The ability to chemically separate hydrocarbons and alter the composition of hydrocarbon streams can be useful in many oil and gas applications, including NGL production, flare elimination, engine pre-treatment, power generation and recovery, chemicals pre-treatment, etc. Pressure swing adsorption (PSA) technology can be coupled with engines, liquefaction units, compressors, or other upstream/downstream equipment, based on operator needs. Figure 1 shows four potential hydrocarbon separation configurations.

A simple hydrocarbon separation system could be utilised in any application where modified hydrocarbon composition is required. The system can be installed upstream of existing equipment – where heavy hydrocarbon species in methane may be problematic.

The design incorporating hydrocarbon separation upstream of an engine may be useful in environments where power generation is required and when composition is too rich for efficient power generation. Installation of the technology helps power-generating equipment obtain quality fuel gas to maximise

Ross Dugas, The Dow Chemical Co., USA, shares how hydrocarbon separation technology can help with cost-efficient C3+ removal from natural gas streams.
power output. The technology can be installed upstream of existing power generation equipment to recover power de-rating and reduce excess emissions, which result from burning natural gas with excess air.

Hydrocarbon separation with liquefaction can be implemented in areas of stranded gas, where liquid recovery is desirable. In liquid form, NGLs can be transported more easily to a region where they can be utilised. The incorporation of liquefaction technology allows the possibility of recycling liquefaction offgas back to the PSA. The offgas results from the fact that the gas phase heavy hydrocarbon stream contains some methane and ethane. These components will not condense to a liquid in the liquefaction unit. Recycling of offgas allows for valuable C3+ species swept away by the offgas to be recaptured by the PSA. The design can capture essentially all C3+ species as liquids, since heavier hydrocarbon species can be kept from escaping through the top of the PSA.

The PSA receives a feed stream and splits it into two streams: one treated gas stream void of heavy hydrocarbon, and a second tail gas stream concentrated with heavy hydrocarbon (Figure 2). In the simplest sense, the PSA can be viewed as a regenerable heavy hydrocarbon filter. A very low pressure drop is typically observed across the bed (0.3 – 0.7 atm).

The technology was field tested at a US-based customer site in 2016. The unit consists of two 18 in. adsorption beds with 6 ft of adsorbent. The system is compactly mounted on an 8 ft x 8 ft skid. The programmable logic controller (PLC) runs the adsorption/regeneration cycles and relays live process data to a laptop. During the trial, the system typically processed approximately 0.07 million ft$^3$/d with a feed gas ranging from 5 to 10% C3+. The PSA was capable of processing significantly more gas, but other factors not related to the PSA limited throughput.

The pilot unit required very low utility consumption. The hydrocarbon separation unit consumed approximately 2 kW of power and a small amount of instrument air to operate the pneumatic valves. Low utility consumption is a primary advantage of a PSA system compared to temperature swing adsorption (TSA) systems and other competitive technologies.

The field trial was designed to inject pure propane or butane into a pipeline natural gas stream containing hydrocarbon stream into power plus NGLs. This configuration produces no gas phase products, and can offer complete flare elimination. The hydrocarbon separation with liquefaction and engines design can be useful in regions that restrict additional oil production due to excessive flaring. Flare elimination can lead to greater access to oil resources, while producing valuable power and NGLs.

Field trials

The Dow Chemical Co. has developed a PSA technology to remove NGLs or other hydrocarbons from a natural gas or hydrocarbon stream. The modular, skid-based technology utilises a robust polymeric adsorbent, named UCARSORB™ HH Adsorbent, which preferentially picks up heavier hydrocarbons and allows lighter hydrocarbons to pass through the bed. The technology can be tailored to capture and remove C3+ hydrocarbons to meet treated gas specifications. The chemical nature of the adsorbent allows deep capture efficiencies. The hydrocarbon separation technology also allows for flare elimination due to the ability to separate an undesirable hydrocarbon stream into two useful streams.

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approximately 4% ethane. C3+ was vaporised, mixed with natural gas and then compressed to 250 psig. The PSA system then separated C3+ from the methane to create a methane-rich treated gas stream, and a tail gas stream rich in C3+.

The skid was equipped with gas measurement capabilities, measuring hydrocarbon composition from the four sample points of the system. The system routinely removed 90 – 95% C3+ (Figure 3).

It is also important to evaluate technologies for robustness. Industrial applications can be unpredictable, and process upsets routinely occur. During the field trial, a dramatic process upset was created to evaluate the technology’s resilience. Over a 2 hr period, the concentration feeding the hydrocarbon separation unit was varied from 1 to 10 mol%. Despite substantial changes in the feed composition, the technology was able to continually produce a treated gas with minimal C3+. The robust nature of the process is advantageous in process applications that experience upstream process upsets.

After initial commissioning, the system did not encounter any operational issues and ran smoothly throughout the entire trial. Near the end of the trial, earlier experimental conditions were repeated to evaluate adsorbent longevity. No statistical difference was observed in these repeat experiments.

**Applying the technology**

This hydrocarbon separation technology is targeted for C3+ removal and recovery. UCARSORB HH adsorbent was not designed for the efficient capture of ethane, carbon dioxide (CO₂), water or hydrogen sulfide (H₂S), but can partially separate these species. In general, ethane and CO₂ will be retained in the methane-rich hydrocarbon stream. Water and heavy hydrocarbons will exit with the heavy hydrocarbon stream. The destination of other species depends on the adsorbent affinity, as well as the operating strategy of the system. If strict CO₂, H₂S or water separation is required, technology options can be coupled with the system.

An operator may desire NGL production, in addition to treated methane-rich stream. NGL production is often economical for feed gases greater than 10% C3+. The PSA technology can be coupled with liquefaction integration processes to produce NGLs with minimal CAPEX and OPEX. To facilitate designs, Dow has developed proprietary physical and chemical property data sets and simulation methods. The software is dynamic and rigorous in its calculation methods. This offers the opportunity to evaluate the performance of the system and modify either equipment design or process control strategy to perform more efficient separations that incur lower costs. Modelling results were validated by laboratory experiments, laboratory-scale pilot units and field trials.

The rigorous modelling capability allows accurate performance predictions under a variety of inlet gas conditions and treated stream specifications. Figure 4 shows the performance estimates for an operator desiring a lean-treated gas stream and the production of NGL, which can be transported by truck. The hydrocarbon separation technology outlined in this article can help satisfy strict hydrocarbon purity requirements.

**Conclusion**

To effectively monetise natural gas and avoid wasting valuable hydrocarbons through processes such as flaring, oil and gas operators rely on a variety of separation methods. Each method has an optimum application range and the economics depend on multiple factors, including capital costs, operating costs and the values of the separated streams. One approach does not fit all needs, which is one reason Dow developed a new PSA process for treating natural gas to effectively recover C3+ fractions with minimal energy usage. This approach is targeted at engine gas pre-treatment, NGL production and flare elimination, and offers operators another option to cost-effectively treat natural gas.