

Natural Gas Sweetening by Wetted-Wire Column

Sarah Taheri, Shahram Ghanbari Pakdehi, Arash Rezaei

Abstract—Natural gas usually includes H_2S component which is very toxic, hazardous and corrosive to environment, human being and process equipments, respectively. Therefore, sweetening of the gas (separation of H_2S) is inevitable. To achieve this purpose, using packed-bed columns with liquid absorbents such as MEA or DEA is very common. Due to some problems of usual packed columns especially high pressure drop of gas phase, a novel kind of them called wetted-wire column (WWC) has been invented. The column decreases the pressure drop significantly and improves the absorption efficiency. The packings are very thin rods (like wire) and as long as column. The column has 100 wires with a triangular arrangement and counter current flows of gas and liquid phases. The observation showed that at the same conditions, the absorption performance was quite comparable to conventional packed-bed towers and a very low pressure drop.

Keywords— H_2S , Natural gas, separation, wetted-wire column (WWC).

I. INTRODUCTION

MANY natural gases contain hydrogen sulfide (H_2S) in concentrations ranging from barely detectable quantities to over 30 mole %. Gases containing H_2S are classified as “sour” and gases free from it are called “sweet”. Natural gas that is transported to the fuel market must meet legal requirements, which specify a maximum H_2S content in the range of 4-8 ppmv. These requirements are justified since H_2S is a toxic gas, also its combustion products are sulphur dioxide or trioxide [1].

The removal of H_2S from natural gas is accompanied by the removal of carbon dioxide (CO_2), if present, since CO_2 has similar acid characteristics. Corollary benefits obtained from the removal of both acid gases from a pipeline stream include decrease in corrosive effects, especially when liquid water is present [2].

H_2S is a flammable, toxic, colourless, malodorous gas that is soluble in water and alcohol. It is a frequent component of high-temperature gases. H_2S may act as an oxidizing agent in the formation of sulfide scales on metal substances at high

temperatures [3]. When dissolved in water, H_2S is a weak acid and therefore corrosive. Hydrogen sulfide is both an irritant and a chemical asphyxiant with effects on both oxygen utilization and the central nervous system. Its health effects can vary depending on the level and duration of exposure. An amine solution is usually used to remove H_2S and CO_2 from natural gas. The acid gas contents are removed through chemical reaction with the amine. After treatment, the natural gas becomes suitable for consumer use or further chemical processing. This process is often referred to as a gas sweetening process, and treated gas is called sweetened gas [2], [4].

In industry, random packed bed columns are usually used for sweetening process and the liquid absorbent is diethanolamine (DEA) or monoethanolamine (MEA), depends on the operation conditions. The advantage of these columns is their high efficiency but the pressure drop of gas phase is a main problem [5]. To solve the problem, an especial kind of arranged packed bed column has been introduced in this study which was called wetted wire column (WWC). The idea of the new column belongs to a group of Japanese scientists who constructed it for the first time [6]. The novel column has efficiency quite comparable to the conventional packed bed column in the same condition with a very low pressure drop. In this manuscript, the column efficiency and pressure drop of gas phase has been evaluated experimentally.

II. EXPERIMENTAL

In the present study, the prototype WWC was constructed by using the idea of Japanese scientists. The column included 2 parts. The upper part is used as the liquid absorbent reservoir and the lower one as gas-liquid contact area for mass transfer. The divider was a thick PMMA (Poly Methyl Methacrylate) plate which included 100 holes. The diameter of these holes was a bit larger than the wires. Since the diameter of the wires was 3mm so after several trial and errors the diameter of the holes was chosen to be 3.4 mm.

The material of the column was glass with 90mm ID and about 1 meter height. The packings are oriented in the tower vertically and fixed to the tower in both sides in triangular arrangement (Fig. 1). The wires were made of stainless steel 316L. The liquid absorbent, which is a solution (25 to 35 wt %) of diethanolamine (DEA), flows down the packings (wires) from the absorbent reservoir like a thin film while the gas mixture goes upward and contact with each other.

