COMING OUT OF THE ICE AGE

COVER STORY

Margaret Greene (USA), William Dolan (USA), Justin Pan (USA), Al Maglio (USA), Tobias Eckardt (Germany), BASF, and Harold Boerrigter (Netherlands), Marco Smaling (Netherlands), and Imelda Rusli (UK), Shell, detail a dual-purpose adsorbent technology for combined heavy hydrocarbon and water removal from lean feed gas in LNG to prevent cold box freezing.

Lean feed gas to LNG plants is becoming increasingly prevalent as several recent LNG projects are based on pipeline gas which contains predominantly methane with low natural gas liquid (C2-C5) and lower heavy hydrocarbons (C5+) content than typical conventional natural gas.[1] However, the leaner compositions, especially dew pointed pipeline gas, can manifest a small but significant 'heavy tail' of heavy hydrocarbons and BTX which can be challenging to define and remove.

Removal of heavy hydrocarbons (C8+ HHCs) and aromatic (BTX) components from natural gas prior to liquefaction is critical for continuous LNG production. Even trace concentrations of certain HHCs and aromatics can cause precipitation of solids (freezing) and fouling of main liquefaction heat exchangers. For example, even existing LNG plants supplied by relatively lean feeds or experiencing feed gas composition fluctuations often face challenges with currently installed technology to deal with trace heavies in lean feed gas.

A lean feed gas presents many challenges to the conventional heavy hydrocarbon removal methods such as a scrub column and natural gas liquids extraction unit. The natural gas liquid extraction unit is a capital-intensive unit with a high equipment count, and it requires considerable utility demands during operation. With low yields a natural gas liquids extraction unit becomes uneconomical. The integrated scrub column may become unsuitable due to the low levels of C2-C5 components, as there is insufficient liquid traffic within the scrub column to stably operate the unit at available condensing temperatures.

In this article, a line-up study is presented comparing dual-purpose temperature swing adsorption (TSA) technology (Durasorb Cryo-HRU) to conventional processes for the removal of C8+ HHCs from lean feed gas. The analysis will highlight the benefits of the adsorption technology under specified feed gas and operating conditions. The case will be made that dual-purpose TSA technology presents significant benefits, including for dehydration retrofit applications, with regards to reduced complexity, improved CAPEX, ease and flexibility of operation, and reliability. The novelties of the technology are discussed with results from extensive testing, illustrating that the combined HHC and water removal in one system is robust. The specifications for the feed to the main cryogenic heat exchanger (MCHE) of the liquefaction unit – as referred to in this article – are summarised in Table 1.[2]

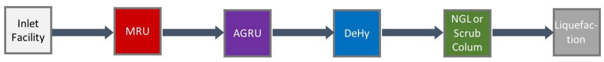

Figure 1. Typical line-up for conventional LNG plant.

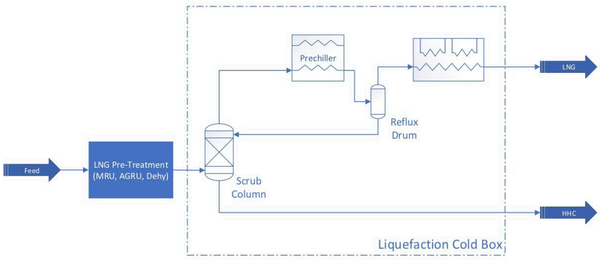

Figure 2. Heavy hydrocarbon (HHC) removal with a scrub column inside cold box.

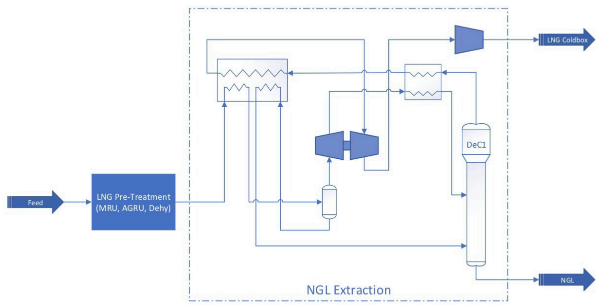

Figure 3. Natural gas liquids turboexpander.

