PERFORMANCE OF LOCALLY MANUFACTURED HOLLOW-FIBER MEMBRANE FOR CO_2 SEPARATION

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ABSTRACT

Hollow fiber membrane is the latest and advanced gas separation technology currently employed in the gas industries. Malaysia which is rich in natural resources has huge natural gas reserves amounting to more than 5 Trillion Standard Cubic Feed (5 TSCF). Membrane Research Unit has produced a hollow-fiber module by using a locally made spinneret which is capable of producing hollow fiber membranes using a wet-spinning method. This module contains hollow fiber membranes with surface area of 72.22cm^2. The module is utilised in the existing membrane gas separation pilot plant (MGSPP) for performance test. The performance of this module was based on its permeation rate and selectivity for each pure gases tested namely N_2, CO_2 and O_2. Based on the result obtained the module has the capability to separate CO_2 from natural gas, helium recovery in Enhanced Oil Recovery (EOR), nitrogen and oxygen recovery in the production of urea.

INTRODUCTION

In order to apply membranes on a commercial scale, large membrane areas are normally required. The smallest unit into which the membrane area is packed is called a module. The module is the central part of a membrane installation [1] .The simplest design is one in which a single module is used. Figure 1 below gives a schematic diagram of such a single module system.

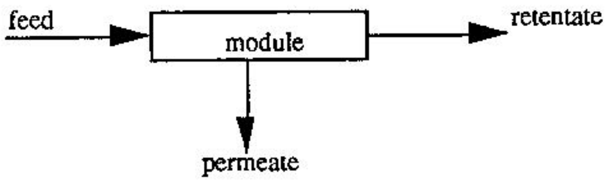

Figure 1 : Schematic drawing of a module

A feed inlet stream enters the module at a certain composition and a certain flow rate. Because the membrane has the ability to transport one component faster than the other, both the feed composition and the flow rate in the feed stream the module will change as a function of distance. The feed inlet stream is separated into two streams, i.e. a permeate stream and a retentate stream. The permeate stream is the fraction of the feed stream which passes through the membrane whereas the retentate stream is the fraction retained.

Different module configuration designs are possible and which are based on two types of membrane geometry : (i) flat; and (ii) tubular. Plate-and-frame and spiral-wound modules involve flat membranes whereas tubular, capillary and hollow fiber modules are based on tubular membrane configurations. The difference between the latter types of module arises mainly from the dimensions of the tubes employed, as is shown in Table 1[1].

configuration	diameter(mm)
tubular	>10.0
capillary	0.5 - 10.0
hollow fiber	<0.5

Table 1 : Approximate dimensions of tubular membranes

If tubular/hollow fiber membranes are packed close together in a parallel fashion than the membrane area per volume is only a function of the dimensions of the tube.

The membranes are self-supporting . Two types of flow arrangement can be distinguished (1):

(i) The feed solution passes through the bore of the capillary (lumen) whereas the permeate is collected on the outside of the capillaries ("inside-out")

(ii) The feed solution enters the module on the shell side of the capillaries (external) and the permeate passes into the fiber bore ("outside-in").

The choice between the two concepts is mainly based on the application where parameters such as pressure, pressure drop, type of membrane available, etc. are important. Depending on the concept chosen, asymmetric capillaries are used with their skin on the inside or on the outside.

Hollow fiber module

The hollow fiber module is the configuration with the highest packing density, which can attain values of 30,000 m2/m3 (1). The hollow fiber module is used when the feed stream is relatively clean, as in gas separation and pervaporation. Hollow fiber module have also been used in the case of sea water desalination, another relatively clean feed stream. The module construction is given in Figure 2. In gas separation the module will be of the "outside-in" type to avoid high pressure losses inside the fiber.

The choice of the module is mainly determined by economic considerations. This does not mean that the cheapest configuration is always the best choice because the type of application is also very important. In fact the functionality of a module is determined by the type of application.

METHODOLOGY

The hollow fiber membranes were produced by a locally made spinneret using a wet spinning method[1]. The hollow fiber module consists of a large number of membranes assembled together in a module as shown schematically in Figure 3. The free ends of the fibers are potted with an epoxy resins.

