NEW HEAT RECOVERY SYSTEM THROUGH AGR-FO INTEGRATION UNITS FOR SAVING ENERGY AND WATER TREATMENT

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Abstract- A novel integration between Acid Gas Removal (AGR) and Forward Osmosis (FO) regeneration system is proposed to reduce the energy consumption in both systems: in the AGR and FO regeneration unit. This process utilizes Ethanol (EtOH) as a draw solution coupled with n-pentane as a low boiling point agent. A low boiling point light hydrocarbon immiscible in water is used to facilitate the separation of ethanol-water mixture at low operating temperature. The light hydrocarbon is used as a cross component between AGR & FO units; it is used to reduce AGR energy consumption and ensuring smooth operation by replacing the circulated lean amine conventional cooling equipment "air cooler and trim cooler" with a new economizer, where the light hydrocarbon (n-pentane) is used as the economizer coolant fluid. This work has been developed using Aspen HYSYS V8.8. The results show that the novel integration between AGR-FO process could save 17 to 20 % of new AGR plants capital cost (Capex) due to eliminating some cooling equipments in AGR system.

Keywords-Acid Gas Removal, Forward osmosis, co-processed water, Regeneration, N-pentane, Ethanol

I. INTRODUCTION

The light hydrocarbon such as natural gas (NG) is a key factor in the world's supply of energy for industrial and domestic operations [1] .The harsh drive to develop energy efficiency is causing worldwide energy consumption to slow down. The science and energy mix is shifting in the direction of lower pollutants and less cost driven by environmental needs and process technological advances[2] . Natural Gas is the cleanest source of energy and power [3] . Normally N.G is extracted from oil and gas reservoirs as a mixture of light hydrocarbons and other impurities such as sour gases and sour water[4] . It is called a sour gas when several contaminants such as H_2S and CO_2 are present. Moreover, CO_2 has no heating values, considered as a critical greenhouse gas that causes global warming and reducing the efficiency of several industrial processes in the oil and gas sector [5] . In addition, natural gas sometimes contains other contaminants such as carbonyl sulfide (COS), mercaptans (R-SH), and carbon disulfide (CS_2) [6] [7] . The most critical issue in AGR system is the huge amounts of energy required for regeneration of the rich amine, which is equivalent to 60 to 70% of the total operating cost of the AGR system[8] . As an example, the energy consumption in an amine system using (MEA) was reported to be about 4.2 GJ/tone CO_2 removed [7] , while in piperazine and some developed scrubbing amine systems, the required heat is 2.6 MJ/CO_2[8] . A detailed study was conducted and reported by Abotaleb et al, for improving the acid gas loading by manipulating the amine system [8] Co-produced water is a waste by-product that is produced during gas extraction processing. It is estimated that the oil and gas sector produces about 14 billion bbl. of co-produced water annually[10] [11] . The present proposed process technology is suggested to integrate a FO and AGR unit in a closed cycle system using a low energy technique for FO draw solution (DS) regeneration. The AGR unit is used to provide a source of heat for FO-DS separation unit. The separation of ethanol-water mixture is energy intensive[12].Therefore, a low energy consumption process is suggested to regenerate the agent that is diluted through the FO process. The ultimate aim of this study is to develop a new waste heat recovery system through AGR-FO integrated units with minimal modifications to reduce the energy consumption in the AGR and FO regeneration unit.

II. INTEGRATED AGR-FO

This proposed system uses light low boiling point hydrocarbons (n-pentane), a new direct contact absorber and new economizer (plate-plate Heat exchanger), where n-pentane is the cross component between AGR & FO plants. N-pentane is used to reduce acid gas removal plants energy and provides heat for FO regeneration unit as well as ensuring smooth AGR system, n-pentane is used as the economizer coolant fluid. It is fed from the pentane tank as a vapor at (34°C) and slight positive pressure to cool lean amine after interchanger from (84°C) to the optimum lean amine temperature (52°C) before entering acid gas contactor. The heated pentane (75°C) is then transferred to water treatment plant "low-energy osmotically driven Forward Osmosis (FO)" specifically the draw solution separation section by absorbing ethanol from the diluted draw

solution in a new absorber column to produce high quality treated water.The Absorber column has ten to twelve theoretical stages where n-pentane is entering from bottom and diluted draw solution from FO to absorber top space at 25-30 ◦C in a liquid state. Absorber bottom product is pure water with ethanol concentration less than 3.5E-06 ppm, wt. and very minor pentane while the top product is a mix between n-pentane and ethanol with ethanol concentration less than 2.8% wt. furthermore, the ethanol will be recycled to draw solution tank and n-pentane to pentane tank as can be seen in fig (1).

