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EXECUTIVE SUMMARY

Natural gas is marketed on the basis of its heat content (950 BTU/cu ft or higher). U.S. pipeline specifications vary but generally require nitrogen (N_2) to be less than 5% resulting in 32 tcf (17% of known reserves) to be categorized as low-BTU “sub quality”. N_2 is thus a major target for removal to upgrade natural gas to pipeline quality. A significant portion of the nation’s N_2-rich low-BTU gas is trapped in modest to small fields owned by stripper operators, or isolated behind pipe. These small fields are not amenable to upgrading technologies such as cryogenic separation and conventional pressure swing adsorption (PSA) because these fields cannot usually deliver the large feed volumes necessary for profitable operations of these types of technologies.

In an attempt to encourage economically viable upgrading of low-BTU gas from stripper wells, a demonstration project that encompasses the planning, design, construction, operation, and optimization of an easily built, low-cost, 2-tower micro-scale PSA plant for N_2-rejection using non-patented processes and commonly available equipment is proposed. User-friendly public-domain or inexpensive well-analysis software will determine likely feed volumes (anticipated to be from 40 to 200 mcfd) which, in turn, will dictate the size of key components in the plant. The proposed plant will use easily obtained and inexpensive activated adsorbent charcoal. It will be designed to be mobile and scalable, with skid-mounted units being attached or detached depending on input volumes. It will have a small environmental foot print (400 sq. ft) and will produce no volatile organic compounds (VOCs). Labor and maintenance costs for the plant are anticipated to be minimal, for it will have few moving parts (<10) outside the engine and compressor, and will not require more than two daily visits by the operator.

This project is a joint effort by the Kansas Geological Survey and American Energies Corporation (a company that primarily operates stripper wells in Kansas). The project along with technology transfer workshops (to be scheduled upon completion) will show that stripper gas well operators can easily build micro N_2-rejection plants for about \$100,000, operate it at attractive rates of return (of at least 40%), and significantly add (~1 tcf) to the nation’s reserves.

1.0 TECHNOLOGY OVERVIEW

1.1 How proposed technology is different from existing technology? - The main objective of this proposal is to design and demonstrate a patent-free, micro-scale pressure swing adsorption (PSA) plant, with economics tailored to small, shallow, low-BTU gas fields. Most commercial PSA plants being offered for sale or rent have 3 or 4 towers with patented adsorption beds and purge cycles and are economic at feed volumes between 500 mcfd to 20 mmscfd. We propose a smaller type of design - a 2-tower system with two adsorption beds. Instead of using patented purging technology and surge towers, our system will use pressure equalization by pause with vent gas, and a discharge gas accumulator to hold and blend desorbed methane (CH_4) from 2 cycles. Our proposed design is simple and easy to build and has less than 10 moving parts outside the engine and compressor. It will utilize readily available palletized activated carbon made from coconut husks to adsorb CH_4. The design is intended for low pressures (less than 100 psi) and low volumes (between 40 mcfd to 200 mcfd), and these operating conditions are anticipated to result in longer-life of the adsorption bed and minimal dust emission that could fowl the vacuum compressor. The process will upgrade natural gas to a uniform composition with a heating value of ~975 BTU per standard cubic foot (BTU/cu ft) and <4% nitrogen (N_2). Our micro-scale plant is intended to be modular, so-that skid-mounted units can be linked together to work in parallel in times of high feed volumes and can be individually removed when production declines. Conversely, conventional plants tend to be large-sized and are generally beyond the investment means and risk tolerance of stripper gas operators. They are less amenable to scale-ups or scale downs.

1.2 Is existing technology covered by existing patents? - To our knowledge, the proposed process and its components are not covered by any existing patents.

