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Membrane Distillation Technology Using for Desalination of Associated Oil Water Production and Study Efficiency of Feed Water Operation Parameter on Air Gap Membrane Distillation Process Production

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Abstract

In this study; membrane distillation technology using to associated oil water production desalination by air gap membrane distillation unit to removed salt from the water after separating oil product, via PTEF commercial hydrophobic membrane distillation with 0.22 µm porous and 0.011 m contact surface area, evaluated the desalination system and operation parameter for feed water effected on process production by employment the distillation under boiling point temperature that getting commercial increments and study the energy gain by calculating the GOR of the desalination process.

The study focusing on the air gap membrane distillation desalination process by a range of temperature after primary simple sedimentation and filtration it's obtained salt rejection up to 98.9% that proves process separation efficiency. Evaluated the mean operation parameters of feed water affected on permeate water production when selected the feed temperature and flow rate with fixed coolant temperature, coolant flow rate, and air gap width to get an optimum range for feed water operation parameter to obtain optimum value to permeate water production and saving energy.

Keywords: Product water, Air Gap Membrane Distillation, Membrane Distillation, Desalination.

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استخدام تقنيات اغشية التقطير في عمليات تحلية المياه المصاحبة للنفط ودراسة المؤثرات التشغيلية للمياه المغذية على انتاجية وحدات التقطير بالاغشية ذات الفجوة الهوائية

الخلاصة

في هذه الدراسة تم استخدام تقنية اغشية التقطير لتحلية الماء المصاحب لانتاج النفط في حقول البصرة حيث استخدم وحدة التقطير بالأغشية من نوع الفجوة الهوائية AGMD لازالة الاملاح من الماء المصاحب الناتج بعد عملية عزل النفط المنتج , بواسطة غشاء كاره للماء تجاري من نوع PTEF ذي مسامات بحجم 0.22 µm و بمساحة تلامس سطحية 0.011 m و تقييم نظام ألتحلية والعوامل التشغيلة للماء المغذي المؤثرة على انتاجية العملية حيث يتم التقطير بدرجة حرارة اقل من درجة الغليان التي تمثل احد المكاسب الاقتصادية ودراسة الربح بالطاقة عن طريق حساب GOR للعملية التحلية.

تم التركيز على دراسة عملية التحلية بوحدة غشاء التقطير ذو الفجوة الهوائية بمدى من درجات الحرارة بعد عمليات تركيد و ترشيح اولي حيث تم الحصول على نسبة عزل للملاح تصل الى اكثر من 98.9% مما بيين كفاءة لعملية الفصل. و دراسة اهم المؤثرات التشغيلية للمياه المغذية على كمية الماء الناتج حيث تم اختيار درجة حرارة الماء المغذي و معدل تدفقه مع تثبيت درجة حرارة ماء التبريد و معدل تدفقه اضافة الى سمك الفجوة الهوائية بين الغشاء و سطح التبريد و ليتم تحديد افضل حدود المتغيرات التشغيلية للماء المغذي للحصول على افضل تدفق للماء الناتج و توفير بالطاقة.

1. Introduction

Associated water is one of the main problems at a duration of the oil gas production, it's represented a largest west production stream [1], [2], that the biggest drawback from oil and gas industry on the environment [3], [4]. The volume of west water approximated by three barrels of water for the barrel of oil product [5], [6]. The property of water production depends on two reservoir factors; geographic location and geological formation that denoted the type and concentration of organic (hydrocarbons) and inorganic species (salt, silt, metal, NORM , ... etc)[7], [8] . Also, the ratio of water oil production depends on reservoir age and with extraction years, it can rise to reach 1 to 10 or above [5], [9]. The estimated global annual of water production quantity at 202 billion barrels in 2014 and it rising in 2020 to 340 billion barrels Figure (1) Show that [10].

