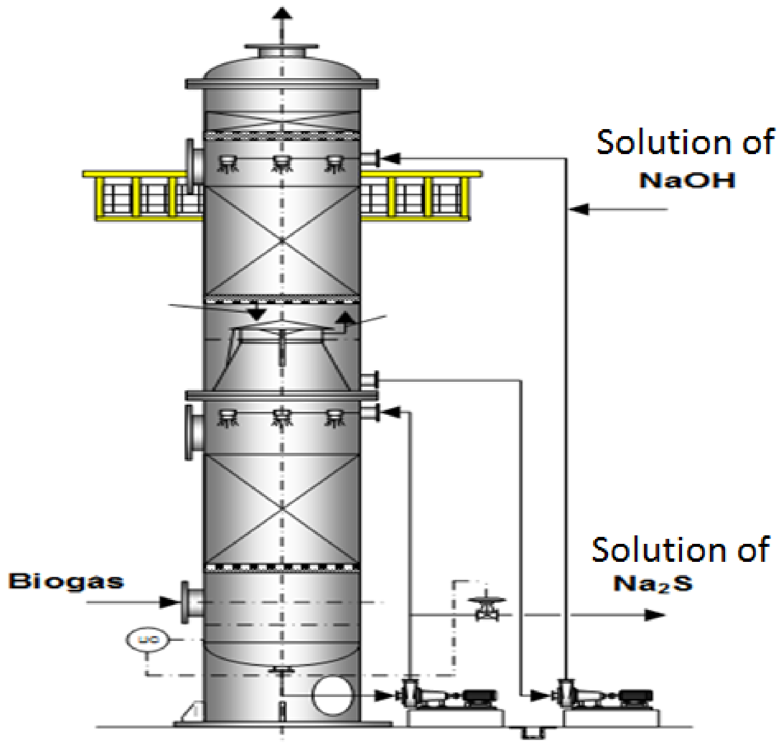

Figure-2. Packing tower details.

The packing height of the absorption column, Zt, is calculated with Equation 3.

$$Z_t = N_{0y} \cdot H_{0y} \tag{3}$$

Where: H_{0y} the height of a transfer unit, obtained in Figure 3 and N_{0y} the number of transfer units, being quantified by Equation 4 as a function of gas flow (G) and liquid (L).

$$N_{0y} = \int_{y_{saída}}^{y_{entrada}} \frac{dy}{y - y^*} \tag{4}$$

Where: y and y* mole fractions of the solute in the gaseous phase and the balance with the absorption liquid.

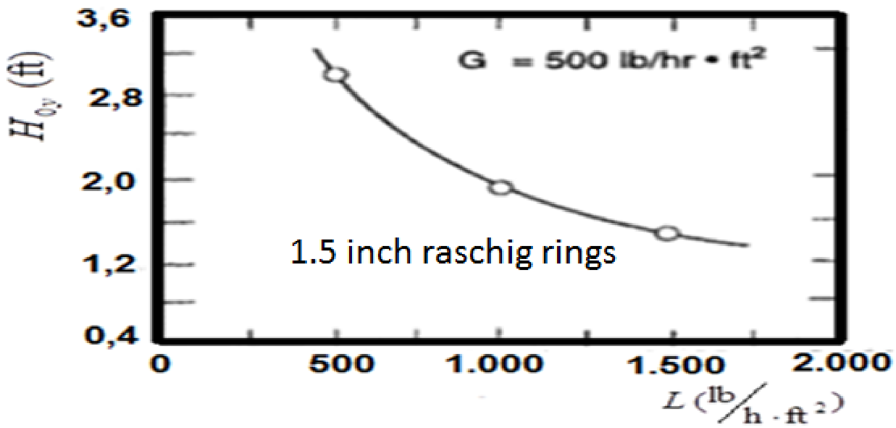

Figure-3. Transfer unit height (Norman, 1962).

Source: Norman (1962)

The pressure drop (inches water/ft packing height) in the flood condition is obtained by Equation 5, where FP = 95 to Raschig rings of 1.5 inches (Mccabe *et al.*, 2005).

$$\Delta P_{inundação} = 0{,}115 \cdot F_P^{\ 0,7} \tag{5}$$

2.1. Production System of Hydrogen Sulfide

This study is part of a biogas system, as shown in Figure 4, a biodigester installed at the farm school at the University of Uberaba - MG. The digester produces 12,5 m³ / h of gas at 3 mol% (3.5% m/m), on average, H_2S, measured at 25 °C and local barometric pressure. It should absorb 99% of hydrogen sulfide.

