A REVIEW ON USE OF A HOLLOW FIBER MEMBRANE AS A NEW TECHNOLOGY (APPLICATIONS)

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ABSTRACT

In the last decades, the hollow fiber membranes have attracted substantial importance as a potential structural material for different applications. Research and development efforts are being made to use hollow fiber membranes as VARs for the automotive applications, heat exchangers and filtrations of the contaminations. Hollow fiber membranes, a relatively new group of materials are in considerable demand in recent years by technological, economical and ecological aspects. . The use of hollow fiber membranes offer a number of advantages, since they are derived from a hydrophobic materials, require low energy inputs in their manufacture, and can be disposed of at the end of their life-cycle by composting and can be renewable by very small maintenance activity. Further the hollow fiber membrane cost as well as having satisfactory mechanical properties. Hollow fiber membranes can play very important role in the implementation of the new generation technologies and it also increases the performance of the system. Thus the hollow fiber available very cheaply and are easy to maintain, this criteria makes it very popular now a days. The aim of this paper is to provide a consolidated report of the researches in the field of different hollow fiber membrane and its applications.

Keyword : - *Hollow fiber membrane, Hydrophobic Membrane(HFMs),*

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1. INTRODUCTION

Hollow fiber membranes (HFMs) are a class of artificial membranes containing a semi-permeable barrier in the form of a hollow fiber. Originally it was developed for reverse osmosis applications. Hollow fiber membranes are packed into cartridges which can be used for a variety of liquid and gaseous separations. HFMs are commonly produced by using the artificial polymers. The primary properties of HFMs are average pore diameter and pore distribution.

Hollow fiber membrane module consists the number of hollow tubes which are bundled together in a single assembly which has certain pore diameter and length. Hollow fiber tube is made of a porous material (generally polymer).It has pore diameter in microns.

The first use of membranes on a large scale was with micro-filtration and ultra-filtration technologies. Since the 1980s, these separation processes, along with electro dialysis, are employed in large plants and, today, a number of experienced companies serve the market.

Depending on the pore size, they can be classified as microfiltration (MF), ultrafiltration (UF), Nano filtration (NF) and Reverse osmosis (RO) membranes. The latter can be facilitated by pressure, concentration, chemical or electrical gradients of the membrane process. Membranes can be generally classified into synthetic membranes and biological membranes. The HFM has pores on its surface and it is flexible and its performance is measured in terms of water mass flux across the membrane layer.

Different types of membranes are available are: Polypropylene membrane, Polycarbonate membrane, Polyether sulfone membrane, Polyvinylidene fluoride membrane, Polytetrafluoroethylene membrane (PTFE), Cellulose acetate membrane

Membranes are also available in different shapes as: Plate and frame module, Spiral wound module, Tubular module, Capillary module, Hollow fiber module