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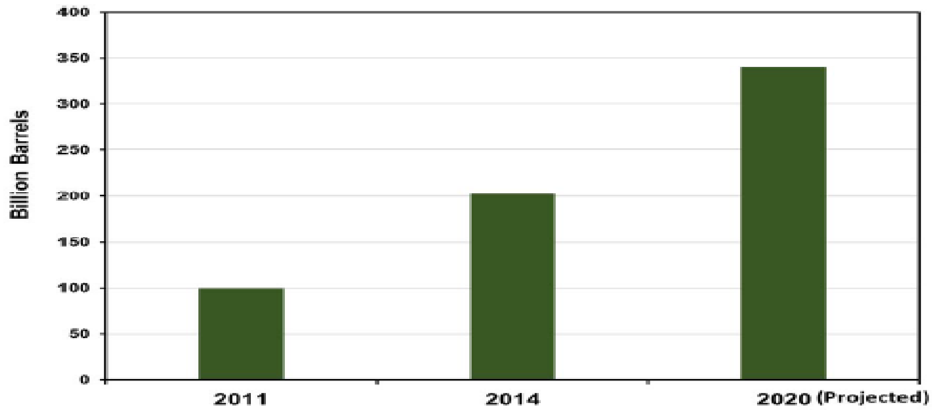

Fig. (1): The estimated global annual of water production

Salinity is a major problem in product water, especially in the Iraqi filed, Table (1) represented properties of water product in Iraq filed [2]. The promising technology to treat it is a membrane separation [9], [11], in nonconventional treatment process used membrane filtration by semi- preamble medium with very small prose by pressure drive to filtrating such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) [12]. Membrane distillation the imaginer thermal microfiltration membrane technology with high potential water treatment by treated any salinity feed water with high water product. This technology depends on deference in partial pressure to generate a vapor pressure in the feed solution, it separate and transfer through a hydrophilic membrane and condensate by direct contact with a cold surface or cold stream of distillate to get a pure produced water [13]. The benefit by apply this technology is reduces the operating temperature compared with the conventional thermal process, used lower hydrostatic pressure[14], and reduces the energy conception by using renewable energy such as solar or geothermal energy [15]. The Air Gap Membrane Distillation is direct contact between the brine with and membrane side, and the vapor transfer through a hydrophobic membrane across the air gap to condensate surface on the cold surface [16].

The main effect of permeate flux products is feed temperature. The permeate flux grows exponentially with feed temperature rise, by reach the vapor pressure growths exponentially (applied of Antoine equation) [17]. And growing the feed flow rate, the polarity effects are decreased owing to turbulent flow and lastly to

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upper permeate flux and the energy conception and gain output ratio GOR, it is an indication of how well the total energy input to the system utilizes to produce freshwater, The GOR is an indication of how useful the total energy input to the system employs to produce fresh water [18].

By applying the design of experimental (DoE) as a statistical optimization approaches a widely used to optimize operation variables, instead of the previous method that depends on effected of single variable dependent, with other variables, kept fixed [19]. Response surface methodology (RSM) is competent to evaluate the interaction between the selected variable to estimate the optimum value on process operation.

In this study, the main aim is to consider the performance of desalination of membrane distillation to treated salinity of product water by air gap membrane distillation process and the affluent and inert action of the feed operation parameter on permeate flux production and GOR.

Table (1) properties of water product in Iraq filed

Characteristics	Value	Characteristics	Value	Characteristics	Value	Characteristics	Value
pH (-)	6.5	Chloride (mg/l)	101898	Oil and greases (mg/l)	654	Sodium (mg/l)	47981
Density (kg/m^3)	1150	Calcium (mg/l)	10926	TSS (mg/l)	290	HCO_3 (mg/l)	567
Conductivity (mS/cm)	210	Magnesium (mg/l)	3251	TDS (mg/l)	165950	Turbidity (NTU)	211
COD (mg/l)	1730	Sulfate (mg/l)	773	Oil and greases (mg/l)	654	Sodium (mg/l)	47981

2. Material and methods

The associated water got from Basra Oil Company (122 m S/cm Conductivity and 6.5 pH at 25 C) is using in experiments to the development the affection of feed temperature and flow rate of water product on permeate flux of treated water production. The feedwater is heated in a 20L by the water bath have an immersed heater with a thermostat for regulated and controlled to temperature, using The circulation pump to circulation feed water from the feed tank to the AGMD module, a valve is using to control the flow and flow meter to measure the flow rate, pressure, and temperature sensors on inlet and outlet feed streams. Also, to circulate

