TO: Texas Hazardous Waste Research Center)

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SUBJECT: Final Project

PROJECT NUMBER: 513UTA0036H

PROJECT TITLE: Coupling of Produced Water Treatment and Flare Recovery in Unconventional Oil and Gas Production

PROJECT PERIOD: 9/1/13-8/31/14

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Project Description

This project aims to investigate the water-energy nexus in waste water management and to develop strategies that can collectively address the water management issue and reduce the amount of wasted flared gas in natural gas extraction. Hydraulic fracturing is a process used in the extraction of shale gas that generates an enormous amount of water. Once an injection cycle has been completed, the hydraulic pressure is reduced, and a cocktail of fluids are returned to the surface. These fluids include not only the extracted gas but also waste waters, which are by far the largest volumes of byproduct streams associated with natural gas exploration. T he economic productivity of shale gas reservoirs depends heavily on the success of its management and development of cost-efficient water treatment technologies for these waters.

Gas flaring is another harmful byproduct associated with hydraulic fracturing. These flares were originally designed as precautionary measures for over-pressurized equipment [3]; however, a great deal of the gas flaring observed today has little to do with emergency prevention but rather with shale production economics, especially at a well site's initiation. Gas flaring is extremely common in areas lacking proper gas processing plant capacity and gasline infrastructure. Additionally, the low value of gas as compared to oil minimizes the incentive to truck the gas using more valuable oil. Naturally, there is a growing commercial interest in recovering and utilizing the heat energy lost during gas flaring.

Hydraulic fracturing, the process most responsible for the boom in the shale gas industry, generates an enormous amount of water. These waste waters are the largest volumetric byproduct streams associated with the fracturing process. Only a fraction of these waters are treated and reused, while a great deal is disposed in injection wells or as surface discharge. Another environmental complexity associated with hydraulic fracturing involves the flaring of gas, an embodiment of increased carbon dioxide emissions and wasted energy. This project aims to investigate the water-energy nexus and to develop a strategy that can address both the water management and reduction of flared gas issue using an optimal design of a produced water treatment system.

Objectives

This project proposed a management scheme that couples the treatment of produced waters while also harnessing the flared gas energy. In this synergetic system, the flaring of gas, which would otherwise function as excess wasted heat, would provide the energy to propel the water treatment process. The resulting treated water can then be recycled as injection fluid for the next hydraulic fracturing cycle.

Shale gas operators must make an important water management decision based on the economics of desalination and choose when to recycle by treating and reusing and when to dispose. Due to possible high salinity of produced water, selecting the appropriate desalination technology is key to the development of a synergistic strategy. There is a wide variety of desalination technologies available, including thermal, membrane, and other types. This study examines membrane distillation, a cost-efficient method for desalination that can operate at low temperatures and utilize energy from waste heat, such as flared gas. The ultimate objective is to provide a computational framework for the cost and energy requirements of the membrane distillation system.

Methodology

This particular study will use membrane distillation, an emerging desalination technology that can utilize low-grade heat sources like flared gas to drive mass transport, for the conceptual process design. Future avenues for exploration in these preliminary simulations are a must and will include investigations into energy efficiency and water production costs associated with different operating variables. This preliminary simulation of the membrane distillation process, constructed in both MATLAB and Aspen Plus, will examine the effect of different operating variables, energy requirements, and a cost assessment.

Accomplishments/Problems

A preliminary MATLAB simulation of membrane distillation suggests that the module is most effective when operating at the highest allowable feed inlet temperature. A preliminary flowsheet of a multistage operation was also constructed in Aspen Plus. This simulation is characterized by 10 stages and composed of a series of feed flash-evaporation and absorption blocks. The recovery ratio, a system performance indicator, was found to be 4.1%. This recovery ratio is relatively high compared to reported recovery ratio of solar powered membrane distillation systems that ranged from 1-4.5%, as seen in the table below. The recovery ratio of 4.1% thus lies in the upper range of recovery ratios obtained from single stage membrane distillation systems previously tested in literature and indicates a high conversion of brine feed to permeate waters.

Performance indicators of solar powered membrane distillation systems.

System	Gran Canaria, Spain (compact system)	Gran Canaria, Spain (two-loop system)	Alexandria, Egypt	Irbid, Jordan	Aqaba, Jordan	Freiburg, Germany	Hangzhou, South China
Recovery ratio (%)	1–3.5*	4–5*	0.5–2*	4–4.5*	2–5	3.5–6.5*	0.25–1.5*
Performance ratio (kg/MJ)	0.1–0.85*	N/A	0.3–1.5*	N/A	0.2–0.3	N/A	N/A
GOR	3–6	3–6	0.97*	0.3–0.9	0.4–0.7	2–3.1*	0.85*
Thermal energy consumption (kWh/m^3)	N/A	180–260	N/A	200–300	200–300	N/A	7850

Performance indicators of solar-powered membrane distillation

Future Work

Future plans are focused on developing ASPEN modules for other water treatment systems to help identify the optimal approach to treatment of the produced water for various produced water conditions. These processes include reverse osmosis and capacitive deionization technologies.

List of Publications and Presentations

Xu, L. A Preliminary Simulation of Membrane Distillation for Treatment of Hydraulic Fracturing Produced Waters, MS Report, Department of Civil, Architectural and Environmental Engineering, University of Texas, Austin, Dec 2013.