2.0 PROJECT DESCRIPTION

2.1 Statement of the Problem - U.S. reserves of natural gas are about 204 tcf (Energy Information Administration, 2006). “Subquality” gas (i.e., >2% CO_2, or >4% N_2 or total noncombustible gas) may constitute as much as 17.5 tcf of reserves in the Mid-Continent, 9 tcf in the Rocky Mountain region (Hugman and others, 1990), and 60 tcf (Lokhandwala and Zammerille, 2006) in the US. Overall, 33% of the 1253 gas analyses recorded in Kansas in the last 50 years are low-BTU (<950 BTU/cu ft) (Newell, 2007). Low-BTU gas is more common in Permian and Upper Pennsylvanian reservoirs in Kansas, but it is found in reservoirs of all ages and lithologies (Newell, 2007). In the Mid-Continent, the great majority of low-BTU gas is caused by the presence of N_2 (Beebe, 1968; Jenden and others, 1988). Nationwide, 17% (>32 tcf) of known gas reserves are “subquality” due to N_2 contamination (Lokhandwala and Zammerille, 2006). Approximately 10% N_2 by volume is sufficient to degrade a dry natural gas (at ~1060 BTU/cu ft) below 950 BTU/cu ft, thus making it unacceptable for pipeline sale.

Much of today’s gas production is from large, accessible fields. In such fields, any low-BTU gas that may be present can be processed in large, centralized upgrading facilities, but such economy-of-scale is not feasible for smaller and often isolated fields. A significant part of N_2-induced low-BTU gas lies trapped in modest to small deposits owned and operated by small independent producers and stripper well operators (Lokhandwala and Zammerille, 2006). To meet the long-term demand for natural gas, much of the new production will have to come from small and remote fields, many containing low-BTU gas. At present, most of this low-BTU gas is either shut-in behind pipe or simply abandoned as it cannot be burned locally or blended with readily available higher-BTU gas. We therefore believe that development of inexpensive N_2-rejection technology, designed for low-volume, low-pressure, low-BTU gas wells, will significantly increase the contribution of stripper gas operators to the nation’s gas supply.

2.1.1 N_2-rejection Technologies – Feed volumes largely govern the technology employed to upgrade low-BTU gas. Cryogenic separation is favored for large input volumes (>5 mmcfd), while conventional pressure swing adsorption (PSA) or temperature swing adsorption (TSA) processes are applicable for gas volumes from 0.5 to 20 mmcfd. Adsorbents such as silica gel, activated carbon, and alumina are employed to adsorb larger hydrocarbon molecules while zeolite targets the smaller N_2 molecule. For smaller gas volumes, lean oil and metallic solvents can respectively absorb hydrocarbons and inert elements. A relatively new process using membrane separation technology is currently under testing.

2.2 Objectives of this Project – Conventional multi-tower PSA systems are expensive to design and build, use proprietary technology, and are economic at feed volumes in excess of that normally produced by stripper wells. Thus, the primary objective of this research is to demonstrate the economic viability of a 2 tower micro-scale N_2-rejection plant (using PSA), free of patented technology and constructed with off-the-shelf, non-proprietary industrial components to upgrade low-BTU feed volumes (less than 200 mcfd) typical of small and shallow fields. We will demonstrate how to utilize user-friendly techniques and commonly available software to make robust estimates of well deliverabilities and decline rates in order to properly size the micro-scale N_2-rejection plant. Finally, lessons learned from this project will be freely disseminated to the stripper well community through workshops, publications, and maps showing N_2 rich low-BTU reserves in Kansas.

2.2.1 2-Tower Micro-Scale PSA-based N_2 Rejection System – The Kansas Geological Survey (KGS) in partnership with American Energies Corporation (AEC) proposes to design, build, operate, and optimize a 2-tower micro-scale PSA-based N_2-rejection system, which will be free of any patented components. We plan to use a commonly available palletized activated carbon made from coconut husks as adsorbent to insure long bed life and to minimize dust fowling problems in the vacuum compressor. Activated carbon has a large surface area between 300 and 4000 m^2/g. Pore-diameter sizes ranging from 10 to 25 angstroms allow adsorption of relatively large CH_4 molecules, while smaller molecules such as N_2, He, O_2, H_2, and CO pass through unhindered. Heavier hydrocarbons, as well as H_2S, CO_2, and H_2O, are also adsorbed by the activated carbon, but these can be pretreated and removed to meet gas specifications and enhance bed life. The adsorbed CH_4 will be regenerated by pulling a strong vacuum on the activated beds, thus yielding a sales stream with high concentration of hydrocarbons and only minor (2 to 4%) N_2. Conversely, the vent stream is N_2-rich with little CH_4 and has no volatile organic compounds (VOCs).