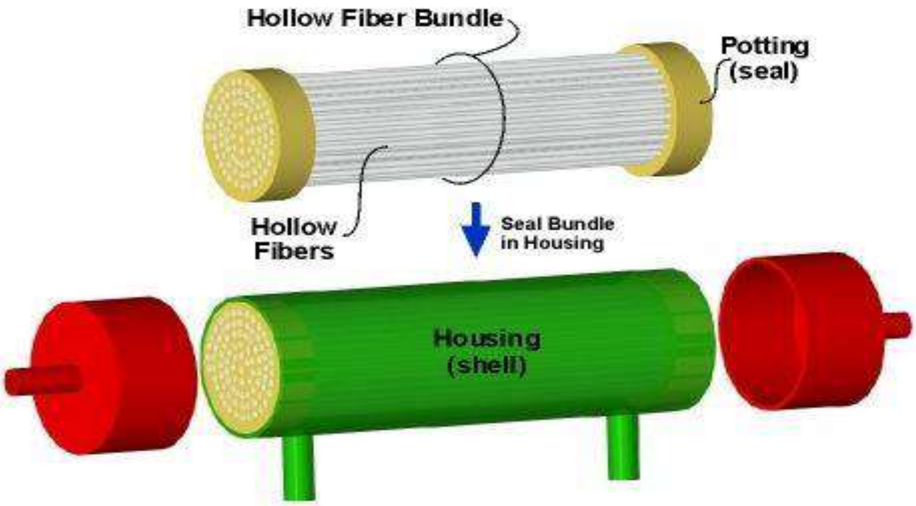

Fig -1: Hollow Fiber Membrane

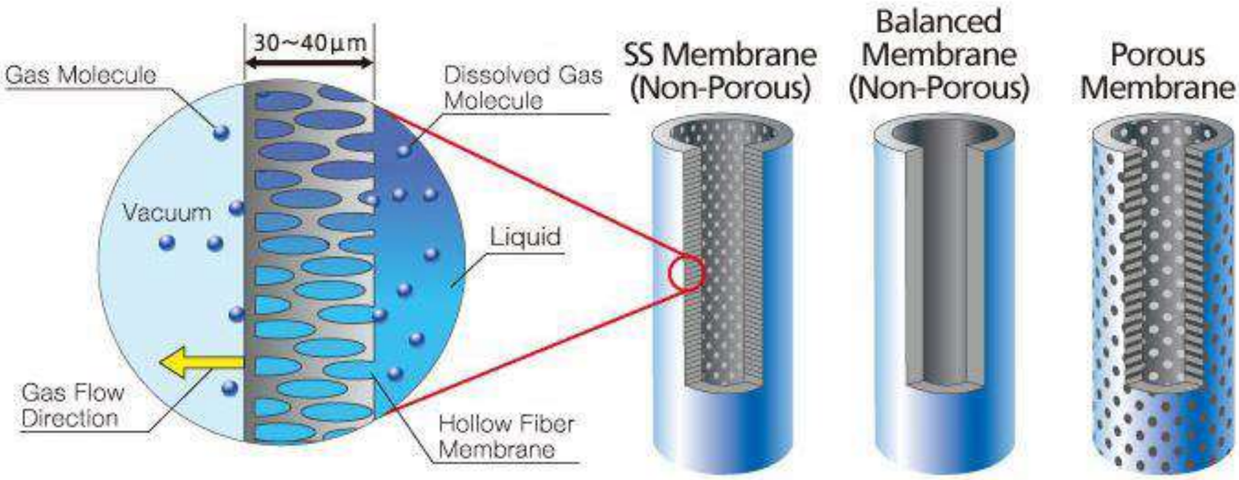

Fig -2: Hollow fiber membrane tube construction

Application of hollow fiber membranes are: Filtration, Reverse osmosis (RO), Gas separation, Membrane distillation

2. HOLLOW FIBER MEMBRANE IN VARs

Vapor absorption refrigeration system is very popular now a days as it uses the low grade heat source or a waste heat as input. When it comes to the automobile sector the performance of the absorption system degrades during the transportation periods due to certain circumstances. And the solution found for the problem having degraded performance of the hollow fiber membrane as it has the hydrophobic property.

Sung Joo Hong et al [P1] had done research for "Novel absorption refrigeration system with a hollow fiber membrane-based generator" in 2015. They studied the performance of vapor absorption refrigeration cycle used in automobile by using the hollow fiber membrane based generator. They had described the mechanism of the HFM-G, and the system performance of the proposed cycle under various operating conditions and reported the performance of the system that was degraded previously that can be upgraded by implanting the hollow fiber membrane in the vapor absorption system in the automobiles. The membrane distillation performance could be improved by varying the membrane parameters, such as pore size, thickness, inner diameter of the membrane, and the number of membranes.

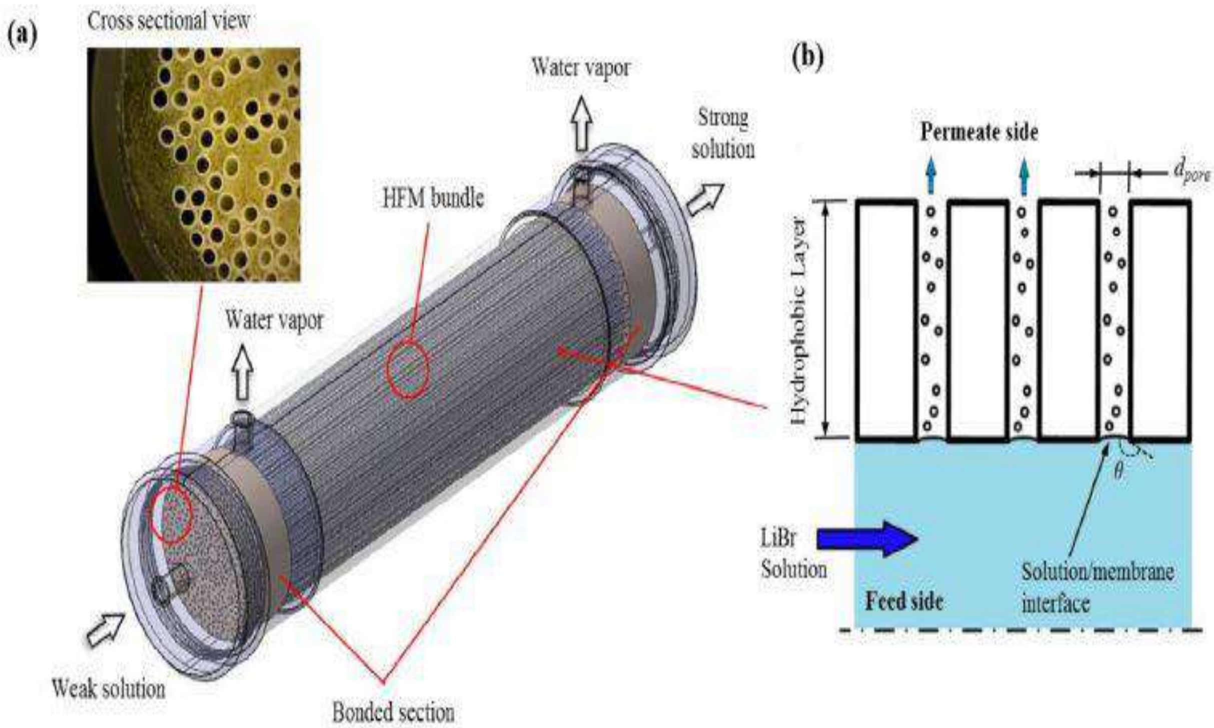

Fig-3: (a) Schematic of a hollow fiber membrane-based generator. (b) Schematic of the evaporation and vapor permeation mechanism from solution flow constrained by a hydrophobic membrane [P1].