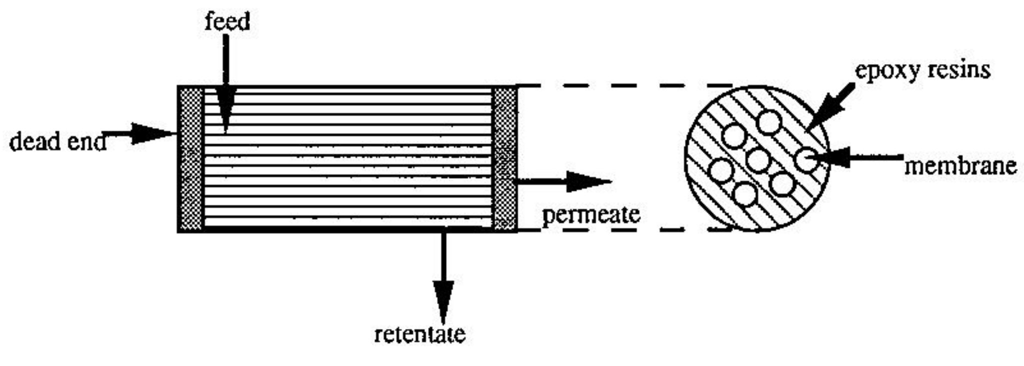

Figure 3 : Schematic drawing of a hollow fiber module , "outside-in" type

These modules were tested using the Membrane Gas Separation Pilot Plant using three pure gases namely; N_2, CO_2 and O_2. The effect of pressure on permeability was analyzed. The permeability and selectivity of the modules was calculated for different gases.

RESULTS AND DISCUSSION

The permeabilities of gases (N_2, O_2, CO_2) are shown in Table 1,2,3 respectively. The data was plotted and shown in Graph 1,2,3 for the dependent of permeability on pressure. Typically for all the three gases, it show a similar trend where its permeation rate increased with feed pressure. The ideal selectivity of O_2 and CO_2 to N_2 are given in Table 4 as a function of feed pressure. The permeability and selectivity for a commercial membrane module for N_2, O_2, CO_2 are shown in Table 5 [3]. The results show that the performance of the locally made hollow fiber membrane module. Its performance was based on the permeation rate and the selectivity.

CONCLUSIONS

The locally made hollow fiber membrane module produce shows a good quality in terms of its permeation rate and selectivity. Based on the above results, this module is recommended in the removal of CO_2 from natural gas, air separation etc.

REFERENCES

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2. Design and Manufacture of Hollow Fiber Membranes for Gas Separation, H.Saidi, R.Abd. Aziz, H.Hassan, A.Ariffin, Seminar Penyelidikan dan Perundingan, Unit Penyelidikan dan Perundingan Universiti Teknologi Malaysia, Hotel Selesa, Pasir Gudang, Johor Bahru, 28 & 29 Ogos, 1993.
3. Arisaka et al. U.S Patent 4,127,625 Nov. 28, 1978.

Table 1 : Permeability of Hollow-Fiber Membrane Module for N_2

Pressure (psi)	Permeation rate (cm3/cm3.sec.cmHg)
5	0.0000056084
10	0.0000068866
15	0.0000080318
20	0.000008472
25	0.000008081
30	0.0000088081
35	0.0000086552
40	0.0000093756
45	0.0000100204
50	0.0000098111

Table 2 : Permeability of Hollow-Fiber Membrane Module for CO2

Pressure (psi)	Permeation rate (cm3/cm3.sec.cmHg)
5	0.000005561
10	0.0000069772
15	0.0000068579
20	0.0000072784
25	0.0000077907
30	0.0000077226
35	0.0000086292
40	0.0000087573
45	0.0000087311
50	0.0000091055

Table 3 : Permeability of Hollow-Fiber Membrane Module for O2

Pressure (psi)	Permeation rate (cm3/cm3.sec.cmHg)
5	0.0000072781
10	0.0000074089
15	0.0000074715
20	0.0000073795
25	0.0000081148
30	0.0000072347
35	0.0000068746
40	0.0000083528
45	0.0000086696
50	0.0000092841