The 2 towers will be approximately 4 ft in diameter by 8 ft in height, connected by 2 in piping. Raw feed volumes of 150 mcfd, composed of 70% CH_4, 25% N_2, 3% heavier hydrocarbons, and 2% other noncombustible gas, are anticipated to yield saleable gas volumes of 100 mcfd at ~975 BTU/cu ft. It is expected that about 5% of CH_4 will be vented with the effluent gas stream, while 4 to 5 % will be used as fuel for the compressor engine. The low feed pressures of the plant (~50 psi) will minimize any hydrate formation. All building materials used in the plant will be made of carbon steel, and all instruments and control valves will be made of low-cost cast iron rated at 125 psi, thus ensuring widespread availability and easy replacement of parts. A discharge-gas accumulator will be incorporated to ameliorate the ten-fold variation in instant gas volume output during each regeneration cycle, and will be designed to retain the CH_4-rich gas produced from two complete cycles, so that a blend of gas with uniform composition (<4% N_2 and ~975 BTU/cu ft) can be produced for the sales stream. The number of moving parts outside engine and compressor in our design is less than 10 and this significantly reduces maintenance expenses.

2.2.2 Cycle Time Optimization – One of the critical objectives of this project is to outline protocols necessary for optimize the plant by determining the shortest cycle time that results in maximum CH_4 recovery. We will selectively vary parameters such as inflow rates, cycle time, and adsorbent quality to minimize bed degradation, compaction, and heaving, and maximize CH_4 recovery at minimum energy consumption. A hotwire (with alarm) will be placed on the vent line to continuously telemeter adsorption efficiency (or CH_4 breakthrough) in effluent gases, and this data will be used to optimize cycle time.

2.2.3 Plant Scalability – Many low-BTU gas fields in the Mid-Continent are small and prone to rapid production decline. We will size our plant based on deliverability and production decline rates (of feeder wells) estimated by analyzing wireline-logs and 4-point tests using readily available software. The modular design of our plant, consisting of skid-mounted units, provides flexibility to operate at high feed volumes (~200 mcfd), resulting from additional drilling and input from wells with large production, as well as at low volumes (~40 mcfd) during production decline. Skid-mounted units can be easily linked or detached to process varying volumes of gas.

2.2.4 Operating Economics - At feed volumes of 40 to 150 mcfd and current gas prices of $5/mscf, our proposed plant is expected to generate a net monthly income varying from $4,500 to $11,250. The initial investment to build this plant is anticipated to be about $100,000. In contrast, conventional multi-tower PSA systems normally cost at least 3 to 5 times that of our micro-scale plant.

2.2.5 Previous Funding of Proposed Work - To our knowledge, the proposed 2-tower micro-scale PSA-based N_2-removal system for low volume wells has not been funded elsewhere. To date, no such systems are operating in Kansas.

2.3 Expected Significance of the Research - A successful demonstration of our micro-scale N_2-rejection plant, followed by several technology-transfer workshops and on-site (field) inspections, will enable hundreds of stripper-well gas producers to exploit known reserves from their low-BTU gas fields. In these workshops, stripper-well operators will get a first-hand exposure to: a) fundamentals for designing micro-scale PSA-based systems for N_2 rejection using non-patented components, b) quick and easy techniques for estimating well deliverability, and c) methods for optimizing plant performance. As a part of this project, we also plan to use a field-portable micro gas-chromatograph to analyze natural-gas compositions from across Kansas to identify and map the distribution of the low-BTU gas occurrences. Such a resource map will be invaluable to stripper well operators interested in unlocking the trapped value in their low-BTU gas fields and pursuing newly revealed low-BTU gas plays.

2.4 Work Plan – The following tasks are anticipated as a part of this project:

1. Estimate well deliverability and production decline rates using commonly-used well-testing and log-analysis software; select 2 to 4 wells for the pilot area and apply for necessary permits.

2. Prepare plant site and lay approach roads.

3. Purchase plant components (adsorption vessels, pipes, compressor, control system), assemble it on skids, and move it to pilot site.

4. Install gathering lines and sales-gas lines for plant. Install gauges, telemetry units, and CH_4-break-through hotwire monitor and flare-activated switches in the vent gas line.