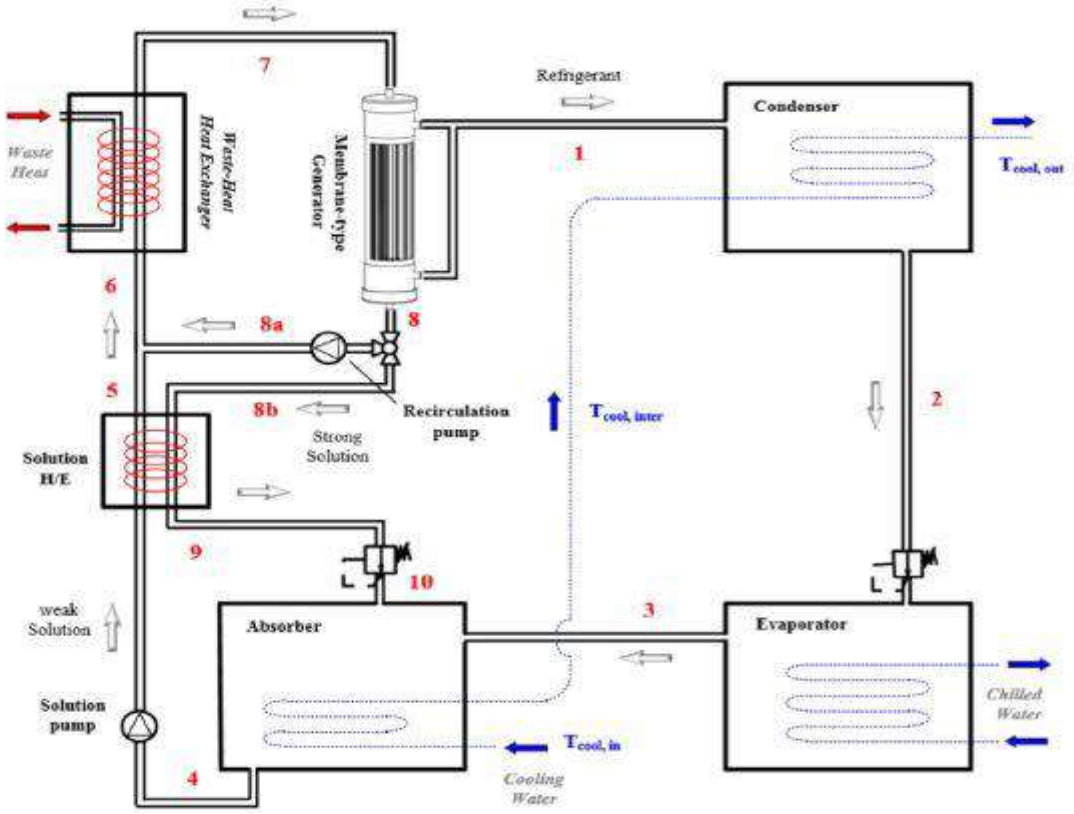

Fig-4: Schematic of the vapor absorption refrigeration system with a membrane-based generator [P1]

