Purification and Dehydration of Natural Gas using Membrane Processes

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Abstract—*Natural Gas (NG) is one of the major sources of energy and its apt exploitation for economic development is of high importance, pertaining to its wide usage as a fuel. The Natural Gas is purified of some unwanted materials (sulfur and nitrogen contents, carbon dioxide and water) up to certain amounts before use, as they are responsible for harmful emissions into the atmosphere, corrosive in nature and lower the heat value of the gas. One of the most efficient and feasible approach to the purification and dehydration of NG is using gas separation membranes which are thin layers of polymeric (organic) and inorganic materials. Membrane technology for separation of materials from NG has been a subject of research in the past and still goes on to be one. It has gained acceptance in industrial use due to its technical superiority, low cost involved, less weight and space requirement and ease of operation. The degree of membrane selectivity and permeability drives the efficiency of separation.Though the polymeric membranes are biodegradable and non-toxic in nature, possess mechanical strength and are economically feasible, they are limited by a tradeoff between high permeability and selectivity and show thermal instability. The inorganic membranes on the other hand display superior gas separation properties, have higher thermally and chemical stability, but are fragile and involve higher costs and are economically less feasible than the organic ones. In this paper, we present a review of the membrane processes that are used for the purification and dehydration of natural gas.*

Keywords*: Natural gas purification, natural gas dehydration, gas separation, membrane processes*

1. INTRODUCTION

Natural gas is called the "Princess of Hydrocarbon" and is the fastest growing energy source in the world. The composition of natural gas depends upon its source. The major component is methane(75%-90%), but natural gas also contains significant amounts of propane, ethane, butane and small amounts of other higher hydrocarbons. It is used in the form of CNG in transportation, for cooking, as a raw material for Petrochemicals and Fertilizer industries and is also used in many commercial areas like generating electricity [1, 2].Lately, there has been a focus on research in the natural gas fieldas the presence of high component of methane in natural gas contributes for the productionof other potential products such as syngas and high purity hydrogen.(3)

Along with methane and other hydrocarbons, natural gas also contains contaminants such as water vapor, CO_2, N_2, H_2S, etc. Therefore, natural gas must be purified of these impuritiesto account for a "clean" fuel and meet the pipe-line quality standard specifications as a consumer fuel, enhance the calorific value of the natural gas and avoid pipelines and equipment corrosion. CO_2 is the largest contaminant and an acid gas thatcauses corrosion to the equipment. Also it reduces the heating value of natural gas and imposes unnecessary transportation cost. Moreover, CO_2 is a major contributor to global warming. Hence, CO_2 should be removed from natural gas to improve the quality of the product before delivery to the pipeline(2, 3, 4, 5).

Membranes are now being used increasingly in industry for gas separation due to their intrinsic energy efficiency [6].

2. MEMBRANE MATERIALS

Membrane is a semipermeable barrier that allows the selective passage of one or more species in a gas and/or liquid mixture solution under certain driving force. These driving forces are concentration, pressure and electrical potential across the membrane [1].

The types of membranes available comprise of organic (polymeric and biological) and inorganic (metallic and ceramic) systems. The essential features taken into account for effective operation are the permeability and selectivity of membrane. High permeability and high selectivity are desirable as they account for lower membrane area and high efficiency of the separation process, respectively. Organic membranes are further classified as porous and non-porous depending on the flux density and selectivity. Porous membranes contain inter-connected pores with a random distribution and are highly voided and rigid. Nature of permeate, size of the pores and their distribution and the membrane polymer size determine the separation effectiveness of these membranes. Thin membranes which are elastomers having cross-linked copolymers show unique permeability for CO_2 coupled with high selectivity towards CH_4, N_2, O_2 and H_2. There exists a tradeoff between permeability and selectivity in polymeric membranes. Though the polymeric membranes are cheap and reproducible, they are structurally weak, prone to chemical degradation and are thermally instable, and hence cannot be used in gas separation at high temperatures. Inorganic membranes are also subdivided into porous and non-porous (dense) membranes. They include ceramic membranes like silica and alumina and dense metal oxide membranes among others. The gas separation in inorganic membranes is a function of membrane material, size of the pores and their distribution and the interaction between the membrane and diffusing gases. Inorganic membranes possess a technical superiority over the polymeric membranes- they are chemically and thermally stable. They are however, expensive [1, 3, 4].

The most recent membrane technology developed is that of the mixed matrix membrane (MMM); it consists of a polymer bulk phase and a dispersed phase of inorganic molecules like zeolite, carbon molecular sieves or nano-size particles. They have the capability for higher permeability and selectivity than the polymer membranes due to the superior separation characteristics provided by the addition of the inorganic molecules. Also, the fragility associated with the inorganic membranes can be efficiently taken care of by using a flexible polymer as the continuous matrix [5].

3. GAS SEPARATION

Presence of water vapor in the natural gas reduces its heating value and its presence in a gas leads to the formation of ice-like crystals called hydrates which may block pipelines. The use of membranes in the dehydration of Natural Gas is a recent technology with only a few of the onshore installations in use, which leaves scope for research to be conducted in this area of natural gas purification. Membrane technology proves to be superior to the conventional TEG plants in NG dehydration as firstly, it is environment friendly with no emissions, secondly it does not require the use of any solvent and thirdly it reduces the size and weight of installations [5, 7].

There are four fundamental transport membrane separation mechanisms: 1. Poiseuille flow 2. Knudsen diffusion 3. Molecular sieving 4. Solution-diffusion[1].

Water vapor gets removed from membranes which have selective permeability to it. One of such processes involves a porous membrane carrying a hygroscopic agent. The permeation of gas through pores is determined by Knudsen flow or diffusion. A great advantage associated with this method is that continuous operation is possible [9].

Permeation is a rate-controlled process and separation is characterized by the selectivity of membrane at the conditions of separation, includingflow rate, pressure, temperature, and area of membrane. The permeate molecules in a dense polymeric membrane, under the influence of pressure and concentration gradient, diffuse through the polymer matrix. Separation of CO_2 with common polymeric or inorganic (e.g. zeolite, sol–gel silica or carbon molecular sieve) membranes is achieved by the varying diffusion rates and/or degree of adsorption of mixture components in the polymer matrix or the inorganic membrane pores[1].

Nitrogen is another contaminant in natural gas that is difficult to remove. Cryogenic distillation is the conventional process that is used to remove nitrogen from natural gas. Due to high complexity and high costs involved, the cryogenic pants are not used widely. Separation of nitrogen from methane for natural gas processing by using nitrogen-selective membrane made from polyacrylonitrile has been reported with high nitrogen/methane selectivities. High nitrogen/methane selectivity has also been observed by using silicone rubber membranes at low temperatures [10].

4. CONCLUSIONS:

The adoption of membrane technology for dehydration and purification of natural gas is a more suitable option than the conventional methods in use, as it provides improved process ability and higher flexibility. Membranes are a potential option for gas separation in remote offshore locations due to their light weight. This technology spares the laborious and costly task of constructing and operating large dehydration installations. It does not involve emissions of harmful gases into the atmosphere during natural gas purification, and hence is environment friendly.

Thus, membrane technology proves to be an effective gas separation tool in the purification and dehydration process of natural gas that can be economically exploited and worked upon in different locations yielding satisfactory results.

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