5. Build portable shelter for plant, charge adsorption beds, and pressure-test equipment to 125 psi.

6. Start and optimize performance of plant by adjusting cycle time and flow rate, and using different adsorption-beds so that CH_4 sales are maximized and energy use is minimized. At anticipated initial feed rate of ~150 mcfd, we estimate production of ~100 mcfd of upgraded gas.

7. Re-evaluate well deliverability using decline-curve analysis to better estimate economic life of project. Disseminate knowledge gained in designing, building, and operating the plant through publications, technology-transfer workshops, and field trips for stripper-well operators.

8. Analyze deliverability of nearby gas wells in preparation of Phase II (outside this project), and sample low-BTU gases from other areas to evaluate potential for micro-scale N_2-rejection operations in Kansas.

2.5 Facilities and Major Items of Equipment Available – The Elmdale field, a low-BTU gas area operated by AEC in Chase County, KS, will be the site for our proposed plant. This field is composed of Permian and Middle Pennsylvanian pay zones (at <1200 ft depth) on the Nemaha anticline. The KGS has the commercial (Fekete's RTA and WELL TEST) and in-house developed, publicly available software (Pfeffer) necessary for estimating well deliverability. The KGS is purchasing a portable micro gas-chromatograph, which will be utilized for optimizing plant performance and analyzing gas compositions elsewhere in the Mid-Continent.

3.0 PROJECT SCHEDULE

The project schedule enclosed below is designed so that our proposed micro scale plant becomes operational before the onset of winter (i.e., by October 2007) in order to avoid problems related to construction and movement of equipment in freezing weather.

		2007 --------------------------->					2008 --------------------------------------->						
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Task 1	**Shortlist wells and evaluate their deliverability potential**												
	1.1 Analyze wireline logs and DST data												
	1.2 Use well testing software to model well deliverability												
	1.3 Shortlist 2 to 4 wells for project												
	1.4 Apply to KCC (and KDHE) for necessary permits												
Task 2	**Prepare plant site**												
	2.1 Prepare pad and build approach roads												
Task 3	**Purchase Equipment & Assemble Unit**												
	3.1 Acquire used vessels, pipes, and new control system												
	3.2 Assemble plant as skid mounted unit												
	3.3 Move unit to plant site												
	3.4 Purchase compressor and set up for use												
Task 4	**Lay gas transport system**												
	4.1 Install gas gathering lines - wells to plant												
	4.2 Install sales gas line to pipeline												
	4.3 Install gas gauges (meters) and telemetry												
	4.4 Install flare in vent gas line												
	4.5 Install CH4 breakthrough HOTWIRE monitor - vent gas line												
Task 5	**Complete building plant and connect to with pipelines**												
	5.1 Build a portable housing for plant												
	5.2 Charge Adsoprtion Beds												
	5.3 Connect piplelines to plant												
	5.4 Pressure test every component connected to flow												
Task 6	**Start up plant and optimize operational parameters**												
	6.1 Start-up plant												
	6.2 Optimize plant performance												
Task 7	**Transfer of technology & best practices**												
	7.1 Re-evaluate well deliverability using decline curves												
	7.2 Summarize best practices												
	7.3 Conduct technology workshops & publish results												
Task 8	**Regional resource evaluation**												
	8.1 Analyze neighboring fields/wells - for Phase II												
	8.2 Sample low-BTU gas from all over Kansas												
	8.3 Map potential for N2 rejection of low BTU gas												

The first major milestone will be starting the plant (Task 6.1). The second major milestone (Task 6.2) will be to optimize the plant performance such that maximum CH_4 is recovered by expending the least energy. The final milestone (Task 7) that we expect to achieve upon operating the plant for 10 months (from October 2007 to July 2008) is the transfer of technology, best practices, and lessons learned in designing, building, and running a micro-scale N_2 rejection plant to independent operators through workshops and publications.

4.0 ANTICIPATED RESULTS

4.1 Significant Production Improvement from low-BTU Stripper Gas Wells – A significant portion of the known gas reserves in the US, i.e., greater than 32 tcf is considered “sub quality” due to N_2 contamination (Lokhandwala and Zammerille, 2006), and much of this “sub quality” gas remains unproduced in small low-BTU fields. In this context, a less expensive N_2 rejection technology, such as that proposed by us, will play a critical role in unlocking the trapped assets from small sized, low volume, low-BTU gas fields that are largely owned and/or operated by stripper well operators, and thereby increase significantly the proportion of low-quality gas in the nation’s gas supply. Cost-effective upgrading of low volume N_2-rich low-BTU gas could add an additional 1 tcf to US reserves (Lokhandwala and Zammerille, 2006).