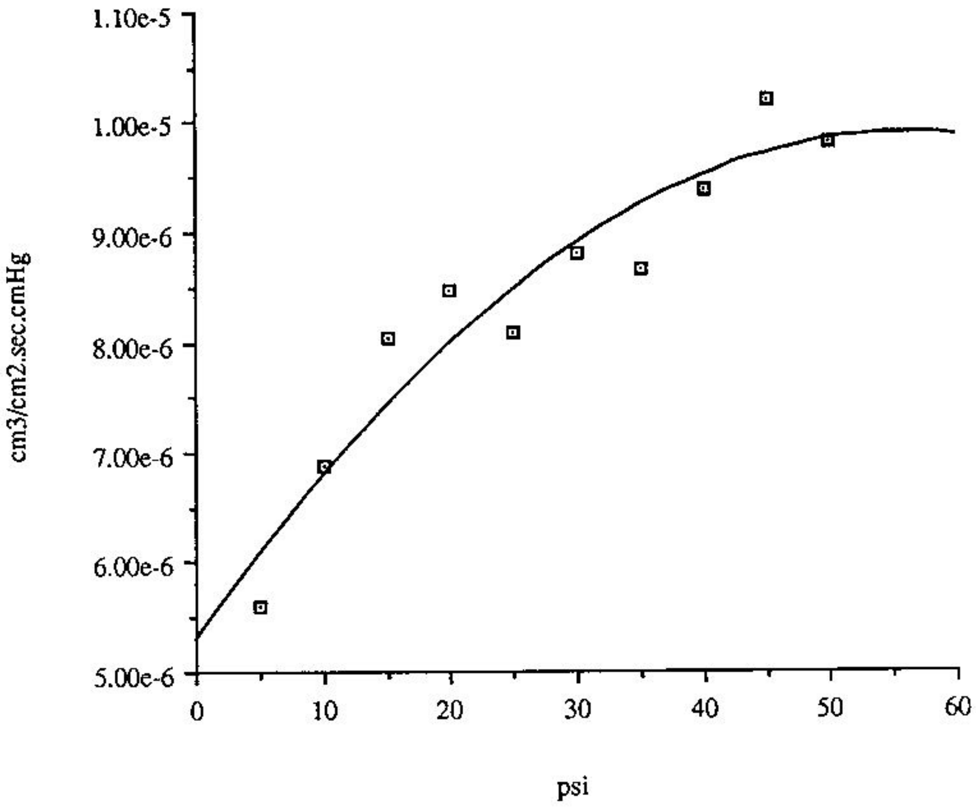
Table 4 : Selectivity for O2/N2 and CO2/N2

Pressure (psi)	Selectivity	
	O2/N2	CO2/N2
5	1.290	0.990
10	1.080	1.010
15	0.930	0.850
20	0.870	0.860
25	1.000	0.960
30	0.820	0.880
35	0.790	0.990
40	0.890	0.930
45	0.870	0.870
50	0.950	0.930

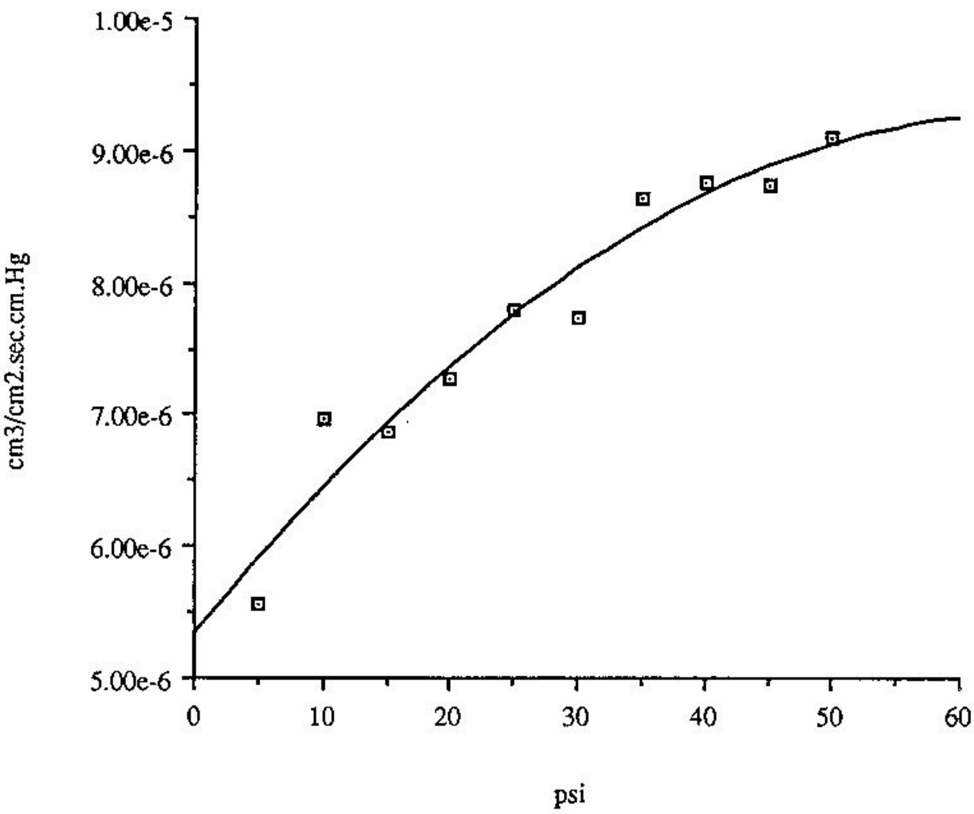
Table 5 : Permeation rate and selectivity(of each gas to N_2)for a commercially hollow fiber membrane module(3).