Table 1. Recommended specifications for feed to MCHE

Component	Specification (ppmv)
H_2O	0.1
C5+	< 500 (LNG rundown) < 0.1 molecular% (LNG product)
nC8	< 0.5 (#)
Benzene/BTX (*)	1 - 3
nC9	≤ 0.3 (below the detectable limit)
nC10	≤ 0.3 (below the detectable limit)

(*) Total of BTX components are lumped to benzene, as this is most critical for the adsorption process.

(#) Solubility of nC8 at -162˚C, 60 bara in liquid CH4 is experimentally measured to be <0.5 ppmv.

Conventional line-up

The analysis presented considers the various technologies for the pretreatment of lean natural gas for LNG production. Lean gas, also known as dry gas, is defined as natural gas containing less than 5% liquefiable hydrocarbons.[3]

The typical line-up for a conventional LNG plant with a non-lean feed gas is shown in Figure 1. After the inlet facility, the gas passes through the mercury removal unit (MRU) to remove the mercury, followed by an acid gas removal unit (AGRU) to remove the CO_2 (to <50 ppmv) and H_2S (to <3.5 ppmv), and a dehydration unit (DeHy) to remove the water (to <0.1 ppmv). An alternative option is to position the MRU downstream of the DeHy. The C5+ specification of <500 ppmv of the gas is reached in a scrub column or in the natural gas liquids section. In these steps the heavier hydrocarbons and the aromatics are removed to well below 1 ppmv.

In a line-up with a scrub column, treated gas from the pretreatment unit is sent to the scrub column to remove HHCs using reflux generated in the liquefaction process (Figure 2). The liquid reflux consists of natural gas liquids (C2-C5) that wash down C6+ components to achieve removal of C6+ and BTX to meet specification. For lean feed gas the amount of liquid reflux is insufficient for stable operation of the column and to achieve the required specifications. A variation would be to supply external washing liquid, but in an LNG plant no suitable stream is available (i.e. the LNG is too light, and the condensate is already HHC saturated) and import of a scrubbing liquid would make the option unattractive.

A natural gas liquid extraction plant can be placed upstream of the liquefaction unit to remove natural gas liquids and HHCs (Figure 3). A natural gas liquid unit can operate at any pressure, handle wide feed variation, and remove C6+ and BTX to liquefaction specifications with low methane loss. However, this line-up is generally unattractive for lean gas as the condensate yield is too low to economically justify the CAPEX and OPEX.

Lean gas line-up options

The methods for HHC removal from lean natural gas considered in this article include the following conventional methods: addition of a TSA hydrocarbon removal unit (HRU) upstream of the DeHy unit and simple cold flash inside the liquefaction cold box. Pros and cons of both methods are described next and are compared to the newly developed BASF Durasorb Cryo-HRU technology.

An option recently made available by BASF is the addition of a HRU upstream of the DeHy unit, as depicted in Figure 4. This option offers several advantages; the Durasorb HRU targets C8+ removal to below 0.5 ppmv, considering a solubility of nC8 is <0.5 ppmv in liquid methane (at -162˚C and 60 bara). The HRU also removes the bulk water, leaving a significantly lighter duty for the downstream DeHy unit that only must remove the last 50 ppmv of water. The removal of bulk water by the HRU allows for the DeHy unit to be smaller and achieve a longer bed life, in some cases up to 12 years between material change out.[4] The bulk C5-C7 removal to meet the C5+ specification is achieved with a flash. Although the DeHy unit can be as much as 40% smaller, the addition of the HRU adds a regeneration system and doubles the piping and valves required for the overall system. This downside can be overlooked if the increased flexibility and reliability is considered and valued.