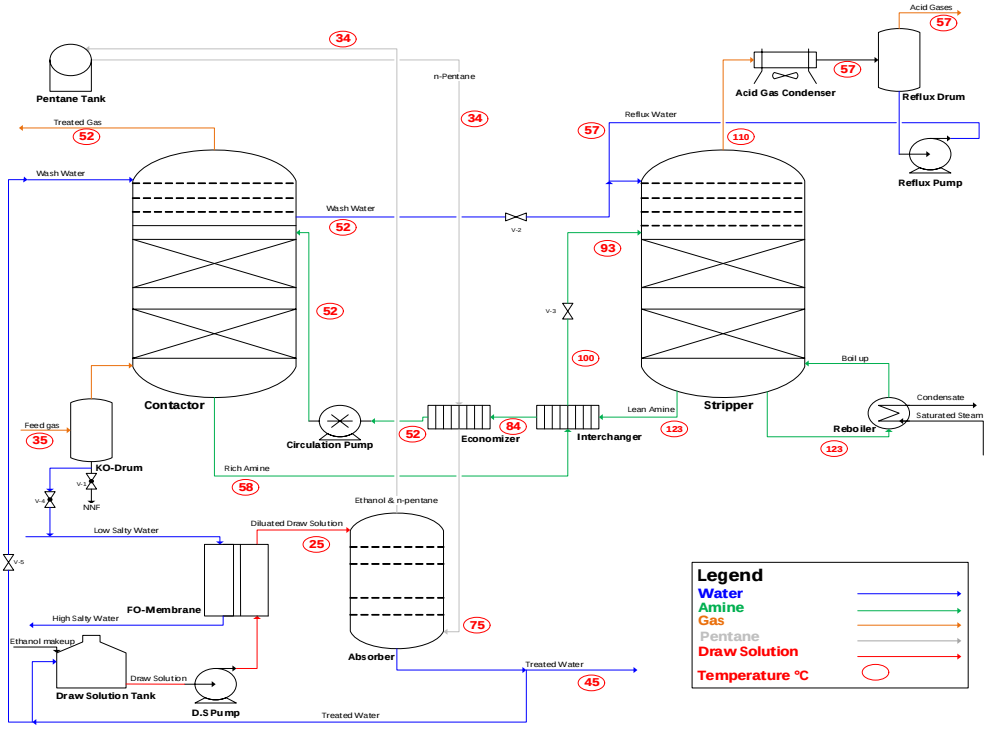

Figure 1. Hybrid AGR-FO schematic process flow diagram

III. RESULTS AND DISCUSSIONS

A technical simulation study has been conducted to ensure an efficient separation by finding the optimum n-pentane to diluted draw solution mass ratio. The study started from the mass ratio ranging from 1:1 to 10:1 n-pentane to diluted draw solution. It was found that, to separate the majority of ethanol from water, the n-pentane ratio must be higher than 3.76. Moreover, it is confirmed that increasing the pentane ratio higher than 4:1 have no significant change on the ethanol separation process. Hence, the optimum mass ratio is 4:1. The ethanol is highly soluble in water, but it is immiscible in water when mixed with light hydrocarbons such as n-pentane. Therefore, it is possible to exploit this property to extract the ethanol from water without adding any heat in the proposed absorber column. However, the process is based on the competition between water and hydrocarbon to bond with the ethanol. The high mass of n-pentane in the diluted draw solution increases the chance to form n-pentane-ethanol mixture, leaving aqueous solution with very low ethanol concentration as the absorber bottom product. Moreover, the immiscibility of n-pentane in water assists the water separation. A 75 to 80 % by wt. of absorber inlet diluted draw solution could be recovered as a bottom product “Treated Water” with ethanol concentration less than 4.0E-06 ppm, wt. and nil pentane. As can be seen in table (1).

Table 1. Summary of process parameters and results.

Process Efficiency Parameters			Mass Ratio	Temperature	
Treated Water Recovery (%)	Ethanol Conc in Treated Water (ppm,wt)	Ethanol Fraction in mixture (Mass %)	n-Pentane/ Draw Solution	Treated Water (°C)	Ethanol Top Product (°C)
75 -80%	4.0E-06	2.841%	4:1	45	33.82

CONCLUSIONS

This novel process provides a new integration concept of acid gas removal plants with water purification “Forward Osmosis” to eliminate the energy required in cooling the circulated lean amine, ensure smooth operation at summer times, reduce new plants capital cost, reduce electrical and utility consumption and purify the wastewater with minimal thermal energy requirements. This novel process facilitates water-ethanol separation with a projected separation efficiency >80% of ethanol from water; a 75 % by wt. diluted draw solution could be recovered as a high quality treated water with ethanol concentration less than 4E-06 ppm, wt. and no

pentane. It conclude that the process is promising and it could help making the water desalination using Forward Osmosis commercially applicable and viable at low capital and operating cost.

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