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the cooling water through the cooling section a 10L chiller water bath with circulation pump is used, flow meter and temperature sensors on inlet and outlet cooling steam. Data questions are connected with computers and all measuring sensors. Fegure (2) show the AGMD module, the hot inlet stream of product water feed directly flows over the flat sheet microporous hydrophobic membrane (commercial 0.22 µm polytetrafluoroethylene PTFE supported on polypropylene PP with Thickness 180µm, Porosity 85%, and Contact 120° angle were provided by Hangzphuo Tianshan Precision Filter Material Co., China) which have an aluminum orifices plate supporter. Another side for circulated cooling water on the inside of the aluminum plate is used as a cooling surface, and between them creates the gap by using a 3mm spacer. The condensed vapor (permeate) is collected in a spacer gap and the permeate outlet at the bottom of the air gap is accumulated in the measuring flask. The effective area of the used hydrophobic flat sheet membrane is 0.0198 m2 and coolant flow and temperature are 3 l & 20 C respectively.

Used Temperature and pressure sensors to monitor the operation parameter in the inlet and outlet for feed and coolant waters, and controlled by proportional valves on water flow rates at the inlet of the feed and coolant sides for the MD module and monitored by flow meters. After the system reached steady-state conditions, for each experiment, collected the volumes of the distillate and measured the sample's time, and calculated Permeate flux in units of kg/m2 h. calibrated conductivity meter used to measure the concentrations of the feed water and permeate production.

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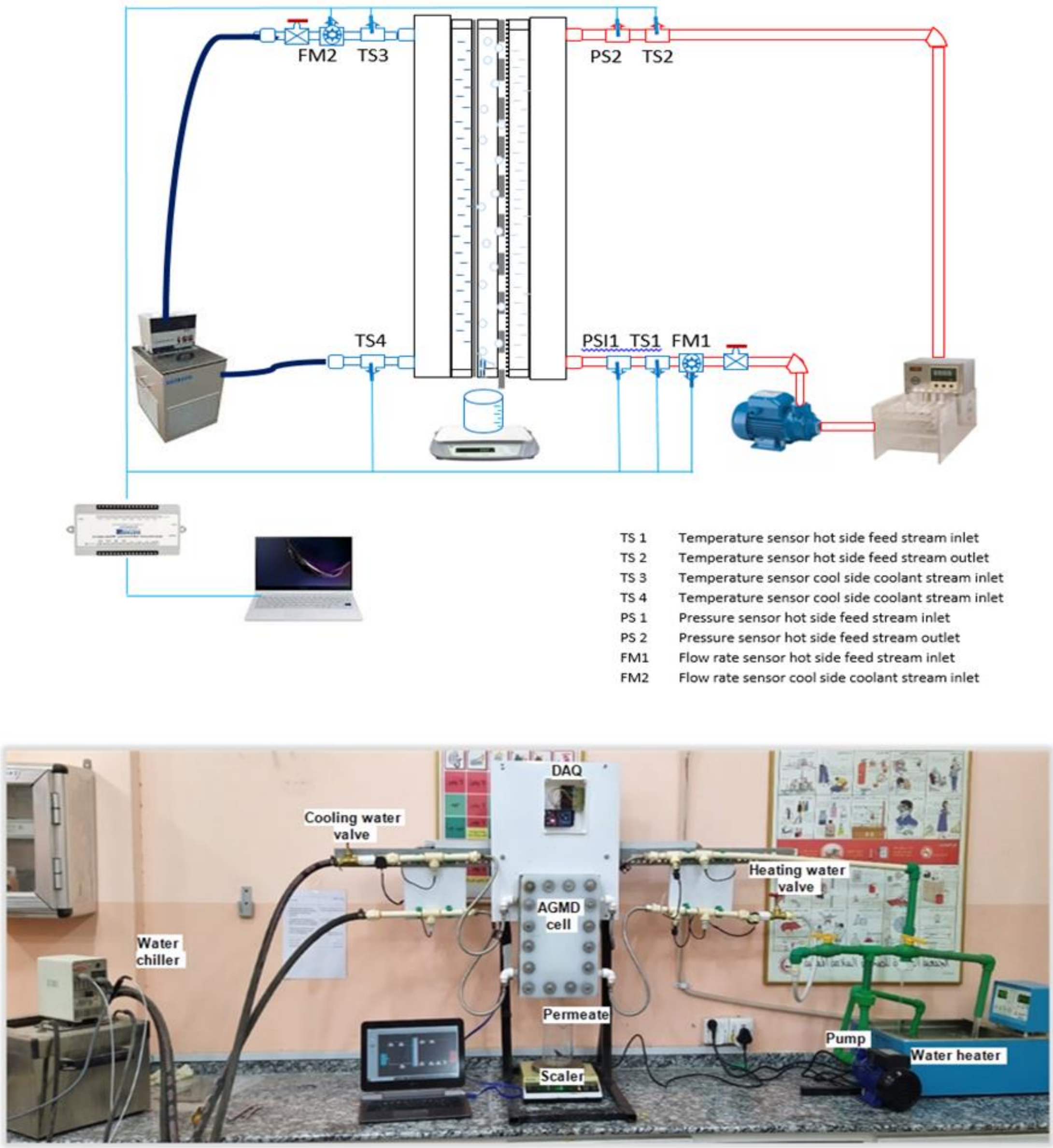

