CHAPTER 1

INTRODUCTION

1.1 General

Adsorption describes any process where molecules of a gas, liquid, or dissolved solid adhere to a solid surface. Adsorbents may be divided into two classes; *viz*., physical adsorption and chemical adsorption –chemisorption- where a chemical reaction takes place between the surface and the adsorbate [1]

Dehydration of natural gas is the process of removing water vapor from the gas stream to lower its dew point. Water is the most common contaminant of hydrocarbons.

Water is always present in the gas-oil mixtures produced from wells. The dew point is defined as the temperature at which water vapor condenses from the gas stream. The sale contractors of natural gas specify either its dew point or the maximum amount of water vapor present. [2]

There are three basic reasons for the dehydration of natural gas streams; namely,

1- prevent formation of hydrates and condensation of free water in processing and transportation facilities,
2- meet a water content specification, and
3- prevent corrosion.

Techniques for dehydration of natural gas, associated gas, condensate and natural gas liquids (NGLs) include,

1- absorption using liquid desiccants,
2- adsorption using solid desiccants,
3- dehydration with $CaCl_2$,
4- dehydration by refrigeration,
5- dehydration by membrane permeation,
6- dehydration by gas stripping, and
7- dehydration by distillation.

Pressure swing adsorption (PSA) is a process where adsorption takes place at high pressure and desorption at low pressure. The pressure energy is better utilized. The regeneration effect of the purge stream depends on its volume rather than on its mass, so only a fraction of the high pressure effluent about 20% is needed for effective regeneration.

The original aim of this process was to separate oxygen and nitrogen from air. With the range of adsorbents then available, neither process was particularly successful for that application. [3]

This study is focused on the modeling of two case studies: (i) the first is adsorptive natural gas drying using molecular sieves, and developing the model of the mass transfer in fixed bed, and (ii) the second is nitrogen separation process from air by pressure swing adsorption (PSA). These developed models are tested using data obtained from Amerya LPG Recovery Plant of Egyptian Natural Gas Company (GASCO).

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1.2 Objectives

1. To study the adiabatic adsorption and PSA process in gas processing field.
2. To develop a mathematical model to describe those industrial processes.
3. To solve the model using MATLAB.
4. To compare the results obtained from the mathematical model with the actual data collected from the Egyptian Natural Gas Company (GASCO).

It should be noted here that in the first case, adsorption of water vapor from natural gas using zeolite molecular sieves is studied and model validation is run. Prediction of the breakthrough time and the general equations for breakthrough time at different inlet concentrations of water vapor in natural gas at different gas velocities were established. In the second case, production of pure N_2 gas from air by PSA on carbon molecular sieves and the effect of feed air velocity on N_2 purity were predicted.

1.3 Contributions and Significance

1.3.1 Contributions

- Similar mathematical models were applied earlier on the laboratory scale only over smaller intervals of time. In the present work, the model is applied on an industrial scale of gas processing for 48 hours.
- The model has been shown to be capable of predicting the practical mass transfer zone and breakthrough curves at different feed velocities and different inlet concentrations of water vapor in natural gas.
- The breakthrough curves indicate that increasing the adsorption time in the plant result in decreases the fuel gas consumption used in direct fired heater in heating step. This should reduce the electric power used in operating the compressor, air coolers and blowers used in the regeneration cycle.
- The present study shows the possibility of improving the adsorption cycle to reach the optimum time for adsorption.

1.3.2 Significance

1. For the dehydration step the equation obtained by:

   $$t_b(h) = -6708 \ln(u_s) + 1187.9$$

   Sensitivity analysis can be used to calculate the value of u_s (linear gas velocity) that will give a breakthrough time of 200 hours at 1.1587 m/s (430%). So the obtained equation can be used to increase the production rate of dehydrated gas (which has an average inlet dew point of 35 ppmv and an average outlet dew point of (0.09 ppmv)

2. For the PSA unit by sensitivity analysis the following equation was obtained:

   $$N_2 \text{ (mole \%)} = -51.35\, u_s + 99.13$$

   By using N_2 mole % = 95 (which the minimum acceptable concentration, the value of u_s 0.1317 m/s) the obtained value of us will give 460% increase in the production rate of N_2.