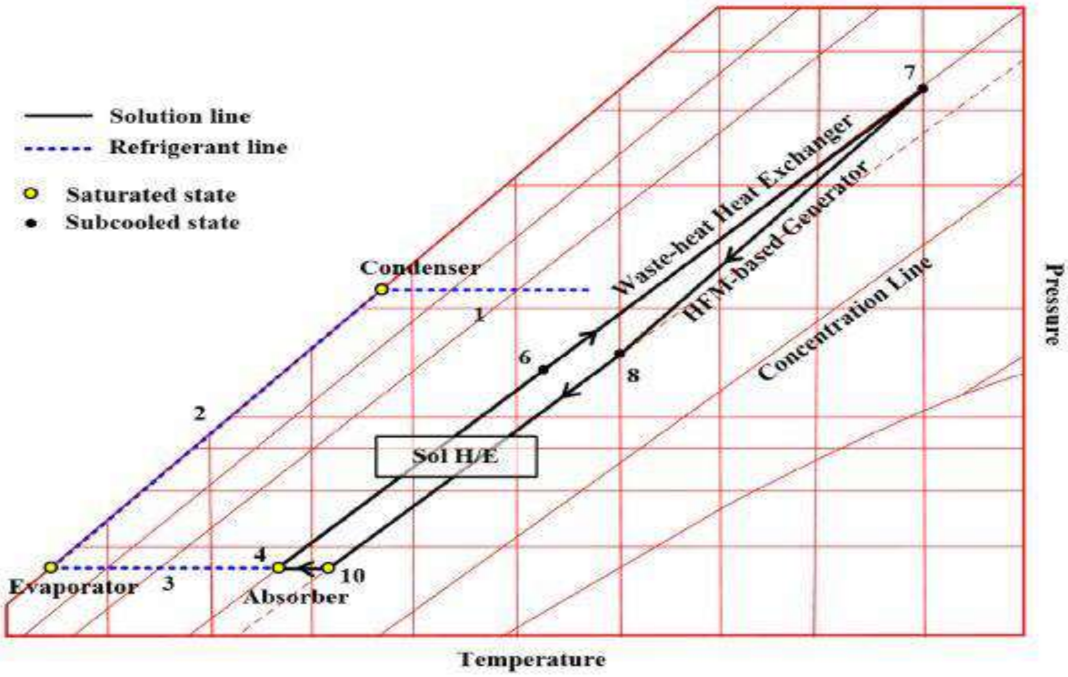

Fig-5: p–t–x diagram for the absorption cycle [P1]

After doing the numerical analysis based on previous experiments and they found that the system coefficient of performance is being degraded during the running condition of the vehicle to the 0.27.But by implanting the hollow fiber membrane, the coefficient of performance of the membrane based system is increased to 0.57.

3. MEMBRANE IN DISTILLATION TECHNOLOGY

WANG ZanShe et al [P6] had done research for "Applications of membrane distillation technology in energy transformation process-basis and prospect" in 2009. They explored the new characteristics and utilities of membrane distillation in traditional energy transformation process based on the experimental test and mathematical simulation about saline solution and membrane heat exchanger. They had concluded that the Influence of feed temperature, feed flux and vacuum degree on permeation flux on the membrane distillation technology. They had found that as feed temperature increases the penetration flux increases, feed flux increases the penetration flux increases accordingly and vacuum degree penetration flux.

This paper discussed the fundamental applications of membrane distillation in energy transformation process and analyzed their potential applications, based on the mechanism of membrane distillation process and the energy transformation process.

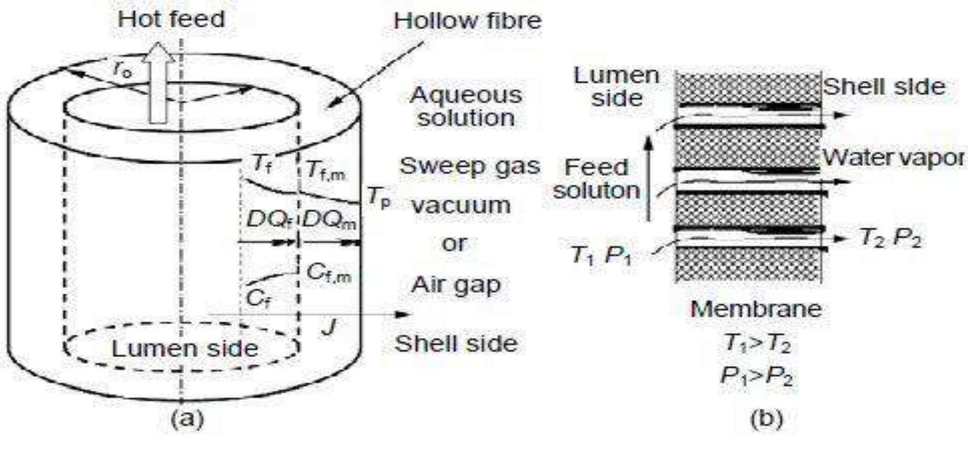

Fig-6: Microscopic schematic of membrane distillation model (a) Mono-membrane; (b) vertical section [P6]

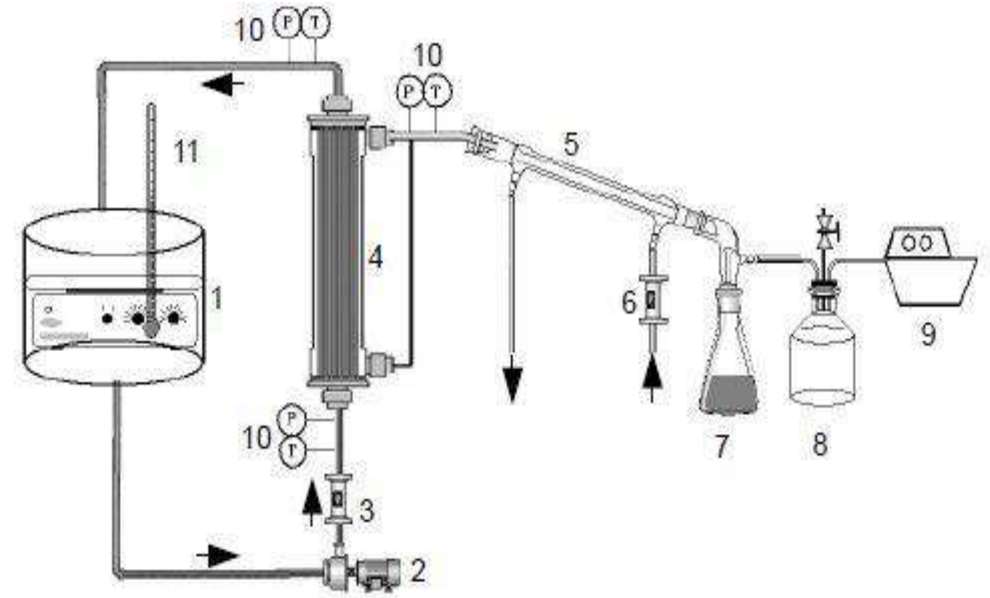

Fig-7: Schematic of the experimental set-up of Experiment on desorption of high concentration saline solution by VMD process [P6]

Where,
1. Thermostat water bath: 2. Magnetic pump; 3. Flowmeter; 4. Membrane module;5. Condenser pipe; 6. Cooling water flowmeter; 7. Receiving tank; 8. Adjuster of vacuum pressure; 9. Vacuum pump; 10. Temperature probe and pressure sensor; 11. Feed thermometer.