Fig. (2): Shows a photo of actual setup of the AGMD.

3. Result and Discussion

At the beginning of work, the stability of process production flux tasting with time as shown in Figure (3), the salt rejected factor in all exterminates with high values from 99.97 to 99.99 and obtained pH to 7.2.

When calculated the permeate flux J by:

$$J = \frac{w}{A \times t} \qquad (1)$$

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Where w Kg is the weight of permeate water at time t h and A m2 is the effective surface area of the membrane [20].

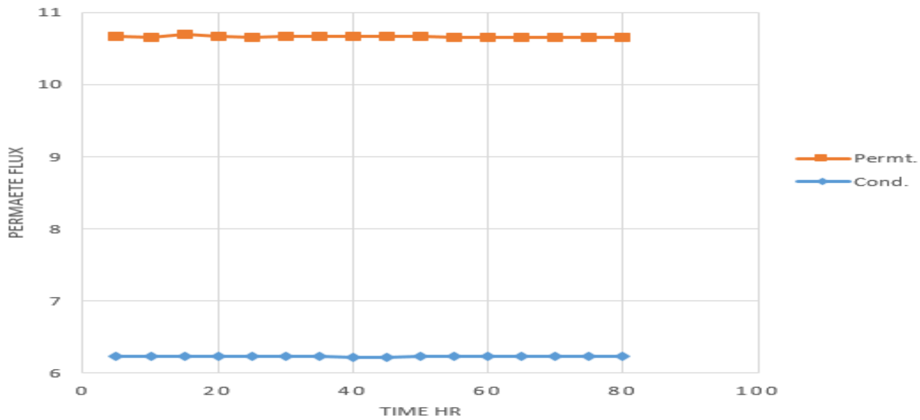

Fig. (3): Permeate flux and conductivity for water product when feed temperature 50 °C, feed flow rate 6, coolant temperature 30 °C, coolant flow rate 3 LPM and air gap 3 mm.

Figure (4) illustration that the increase in water feed temperature leads to growth in water evaporation due to increases exponentially in permeate flux, the Antoine equation exponential relationship leads to rising in the vapor pressure with temperature relationship. And growth permeates flux by increasing feed flow rate lead to because it is making high turbulence inside of member surface gotten reducing the thickness and mixing in the boundary layer is shown in Figure (5).

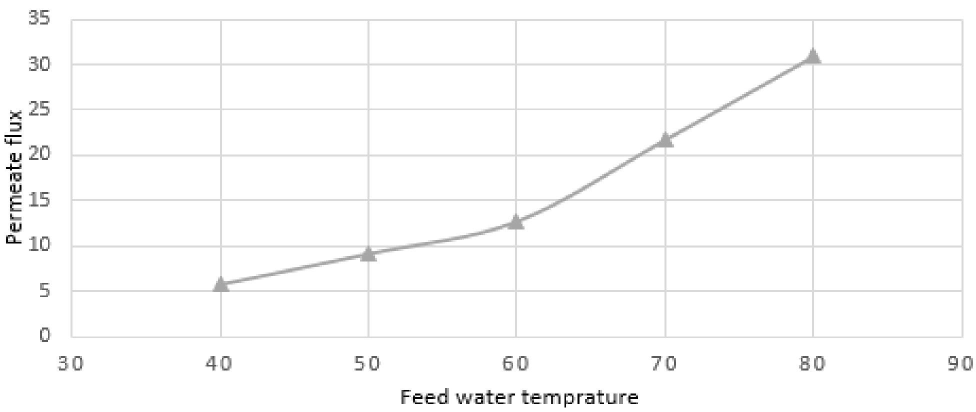

Fig. (4): The effect of feed temperature on permeate flux when feed flow rate 4 LPM, coolant temperature 30 °C, coolant flow rate 3 LPM, air gap width 3mm.