The thickness of the plate was about 20 mm so the holes could act as nozzles for wires. To have a better flow of the liquid over the wires and suitable wetting, the holes are drilled

F. A. Chemistry & Chemical Engineering Department, Faculty of Material and Manufacturing Processes, Malek Ashtar University of Technology, Tehran, Iran. (corresponding author; e-mail: taheri_libra@yahoo.com).

Iranian Offshore Oil Company (IOOC), Tehran, Iran. (email: staheri@iooc.co.ir)

S. B. Chemistry & Chemical Engineering Department, Faculty of Material and Manufacturing Processes, Malek Ashtar University of Technology, Tehran, Iran. (e-mail: sh_ghanbari73@yahoo.com).

T.C. Kito Enterprises Company, Tehran, Iran. (email: a.rezaei@kitoenterprises.com)

conically, instead of cylindrically (Fig. 2). In this case, DEA solution flow down from the thin space between the holes and wires. Since the driving force for the liquid flow is the hydrostatic pressure of the reservoir, so to have continuous and steady flow of liquid over the wires, the level of liquid in the upper part should be maintained constant. At the end, the liquid was collected at the bottom of the tower and drained out. To measure the pressure drop, a differential U-type manometer was used. Due to predicted low pressure drop, a low density liquid (iso-Octane) was used.

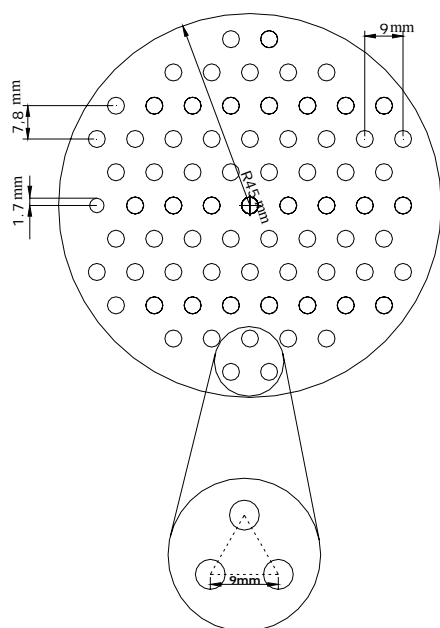


Fig. 1: The geometric arrangement of the wires

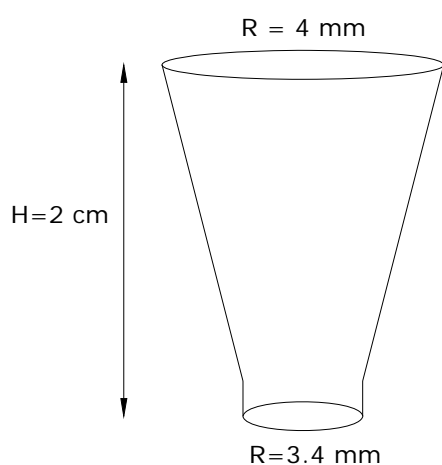


Fig. 2: One drilled conical nozzle through the plate

Fig. 3 illustrates the structure of the prototype WWC. For safety reasons, the chosen concentrations of H_2S were low in gas mixture. As mentioned, the liquid absorbent is 30 wt% of DEA in water. The pressure of the inlet gas was about 1 atm

with the concentration about 50-100 ppm of H_2S . The superficial speed of inlet gas and liquid were between 0-25 cm/s and 0-12 mm/s, respectively. The concentration of H_2S in outlet gas was determined by titration method with standard solution of HCl.

III. RESULTS AND DISCUSSION

To observe the amount of pressure drop in the tower, the liquid entered the tower with the speed of about 6 mm/s. The superficial gas velocity was 0-25 cm/s. The differential manometer showed the pressure drop (Fig. 4). It is observed that the pressure drop is longitudinal and it has been compared with the pressure drop of the packed tower at the same conditions. The packings were $\frac{1}{2}$ -in Raschig rings.

Since the measurement of low speeds of gas was very difficult, the measurement of pressure drop performed in speeds of more than 5 cm/s.

According to figure 4, in all speeds of the gas stream, the pressure drop of WWC is less than the packed bed tower. It is observed that, the pressure drop of WWC is approximately about one-third of the packed tower. Random order of packings prevents gas stream to pass easily through the tower so the pressure losses. Packed towers with arranged packings (like WWC) have always less pressure drop than random ones. It especially becomes noticeable when the flow rate of gas stream is high.