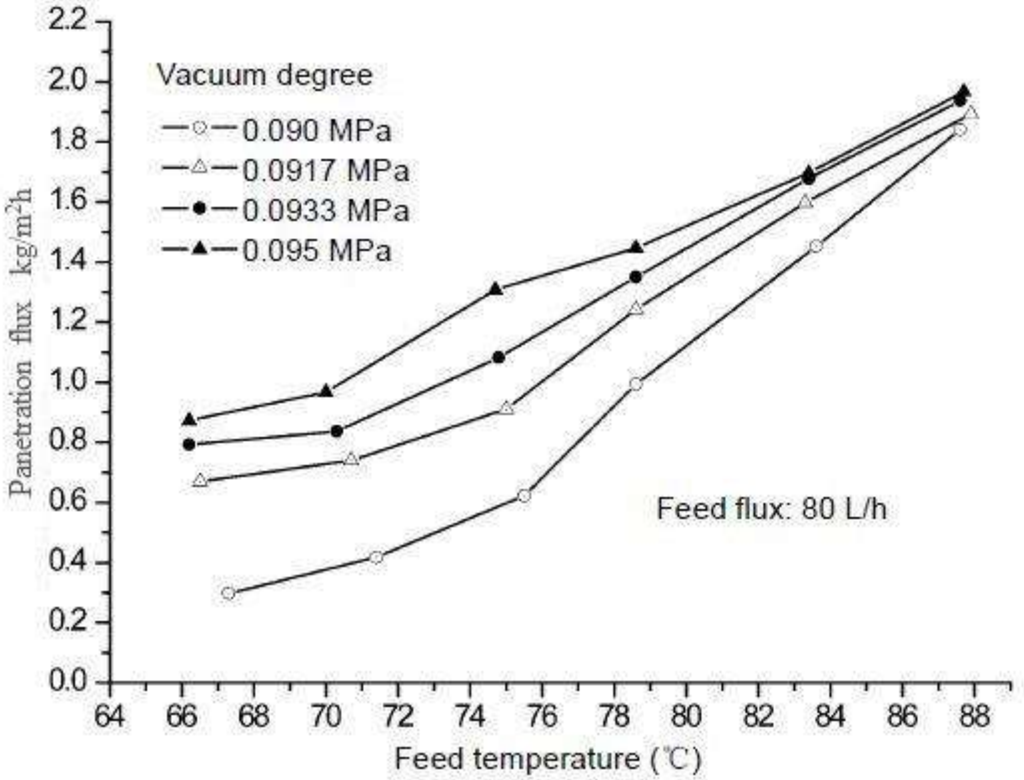

Fig-8: Influence of feed temperature on permeation flux [P6]

