MINIMUM GAS FLOW RATE IN A COUNTERCURRENT ISOTHERMAL GAS STRIPPER

A. SILVA , C. CASTILLO and J. H. KRASUK*

Departamento de Termodinámica y Fenómenos de Transporte, Universidad Simón Bolívar, Sartenejas, Baruta, Edo. Miranda, Apdo. Postal No.89000, Caracas, Venezuela

Abstract **-- It is presented an analytical expression for the minimum gas flowrate required for the design of an isothermal countercurrent gas stripper, when Henry´s law (H > 1) applies and the gas and liquid streams are concentrated in the soluble gas of the binary gas mixture. This solution allows for a faster and more accurate result, for $(G_B)_{min}$, than the graphical procedure presently in use.**

Key Words **– Stripping – Absorption – Separation – Isothermal - Mass Transfer - Minimum Gas Flow**

* Autor to whom correspondence should be addressed

I. INTRODUCTION

One of the first steps in designing an isothermal gas stripper is to calculate the minimum gas flow rate, which satisfies the given specifications. The graphical procedure currently used when dealing with concentrated gas mixtures, consists in employing a Y, X plot, where these are molar ratios or "molal stoichiometric units" (Sherwood et al., 1975) in the gas and liquid phase, respectively. The advantage of using this type of diagrams is that the operating line is a straight line that permits, from its slope, a direct calculation of $(G_B)_{min}$.

The case here considered is the design of an isothermal gas stripper, for highly concentrated binary mixtures, when Henry´s Law applies.

There are several gas/liquid systems of industrial interest that still follow Henry´s law when the gas mixtures are concentrated in the soluble gas; some examples are hydrogen in organic liquids and petroleum cuts (Birthler et al., 1963; Chao et al., 1981; Alessi et al., 1996; Battino and Clever, 1996; Luhring and Schumpe, 1989; Herskovitz et al., 1983; King and Najjar, 1977), carbon monoxide in organic liquids (Luhring and Schumpe, 1989), carbon dioxide in water (Perry, 1963), in organic liquids (Luhring and Schumpe, 1989) and bitumens (Lal et al, 1989) and hydrogen sulphide in hydrocarbons (Lal et al., 1989). Practically all theses systems have a Henry´s constant higher than unity and therefore, as demonstrated in Section II, show an equilibrium curve which is concave upward in the Y, X diagram.

In a Y, X plot, when the equilibrium line is concave downward and Henry´s Law applies, as is the case for H<1 as demonstrated in Section II, the solution for the inert molar ratio $(L_B/G_B)_{max}$ is straight forward:

$$\left(L_B / G_B\right)_{max} = \left(Y_2^* - Y_1\right) / \left(X_2 - X_1\right) \qquad (1)$$

In the stripper design case all molar ratios in Eqn. 1 are specified except Y^*_2, but this is given by:

$$Y_2^* = y_2^* / \left(1 - y_2^*\right) \qquad (2)$$

where $y^*_2 = H.x_2$ can be obtained from Henry´s Law; consequently, Eqn. 1 allows the direct calculation of the $(L_B/G_B)_{max}$ ratio without any need of performing a Y, X plot for the isothermal stripper of concentrated gas mixtures when Henry's law applies and H<1.

The case we are dealing with is a countercurrent isothermal stripper for concentrated gas mixtures when H>1, which applies to most of the above indicated gas/liquid systems of industrial interest. In this situation the equilibrium curve is concave upwards. Fig. 8.11 in (Treybal, 1980) shows how the graphical procedure, mostly used at present to get $(G_B)_{min}$, is employed. This is also shown in present Fig. 3. From the point Y_1, X_1, which corresponds to the dilute bottom of the stripper, in the Y, X diagram, the operating line is drawn tangential to the equilibrium line. This determines the point Y_M, X_M and the slope of this tangent gives $(L_B/G_B)_{max}$ from which $(G_B)_{min}$ is obtained.

The present development allows the direct calculation of $(G_B)_{min}$, for such case, without any graphical procedure.

II. RANGE OF VALUES OF HENRY'S CONSTANT

Here it is discussed the range of values of Henry´s constant to obtain an equilibrium curve with upward or downward concavity in a Y, X plot. Henry´s Law applies:

$$y = Hx \qquad (3)$$

Substituting Y, X in Eqn. 3 results:

$$Y = H\,X / \left(1 + X\left(1 - H\right)\right) \qquad (4)$$

Since Y and X can not have negative values Eqn. 5 and Eqn. 6 must hold:

$$Y > 0 \qquad (5)$$

$$X > 0 \qquad (6)$$

Consequently, for Eqn. 5 to be true, since H is always positive,

$$1 + X\left(1 - H\right) > 0 \qquad (7)$$

and the following expressions hold :

$$H < 1 \qquad X > 0 \qquad (8)$$

$$H > 1 \qquad 0 < X < 1/\left(H - 1\right) \qquad (9)$$