Since a chemical reaction occurred in the liquid phase between H_2S and DEA, so the mass transfer resistance in liquid phase became negligible and the total mass transfer resistance would be in gas phase.

The amount of H_2S separation, as a criterion of tower performance, is obtained from the tower efficiency; η is defined as follow [7]:

$$\eta = \frac{y_b - y_t}{y_b - y_s} \quad (1)$$

Where:

η = column's efficiency

y = mole fraction of H_2S ,

Subscripts "b" and "t" stand for the bottom and top of the tower, respectively. Subscript "s" denotes the saturation of water with H_2S .

Since there is a chemical reaction in liquid phase, the saturated concentration of H_2S in water, compare with the H_2S concentration at the bottom of the tower, is approximately negligible. Therefore the equation 1 is simplified to:

$$\eta = \frac{y_b - y_t}{y_b} \quad (2)$$

Fig. 5 shows experimental results of the new tower in the range of 0-12 mm/s for the superficial velocity of the liquid absorbent (v_L) and 14, 17, 21, 24 and 28 cm/s for the superficial velocity of the gas stream (v_G).

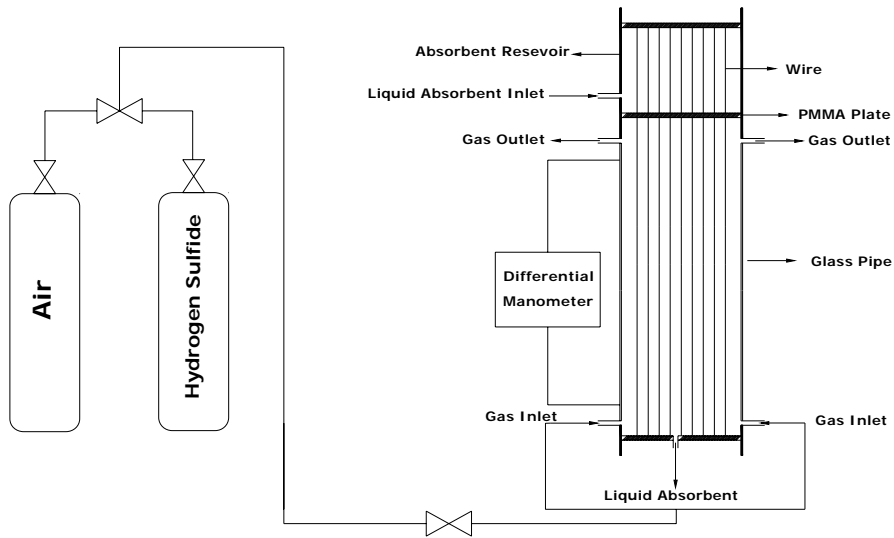


Fig. 3: Prototype WWC equipped with 100 wires.

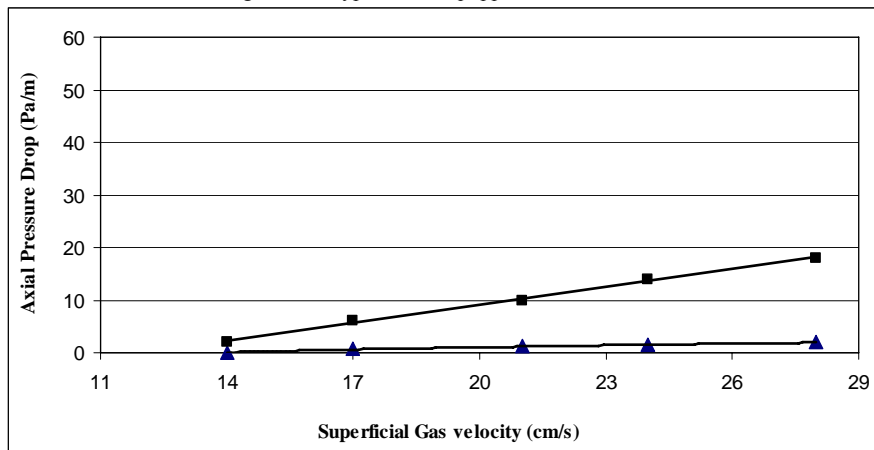


Fig. 4: Comparison of pressure drop between WWC and packed tower at 8 mm/s of liquid velocity (-■-Packed tower and -▲-WWC)

