Mature Assets: Low-cost plant upgrades marginal gas fields

A new micro-scale, low-cost nitrogen rejection plant can now upgrade low-BTU gas and improve marginal fields.

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Published Aug 15, 2008

The micro-scale PSA upgrade unit at Elmdale field, Chase County, Kansas, is designed to handle up to 250 Mcf/d. The two towers are the vessels in which activated charcoal is placed to upgrade low-BTU feed gas using PSA (pressure swing adsorption) process. The surge tank that accepts the sales gas is in the background.

Natural gas is marketed to pipelines partly on the basis of its heat content. Nominally, 950 BTU/cf or greater is considered as pipeline quality.

Noncombustible gases, mostly nitrogen (N_2) and carbon dioxide (CO_2), reduce heating value and need to be removed before the gas is sold. The United States contains an estimated 204 Tcf of natural gas. Low-quality gas reserves, containing greater than 4% N_2, are estimated at 60 Tcf. There is an estimated 17.5 Tcf of low-BTU reserves in the Mid-continent and 9 Tcf in the Rocky Mountain region.

Large volumes of low-BTU gas from big fields can be processed in large volumes in centralized processing plants using conventional technology. However, significant volumes of N_2-induced low-BTU gas reside in marginal fields owned by small operators with limited financial and technical resources. Such production is often characterized by low feed volumes and pressures, remote locations, and rapid declines. Most of these reserves will not be produced if the gas cannot be used on site.

New production from small, marginal fields containing low-BTU gas may help meet the demand for natural gas in the

United States. To encourage upgrading of marginal low-BTU gas, a simplified two-tower micro-scale pressure swing adsorption (PSA) plant for N2-rejection was designed and constructed. This project is a joint effort by the Kansas Geological Survey (KGS) and American Energies Corp. (AEC) using a grant from the Stripper Well Consortium administered by Pennsylvania State University.

Available technologies

Feed volumes and gas chemistry govern the technology employed to upgrade low-BTU gas. Cryogenic separation is favored for substantial input volumes (greater than 5 to 7 MMcf/d) and is used to both upgrade gas and recover helium in centralized processing plants from large gas fields. Conventional PSA or temperature swing adsorption (TSA) is economic for lower feed volumes between 0.5 to 20 MMcf/d. However, such plants are expensive to build and uneconomic at feed volumes of 250 Mcf/d or less.

To handle small feed volumes, technologies such as adsorption by lean oil, metallic solvents, and membrane separation are in various stages of development, but these methods have not yet seen widespread application.

The adsorbent in the PSA unit discussed in this article is inexpensive and commercially available as granular activated charcoal made from coconut husks. It has a propensity to adsorb both methane (CH4) and N2, but CH4 is more readily adsorbed than N2. Once adsorption is complete, the remaining free gas in the adsorption vessel (now dominantly N2) is purged from the vessel by venting. Then, with a reduction of pressure in the vessel, the gas adsorbed on the activated carbon (dominantly CH4) is desorbed and produced as upgraded gas with a BTU substantially greater than the feed gas.

Plant description

Our plant is located in the Elmdale gas field, Chase County, Kansas. This and other nearby fields are multiple-pay structural traps on the Nemaha uplift, containing unassociated gas with heating values as low as 650 BTU/cf at wellhead pressures less than 75 psi.

The plant (Figure 1) has two towers made of carbon steel, each four ft (1.2 m) in diameter and 8 ft (2.4 m) in height, that alternate between adsorption and desorption phases. Activated carbon used to charge the towers was purchased in 1,100 lb bags costing about 7 cents/lb. Feed gas, after passing through a scrubber to remove moisture, enters the plant through a 2-in. line. Electronically controlled solenoid valves allow the feed gas to flow into one tower for adsorption while isolating the other (already charged) tower for desorption under vacuum. A small fraction of the feed gas is used as instrument gas. Hatches at the base of the towers facilitate cleanup and removal of spent bed.