4.2 Reduction in Operating Costs – Once optimized, our plant can run unattended about 95% of time requiring no more than two operator visits a day. Only monthly compressor maintenance and sorption bed level maintenance are required. Our proposed design includes less than 10 moving parts (outside engine and compressor) thus minimizing maintenance and labor costs.

4.3 Minimal Environmental Impact - The plant does not require commercial electric power to operate and can be installed in any remote location. The compressor engine runs on feed gas (~750 BTU/cu ft) and charges the batteries that supply electricity to the unit. Solar panels power the solenoids and the flare igniter in the vent gas line. Where power is available, it can be used to power lights for night and winter operation. Quality control of adsorption process is maintained by observing the flare in the vent gas line, and from alarm signals sent from the hotwire CH_4 detector. When the cycle time gets too long, a large flare occurs and the cycle timer is reduced to prevent CH_4 break through. Besides CH_4 the heavier hydrocarbons as well as H_2S, CO_2 and H_2O are also adsorbed, and thus the vent gas contains little CH_4 and no volatile organic compounds (VOC’s). The compact design minimizes environmental footprint to about 400 square feet. Upon production depletion, the skid mounted plant can be moved to another site and reused.

4.4 Commercialization Viability of the Proposed Research - One of the critical aspects of this proposed project is to demonstrate that a small independent company like the AEC, which primarily operates stripper wells in Kansas, can scale, design, build, and operate a micro-scale 2-tower PSA plant using non-patented technology and without help from design companies who charge about a 1/3rd mark up. Upon completion of the project, KGS will undertake technology transfer workshops for stripper well operator community detailing: a) commonly used techniques to estimate deliverability of low-BTU wells, b) a step-by-step guide to scale and design the micro-scale plant based on expected input volumes, c) best practices for optimizing cycle times, and d) plant maintenance protocols. Free sharing of our experiences with this project will enhance the learning-curve of stripper gas operators such that they can build and operate these micro-scale plants on their own or with limited outside help using readily available activated carbon beds, equipment, and instrumentation. Even when parts of the plant are purchased from vendors, it will be the lowest cost option to bring the low volume, low BTU gas to the market. Our proposed design will be commercially viable for stripper well operators because no patented technology is necessary, capital costs are low, and returns on investment are attractive.

4.5 Specific Groups to Use Projected Results - This project will enable stripper gas operators to economically produce their orphan low-BTU reserves. In areas where no pipeline market exists the resulting fuel grade gas could be used for electric power generation, or as fuel for engines for oil & gas or other operations. Vent gases with Helium concentrations of 10% or higher can be compressed to 3000 psi and trucked to Helium (He) purification plants. Jenden and others (1988), and Newell (2007) have reported that N_2 and He in Mid-Continent natural gases are commonly found in a fixed ratio to each other (~15:1 to 35:1) and increases with decreasing age of the pay zone. At current prices, He is a very valuable by-product that will enhance the project economics of our proposed 2-tower micro-scale N_2 rejection plant. Also, N_2 rich vent gas can be used for pressure maintenance in oilfields and as instrument gas.

5.0 PREVIOUS SWC FUNDED PROJECTS

The KGS and AEC have not received any funding for this or any other project from the SWC.

6.0 RELATION WITH COMPARABLE WORK IN PROGRESS

Membrane Technology and Research Inc. is currently conducting research to commercialize N_2-rejection from low volume gas streams using membrane technology with funding from the U.S. Dept. of Energy (Lokhandwala and Zammerille, 2006). McCoy Petroleum, an independent operator from Kansas, has built a cryogenic N_2-rejection plant to process 5 mmcfd of feed gas from several small fields in eastern Hodgeman and Ness County. Unfortunately, rapid production decline has made this plant uneconomic at present, and this highlights the importance of properly estimating well deliverability and decline rates in designing these plants and the need for plants that are scalable when taking feed from stripper gas wells.

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