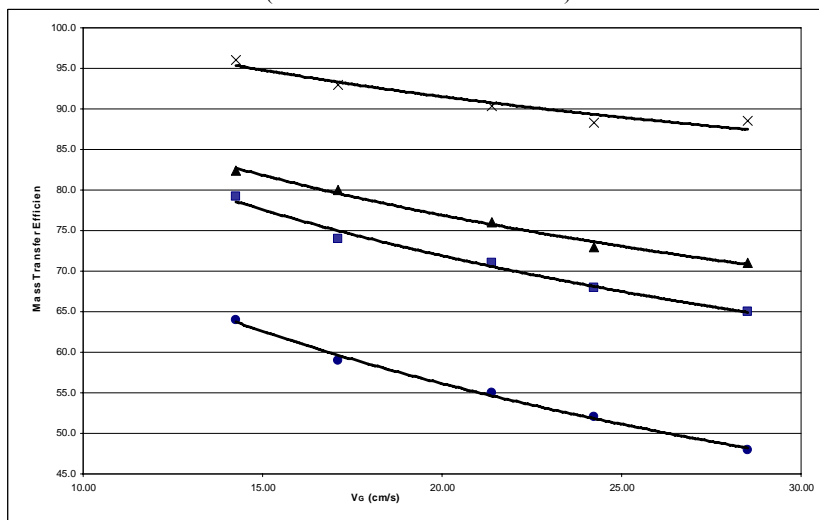


Fig. 5: Absorption efficiency of air-H₂S mixture with absorbent of DEA solution in different liquid velocities, v_L (6 mm/s -●-, 8 mm/s -■-, 10 mm/s -▲- and 12 mm/s -x-)

According to figure 5, for each level of v_L , H_2S absorption and therefore absorption efficiency decrease, while v_G increases. It is due to the fact that when v_G increases the contact time between gas and liquid decreases and there would not be enough time for gas-liquid contact.

Also it is observed that at constant v_G , the absorption efficiency increases when v_L increases. It is because of the fact that when v_L increases, the contact area and therefore the mass transfer efficiency increases.

IV. CONCLUSION

Packed bed towers have been usually used for natural gas sweetening. Despite their high gas absorption efficiency, their only problem is the high pressure drop. This problem becomes noticeable when the system is supposed to remove toxic gases from a gas mixture (such as H_2S). To solve the problem, the WWC has been invented. In this study, WWC was constructed in laboratory scale and used to remove H_2S from natural gas. The results showed that the pressure drop of the tower is about one third of packed tower and above all, it has an absorption performance quite comparable to conventional packed-bed towers. It was observed that, increasing in v_L and v_G led the absorption efficiency of the column to increase and decrease, respectively.

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REFERENCES

- [1] Branan C., (1990), *Rules of Thumb for Chemical Engineers*, pp. 188, Gulf Professional Publishing, USA.
- [2] Katz D. L., D. Cornell, Vary J.A., Kobayashi R., Elenbaas J.R., Poettmann F.H., Weinaug C.F., (1959). *Handbook of Natural Gas Engineering*, pp. 612, Mc Graw-Hill Book Company, New York.
- [3] Fontana M. G., Greene N. D., (1984), *Corrosion Engineering*, pp. 374, Mc Graw-Hill Book Company, New York.
- [4] Greenwood, N. N.; Earnshaw, A., (1997), *Chemistry of the Elements*, 2nd Edn., Oxford: Butterworth-Heinemann.
- [5] McCabe, W., Smith, J. and Harriott, P., (2004), *Unit Operations of Chemical Engineering*, 7th Edition, McGraw Hill.
- [6] Migita H., Soga K., and Mori Y. H., (2005), Gas absorption in a wetted-wire column, *AIChE J.* Vol. 51, pp. 2190-2198.
- [7] Treybal R. E., (1980), *Mass-Transfer Operations*, 3rd ed., McGraw-Hill Book Company.