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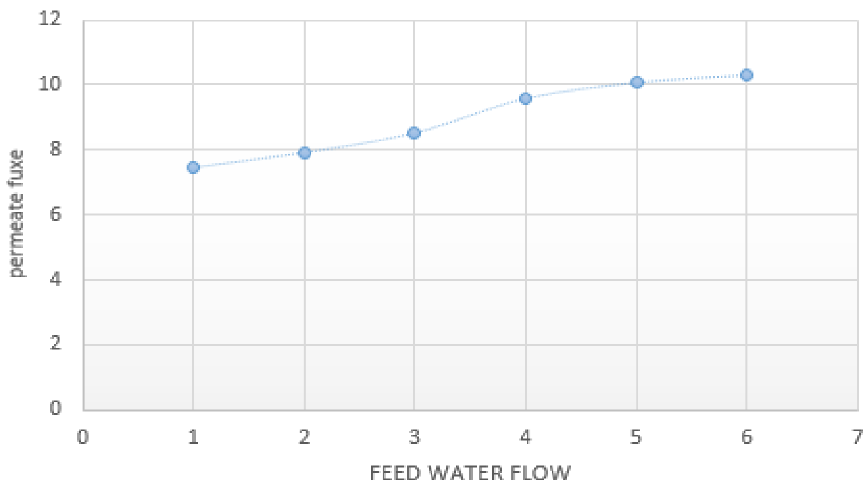

Fig. (5): The effect of feed flow rate on permeate flux when feed temperature rate 70 °C, coolant temperature 30 °C, coolant flow rate 3 LPM, air gap width 3mm.

Employ Response surface methodology (RMS) to invention the relationship between study two operating parameters and permeate flux production to modeling and optimization and gain output ratio GOR in the AGMD process by used Central Composite Design (CCD) to fitting the experimental. Two factorial with three-level given 13 experimental runs, the design of experiments, analysis of variance ANOVA, and RMS regression were carried out by Minitab 15, developed the response surface model by a quadratic regression model to describe the relationship between the output permeate flux and the input design parameter of the AGMD system where fitted by quadratic regression equation:

$$Y = b_o + \sum b_i\, x_i + \sum b_{ii} x_{ii}^2 + \sum b_{ij} x_i\, x_j \qquad (2)$$

Where Y represent the response for permeate flux of water production and $b_{o,}$ b_i, b_{ii}, b_{ij} the coefficient of regression equation .For 13 experimental run adjusted the feed water operation parameter at three level (feed temperature (50 – 60 – 70) C, feed flow rate (2 – 4 – 6) L/min) and fixe the coolant temperature at 20 C and coolant flow rate at 3 L/min with air gap 3 mm, evaluated the model and regression coefficients by used analysis of variance ANOVA and measuring the effect of the

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coefficients by tested the F-value and p-value on the model, the mathematical model has a large F-value and a which (< 0.05) of p-value indicates the model coefficients are significant., the value of R^2 99.59% agreement with R^2 adj. 98.86% means that 99.88% of the variation in permeate flux is obtained by variation in operation variable.

Fig. (6) it can be shown the effect of feed temperature and feed flow rate on permeate flux. The flux increases with feed temperature rise and increasing linearly with feed flow rate, the effect of temperature is strong little value of feed flow rate when the upper the flow rate that exhibition on flux by enhanced heat transfer coefficient in the feed boundary layer and improved turbulence inflow channel, its efficient at high value and denoted possible it controlled on flux production by reducing the thermal energy it can use to rising the feed temperate, and get the optimum value of permeate production in rang of 60 – 65 C and 4.5 – 6 L/min.