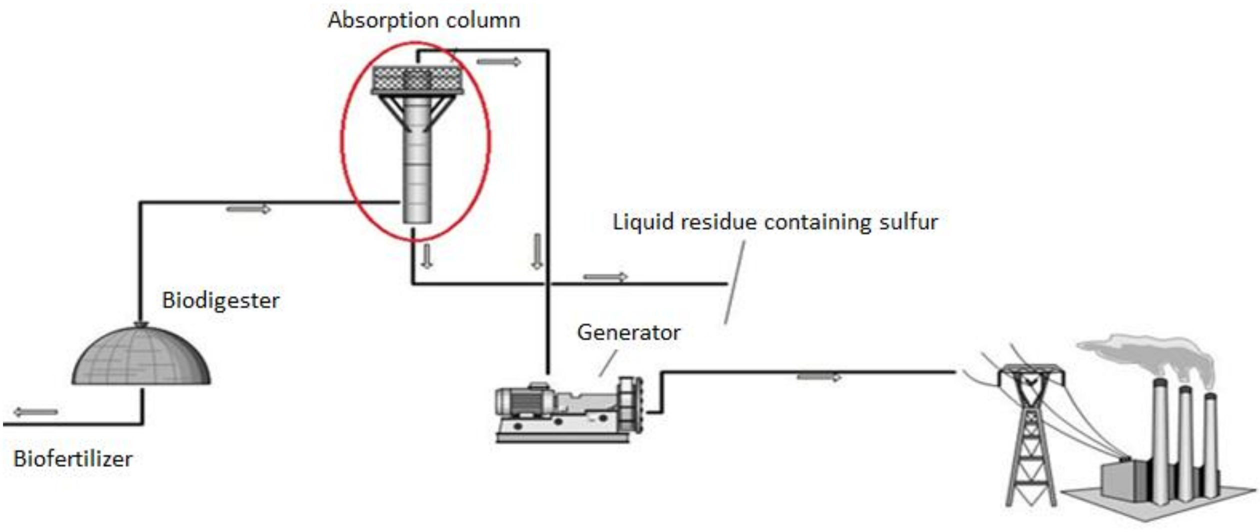

Figure-4. Production system of biogas.

3. RESULTS AND DISCUSSION

3.1. Diameter Absorption Column

For the desing of the absorption column are required stoichiometric parameters used in the design equations. The average molecular weight inlet gas calculated with 3 mol% hydrogen sulfide gas, consisting of 29.15 kg/kmol. The gas density measured at operating conditions using the gas law, is 1.192 kg/m³.

The gas flow rate in the column can be quantified by:

$$W = 12{,}5\,\mathrm{m}^3 / h \cdot 1{,}192\,\mathrm{kg/m}^3 = 14{,}9\,\mathrm{kg/h}\ (32{,}82\,\mathrm{lb/h})$$

The design of the absorption column was performed with use of the operating gas flow 500 lb/hr·ft² used for tower packing with Raschig rings operation of 1.5 inches (Norman, 1962) making it possible to specify the diameter of the column using Equation 2.

$$S = \frac{W}{G_{y\,\text{operação}}} = \frac{32{,}82\,\mathrm{lb/h}}{500\,\mathrm{lb/h}\cdot\mathrm{ft}^2} = 0{,}066\,\mathrm{ft}^2$$

As the column has a cylindrical geometry, calculating the diameter D = 0.300 ft (0.100 m).

3.2. Alkaline Solution Flow Absorption with Chemical Reaction

The amount of hydrogen sulphide in the feed column is obtained the product of the mass rate of gas to be treated by the mass fraction of the current (0.035) consisting of 0.52 kg/hr and the amount of sodium hydroxide is calculated from the stoichiometry of the reaction.

$2\ NaOH + H_2S \longrightarrow Na_2S + 2H_2O$

As the molar ratio is two to one, the theoretical sodium hydroxide charge is 1.22 kg/hr.

However, gases containing carbon dioxide occurs sodium bicarbonate precipitation when the pH is low, and sodium sulfide and sodium carbonate at high pH, but the reactions are slow (Mamrosh *et al.*, 2008). To minimize this effect it selected 20% excess of sodium hydroxide. Thus, the rate of sodium hydroxide to be 1.47 kg/hr and the rate of solution 29.4 kg/hr (64.8 lb/hr) 5% by mass. The solution density is equal to 1054 kg/m3, which allows the calculation of the flow 0.028 m3/h. The solution flow can be calculated:

$$G_x = \frac{64{,}8\,\mathrm{lb/h}}{\pi \frac{0{,}30^2}{4}\, ft^2} = 917\,\mathrm{lb/h}\cdot\mathrm{ft}^2$$

3.3. Column Height

The reaction of hydrogen sulfide with the sodium hydroxide is quite rapid and the balance value with a solution tends to zero, which facilitates mathematical treatment (Mamrosh *et al.*, 2008). Equation 4 allows the calculation of N_{Oy}, simplified the considerations made.

$$N_{0y} = \int_{y\,\text{saída}}^{y_\text{entrada}} \frac{\mathrm{dy}}{\mathrm{y}} = \ln y_{0,0003}^{0,03} = \ln 0{,}03 - \ln 0{,}0003 = 4{,}61$$

The height of the transfer unit is obtained from Figure 3, yielding: H_{Oy} = 1.9 ft and using Equation 3, the column height should be 8.8 ft (2.7 m).

3.4. Pressure Drop in the Column

With Gx and Gy flows, the viscosity of the solution, and the superficial gas velocity 0.44 m/s (1.45 ft/s), calculate C_S = 0.05; the value of the abscissa is measured at 0.052 and:

$$C_S F_P{}^{0,5} \nu^{0,05} = 0{,}05 \cdot 95^{0,5} \cdot 1{,}2^{0,05} = 0{,}5$$

Using Figure 1 is obtained: ΔP = 0,06 inch/water packing foot (0.5 cm water/m). Equation 5 allows to quantify the pressure drop in the flood condition:

$$\Delta P_{inundação} = 0{,}115 \cdot 95^{0,7} = 2{,}8\ \text{inch/water packing foot}$$

The pressure drop in the operation is 2.1% of the pressure drop in the flood, which is in indication of proper functioning of the column and can reduce the size of the packing for improving mass transfer efficiency. The Fp factors for Raschig rings 0.5 and 1.0 inches are 580 and 155, respectively (Mccabe *et al.*, 2005). Equation 5 enables the calculation of the pressure drop in the flooding conditions for the two rings of 0.5 to 1.0 inch equals 9.9 to 3.9 inch of water/foot packing height, respectively.

4. CONCLUSIONS

The study on specification of a gas absorption column to process 12.5 m^3/h of biogas to 3 mol% H_2S resulted in height and diameter 3 m and 0.1 m, respectively, operating pressure loss of 0, 5 cm water/m. The results show that the size of the Raschig rings may be reduced to improve the efficiency of the absorption column.

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