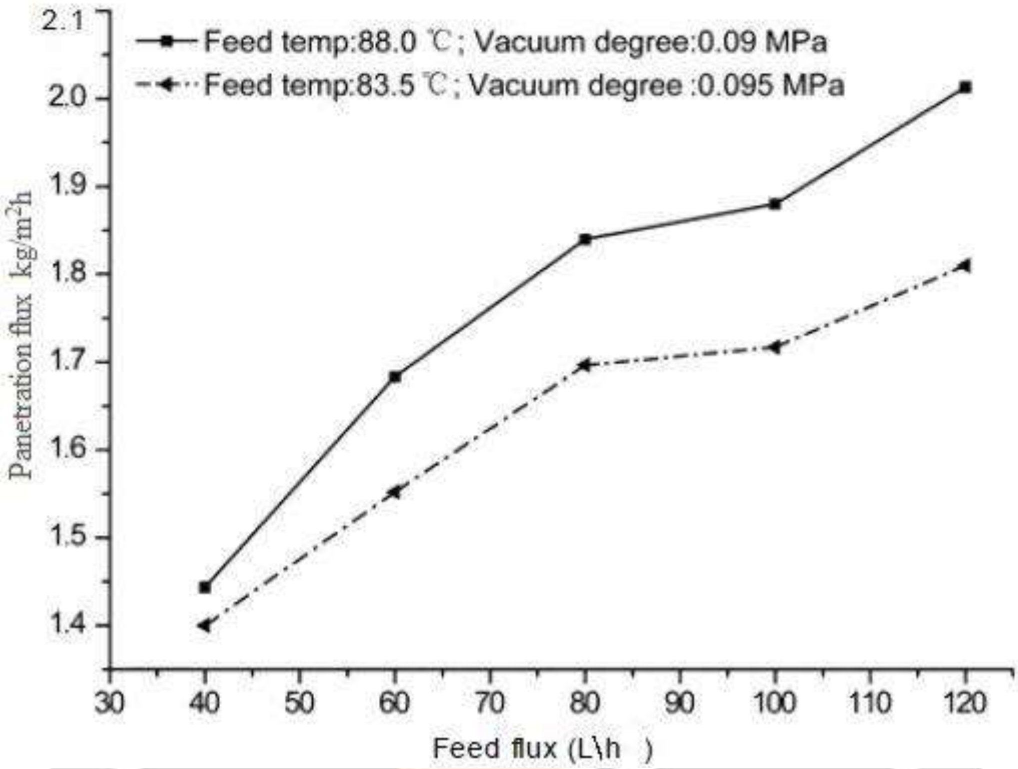

Fig-9: Influence of feed flux on permeation flux [P6]

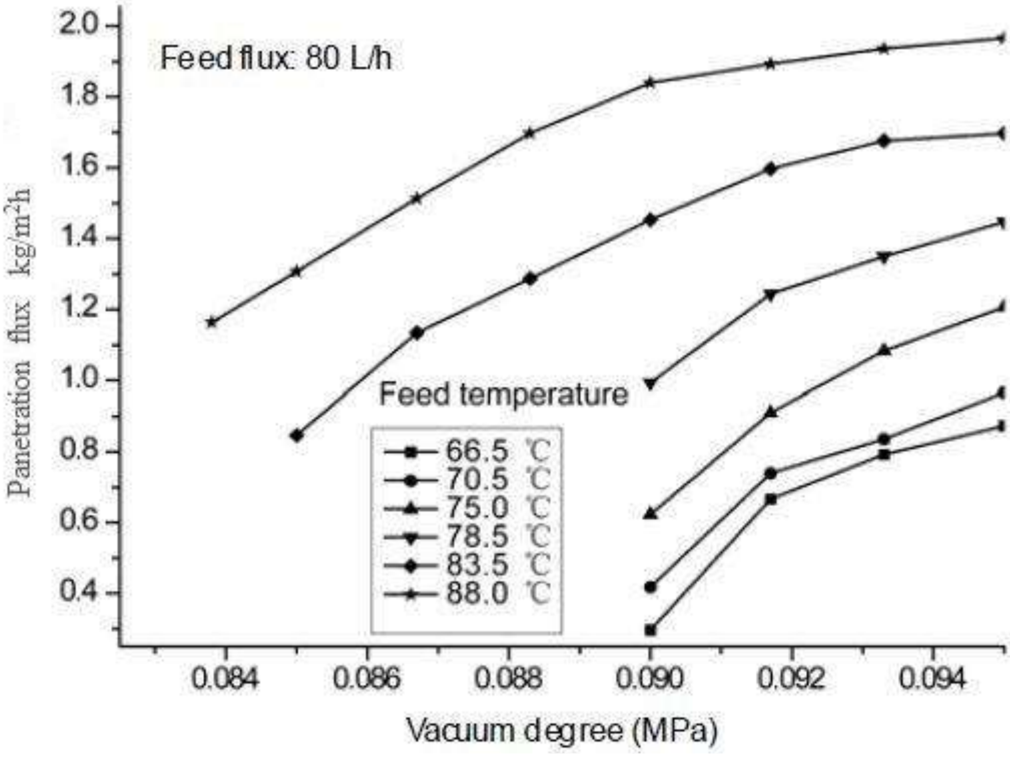

Fig-10: Influence of vacuum degree on permeation flux [P6]

They also discussed the influence of thermal layer in membrane wall on water vapor diffusion influence of temperature polarization and concentration polarization on the partial pressure of water vapor in membrane pores and on the penetration flux, and the thermodynamic equilibrium relations of the unsaturated solution in the interface of membrane pores.

4. AMMONIA REMOVING BY HOLLOW FIBER MEMBRANE

Haiyang Liuand et al [P8] had done research for "Separation of ammonia from radioactive wastewater by hydrophobic membrane contactor" in 2015. They did the experiment on removing the ammonia by experimental setup. In the setup they used mixture of urea and acid-deficient uranyl nitrate solution and then the solution containing tetrahydrofurfuryl alcohol (THFA) and polyvinyl alcohol (PVA) to mix.

Then this whole mixture were added into ammonia solution to form gel particles. Then this ammonia solution added to ^{238}U for further treatment. The presence of high concentration of ammonia made the further treatment of ^{238}U more difficult. So it's essential to remove the ammonia from the solution. The effect of co-existing substances on ammonia removal and the operating parameters were also studied.