A six-cyclinder 50-HP VGG-330 gas-fired engine, fueled by low-BTU feed gas, drives a compressor modified to run a strong vacuum on the desorption tower. The desorbed (upgraded) gas is cleaned by the gas scrubber before entering the compressor via a 3-in. line. The compressed gas passes through a condensate removal tower before flowing into a surge tank (5 ft diameter and 25 ft long or 1.5 m diameter and 7.6 m) with a holding capacity of one hour so that the sales stream can achieve a uniform upgraded composition greater than 950 BTU/cf.

Plant performance

For performance optimization, the plant was tested under various conditions with best results obtained when the towers were charged to 30 psi, then vented to 2 psi, and finally desorbed to -21 in. Hg (mercury). The towers alternate between adsorption and desorption phases for continuous operation. A feed stream containing from 62 to 66% CH_4+ (i.e., 700 to 750 BTU/cf) was successfully upgraded to 82 to 86% CH_4+ (940 to 990 BTU/cf) by recovering about 70% of the hydrocarbons and rejecting 75% of the N_2. Between 61 to 65 Mcf/d of upgraded gas were recovered from a feed of 117 Mcf/d. At current prices of $10/Mcf, this performance translates to income averaging US $500/day from otherwise unselable gas. This pay-out time of around eight months against a capital investment of $120,000 (cost to build the plant) can be further shortened by using a more powerful compressor that evacuates (desorbs) each tower more quickly, thereby raising throughput.

One critical factor that affects performance is the volume of dead space inside the tower. This dead space contains low-BTU feed gas that makes its way to the sales stream during the desorption process. Being unaware of this, we placed the screen supporting the charcoal bed too high in each tower, thus inadvertently creating significant dead space.

Normal operation also gradually creates additional dead space by bed degradation and compaction during charging and blowing it away during venting. After five months operation without bed refill, the dead space was found to represent 20% of the tower volume, and it impaired the plant performance. AEC has minimized the dead space in its next generation of plants by placing the holding screen as low as possible, by increasing the tower height and diameter, and by placing filters to prevent ejection of carbon from the tower during venting and desorption.

Plant advantages

Simplicity, economy, and compactness (less than 400 sq ft or 37 sq m) were the overarching goals in designing the PSA upgrading plant. The plant uses off-the-shelf industrial components and non-patented processes and adsorption beds to minimize construction and repair costs. There are few moving parts outside the compressor and the engine, and this reduces maintenance expenses. The engine runs on the low-BTU feed so the plant can operate in locations outside the electric grid. The activated carbon is inexpensive and non-hazardous to replace. This scalable plant can be easily dismantled and transported to a new location upon depletion of a low-BTU source, while higher feed volumes can be easily handled with the addition of new skid-mounted units.

Low-BTU resources

Low-BTU gas is common in central and western Kansas (Figure 2). Of 1,257 gas analyses compiled by the KGS, 33% are less than 950 BTU/cf. Poorer-quality gases are more common in younger, shallower reservoirs. Resource evaluation around the plant site revealed the presence of five thin gas-bearing sandstones.

Widely varying gas quality measured from identical zones in nearby wells suggests significant reservoir compartmentalization. Such compartmentalization is expected in this cyclic succession of Upper Pennsylvanian lenticular and pod-shaped, shallow-marine bar and fluvial sandstones. Lateral discontinuity is also indicated by examination of sample cuttings, isopach mapping, cross sections, and petrophysical techniques such as depth profiles of bulk volume water (BVW = water saturation x porosity) based on modern wireline logs.

Sandstone distribution appears to be related to local paleotopography and possibly structural deformation concurrent with deposition. Reservoir characterization is important for proper scaling of tower capacity and minimizing costs, particularly in the Elmdale field where pay zones are discontinuous.

We plan to operate the plant under different conditions to further improve CH_4+ recovery and N_2 rejection, such as varying pressures to which the towers are charged with feed gas (e.g., 10, 20, 40 psi) and pressures to which each tower is vented (5, 10 psi). Operating the towers in series will also be tested using feed gases with as low as 45% CH_4+ and as high as 82% CH_4+ to test the upgrading capacity of this plant.

EDITOR'S NOTE: Updated details about project results can be found at www.kgs.ku.edu/ PRS/Microscale/index.html. For information on the Stripper Well Consortium visit www.energy.psu.edu/swc.