Gas	Permeation rate cm3/cm2.s.cmHg	Selectivity
H2	1.01 x 10-2	2.86
He	7.11 x 10-3	2.01
O2	3.17 x 10-3	0.899
Ar	2.73 x 10-3	0.776
CO2	2.62 x 10-3	0.743
CH4	3.64 x 10-3	1.03
C3H6	2.61 x 10-3	0.739

Graph 1 : Permeation rate vs pressure for N2



Graph 2 : Permeation rate for CO2



Graph 3 : Permeation rate vs pressure for O2

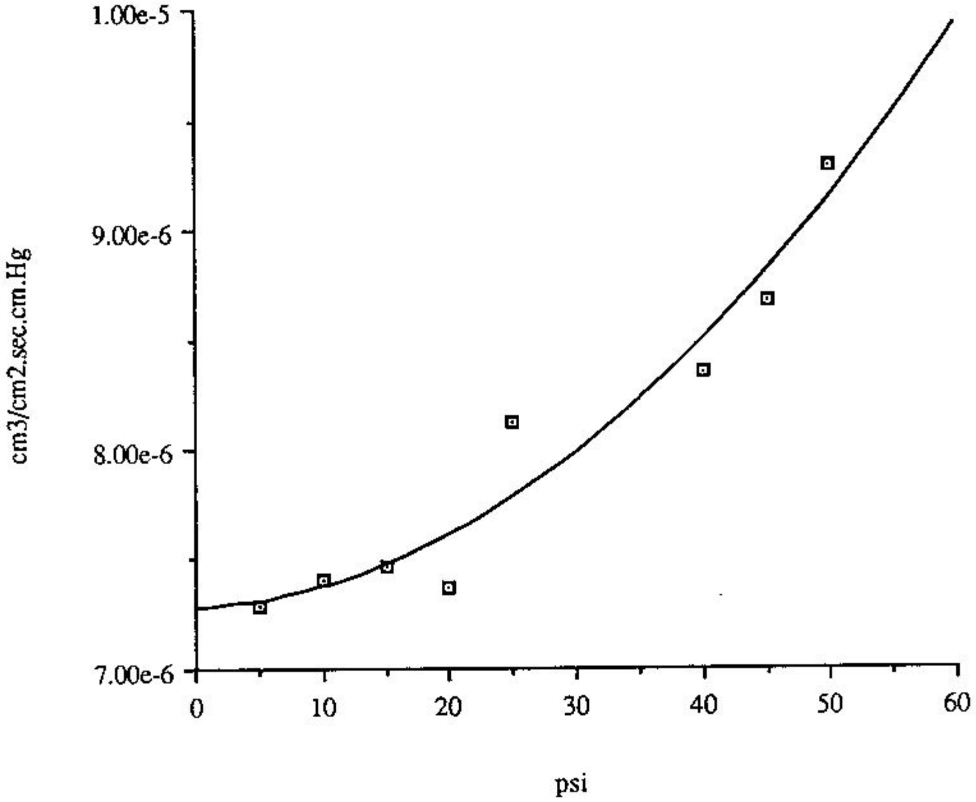


Plate 1 : Hollow Fiber Membrane Module

Plate 2 : Membrane Gas Separation Pilot Plant for Separation Process