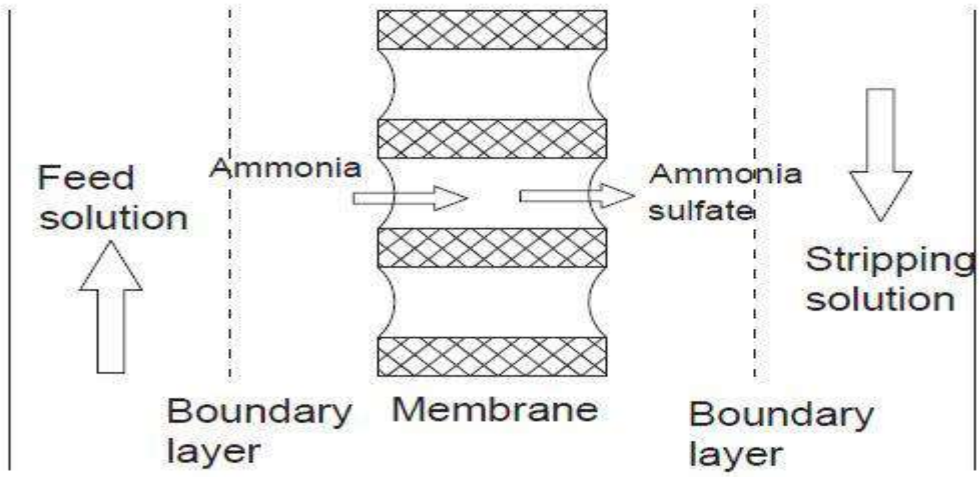

Fig-11: Schematic representation of NH3 removal by Hollow fiber membrane contactor [P8]

By doing this experiment they concluded that as the time increases the concentration of ammonia decreases. HMC was effective for removing ammonia from radioactive wastewater and the ammonia removal efficiency could reach above 90%. The total ammonia mass transfer coefficient increased when feed velocity increased and tended to an asymptotic value.

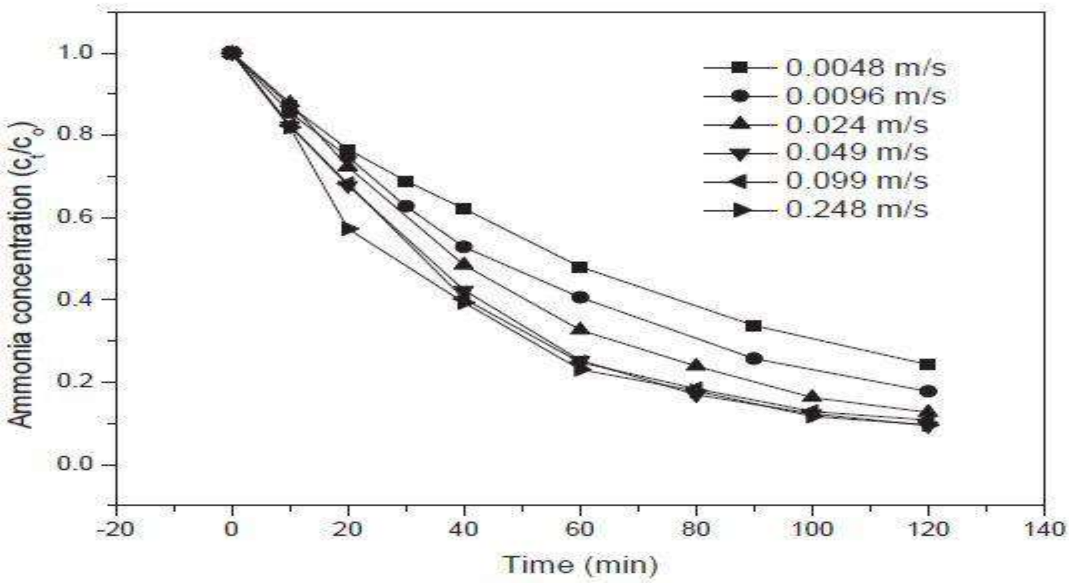

Fig-12: Effect of feed velocity on ammonia removal [P8]

5. HFM as a heat exchanger

Chena et al [P9] had done research for "Experimental investigations of polymer hollow fiber heat exchangers for building heat recovery application". She study is based on the construction and experimental investigations of polypropylene based polymer hollow fiber heat exchangers in the form of shell-and-tube. The number of heat transfer unit (NTU) is discussed in this paper.

Three different PHFHE modules with fiber numbers of 100, 200and 400 were manufactured and the thermal performances were compared in the tests. The experimental obtained overall heat transfer coefficients were 758–1675 W/m^{2}K, 369–1453 W/m^{2}K and 296–1201 W/m^{2}K respectively for Module 1–3. This indicates that module 1 offers higher U value compared with the other two modules. By changing the tube and shell side flow rate, the effectiveness, NTU of PHFHE modules are also investigated.