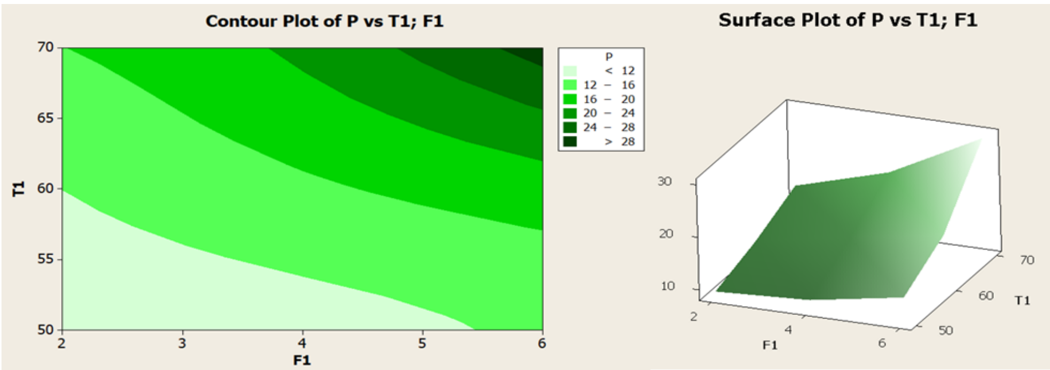

Fig. (6): The efface of feed temperature and feed flow rate on permeate flux by surface and contour plot

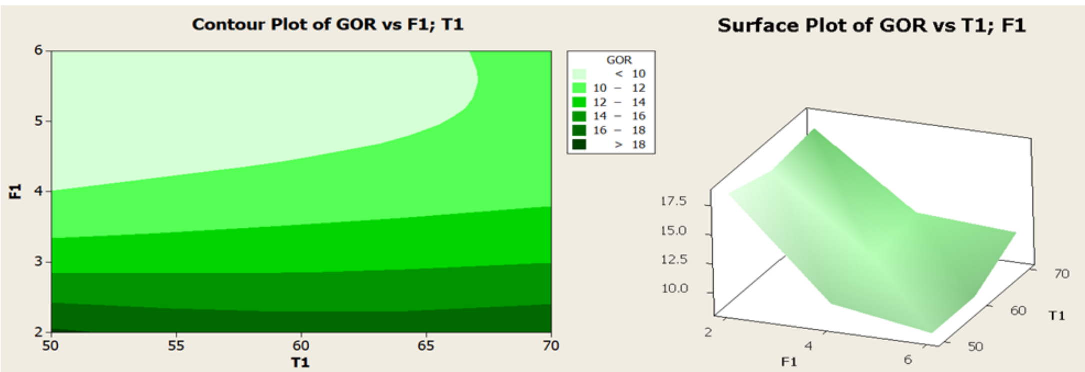

Fig. (7): The efface of feed temperature and feed flow rate on GOR by surface and contour plot

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To evaluate the thermal performance of the AGMD process by study the GOR, it is represented by the equation:

$$GOR = \frac{1000 \times F_p \times H_{fh}}{F_f \times Cp \times \Delta T} \qquad (3)$$

Where Cp and Hfg are heat capacity (KJ/Kg.C) and latent heat of vaporization (KJ/Kg) of water respectively [21]. Figure (7) showing the effect of feed temptation and flow rate on GOR value its obtain the slightly for GOR value with an exchange of temperatures and low and medium value of flow rate and decrees with heist vale of temperatures and flow. And achieve of controlling of flow rat on GOR with rising on lowering feed flow rate by increasing the residence time of feed and heat transfer.

4. Conclusions:

A successful use for commercial PTFE 0.22 μm in AGMD process for desalination of associated oil water production has been gained salt rejection up to 99.9% and neutralized the pH value to reused a large amount of water in a huge rang industry and get optimum ruing to reduced energy consumption with the possible implementation waste industrial or renewable energy and low-cost material.

The feed temperature has been given a major effect on the permeate flux production but it is useful in controlling the temperature in the medium range and rising the feed flow rate to get high thermal performance and useful value for GOR. The response surface optimizing gotten a high value of response for permeate flux 29.975 Kg/m2 h by feed temperature 70 C and feed flow rate 6 L/min.

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