Fig-13: (a) PHFHE heat exchanger. (b) PHFHE heat transfer measurement testing rig [P9]

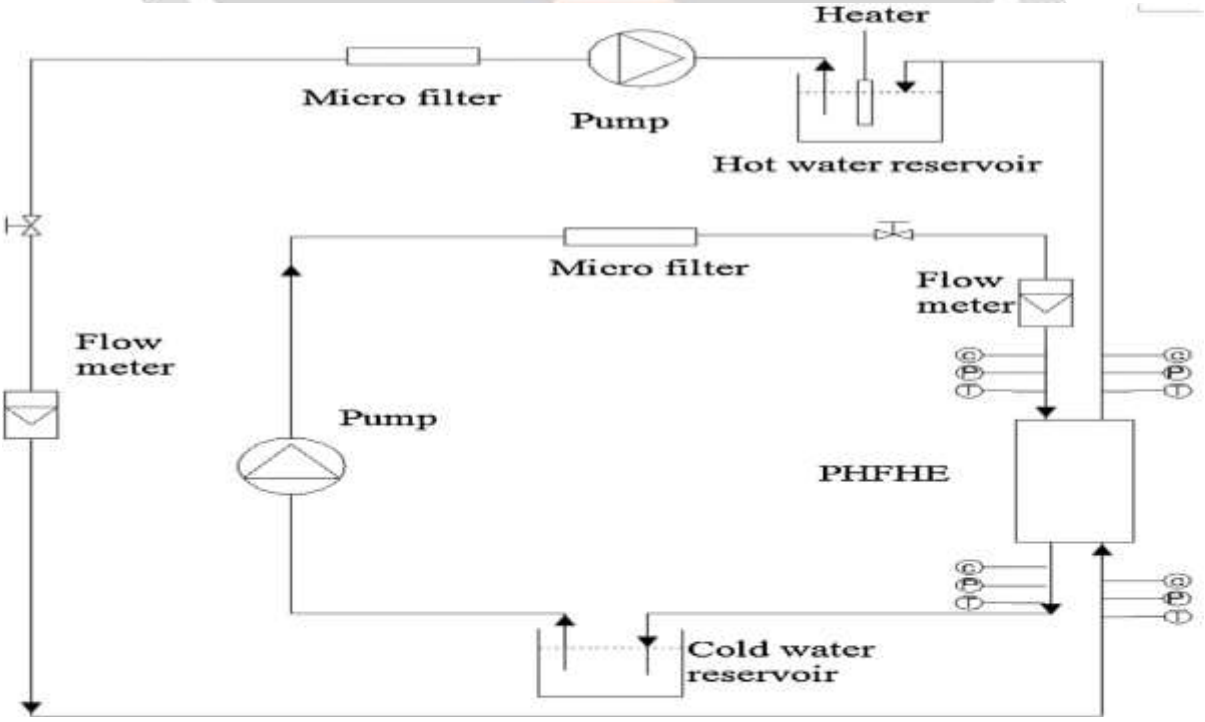

Fig. 2. 16 The experimental schematic diagram for heat transfer measurements in PHFHE [P9]

With the active length of 14 cm, the module 1 of PHFHE could attain high value of effectiveness and NTU, up to 0.991 and 5.065 respectively. Since the surface area per unit volume in such PHFHEs is quite high, in the range of 880–3600 m^2/m^3, their volumetric rate of heat transfer is very high. This superior performance can result in potentially more compact designs based on PHFHE devices, for water desalination, solar water heating system, and automotive applications. Therefore, the superior thermal performance and large heat transfer areas, and the advantages of low price and light weight of polymer materials make PHFHEs a promising substitute over conventional metal heat recovery system for building application.

4. CONCLUSIONS

From the literature survey it is concluded that the use of light weight polymeric hydrophobic microporous membrane contactors can provide a larger interfacial area for heat and mass transfer processes. Thus, not only the size and weight of the components can be reduced but also the system performance can be enhanced.

Use of membrane contactors in the desorber can extend the use of low grade heat sources effectively in absorption refrigeration systems. It is evaluated from the literature review that membrane based desorbers can alter the configuration of absorption refrigeration cycles and the cycle components can be reduced in some cases. Despite these advantages, there are some limitations associated with membrane contactors such as the mechanical strength of membrane contactors, which is very low and the fact that they cannot operate at very high temperatures.

In this review the applications of membrane contactors in the field of absorption refrigeration systems are covered. Membrane contactor modules, components employing membrane contactors, cycle configuration, membrane material characteristics and the working fluid mixtures for the membrane contactor based absorption refrigeration systems are all discussed.

This review reveals that the applications of membrane contactors for absorption is an emerging technique in the field of absorption refrigeration systems, however, a commercial plant has not yet been designed to explore the long term operation of membrane contactor based components in absorption refrigeration systems. Further research is needed to explore the long term operation consequences of membrane contactors in absorption and absorption processes. One of the prominent areas for future investigation is the use of non-conventional working fluid mixtures in membrane contactor components. Membrane contactor modules are available in different types hence, membrane modules other than plate-and-frame membrane module and hollow fiber module should also be investigated.

Membrane contactor surface properties need to be studied further for more efficient use in absorption refrigeration components. In this regard, further research work is required to improve the hydrophobic character of membrane material, enhance the mechanical strength and to improve the compatibility of the membrane material with the working fluid mixtures. Membrane contactors do not suffer corrosion problems as it occurs in conventional absorption refrigeration components. However, fouling of membrane contactors means that more need for research is necessary with regard to absorption refrigeration components employing membrane contactors, so that durability and life span cost of the absorption refrigeration system can be evaluated more precisely. Membrane module should be tested and analysed at higher operating temperatures to investigate the effect of high temperatures on membrane materials and performance.

5. ACKNOWLEDGEMENT

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