Incorporation of a cold flash inside the cold box is another method to remove HHCs (Figure 5). This is the simplest vapour-liquid separation scheme. Treated gas from the pretreatment unit is cooled by a refrigerant and expanded in the liquefaction cold box. The HHCs drop out in the liquid phase in the cold flash separator and are removed, and the lean gas is further processed. The two major drawbacks of this approach are the significant losses of methane and lighter hydrocarbons to the HHC stream, as well as the expansion of >20 bar required to achieve very deep cooling that is necessary to remove highly soluble HHCs to meet the specifications for benzene and nC8+. This process requires recompression to avoid LNG production losses. The expansion and recompression are inefficient from both a pressure management and equipment management standpoint. Furthermore, stabilisation of the HHC stream is required to meet the condensate Reid vapour pressure (RVP) specification, adding additional CAPEX.

Dual-purpose adsorption technology

The newly developed Durasorb Cryo-HRU technology from BASF is designed to be a simple and effective solution for the removal of trace HHCs from lean feed gas. Durasorb Cryo-HRU technology combines the HRU and DeHy unit functionalities into one system by utilising a multi-material approach to achieve both HHC and water removal to the required cryogenic specifications.

The configuration is similar to Figure 4, having the HRU upstream of the DeHy unit, but in the case of dual-purpose TSA, the DeHy unit is removed and replaced with the Cryo-HRU (Figure 6).

The dual-purpose adsorption unit is downstream of the AGRU, which provides the sweet gas feed to the adsorption unit. Durasorb Cryo-HRU technology is a temperature swing adsorption process, where each vessel goes through an adsorption cycle, followed by an elevated temperature regeneration cycle, followed by a cooling cycle, before going

Figure 4. Addition of a TSA HRU upstream of the dehydration unit.

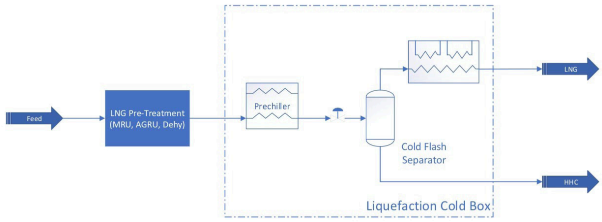

Figure 5. Simple cold flash inside liquefaction cold box.

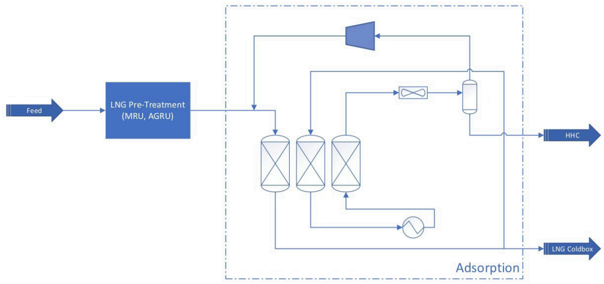

Figure 6. Line-up of the dual-purpose adsorption technology for combined HHC and water removal.

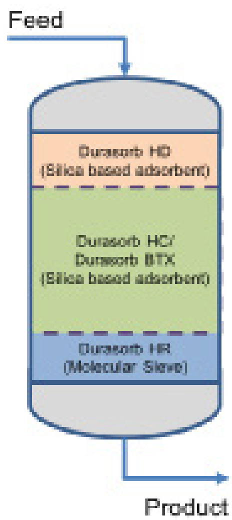

Figure 7. Typical adsorbent bed configuration of BASF Durasorb technology in a dual-purpose concept.

back into adsorption. The vessels operate in parallel but staggered cycles. In units where there are multiple vessels in adsorption at any given time, the outlet gas stream is combined as the product gas going to the downstream cryogenic unit.

The regeneration gas is a fraction of the treated product gas. The design uses a series heat and cool regeneration system. Therefore, regeneration gas first passes through a heated bed in a co-current (downward) direction to cool down the adsorber prior to taking it in adsorption. While doing so, the

Table 2. Summary of the key performance of the standard MSU, HRU, and Durasorb dual-purpose unit

Parameter	Molecular sieve	HRU	Dual-purpose adsorption unit
Functionality	Dehydration	Dew pointing	Deep nC8+ and H_2O removal
Configuration (towers in adsorption + regen)	2+1 / 3+1	X+2	X*+2 / X*+1
Water removal (Residual)	<0.1 ppmv	Approximately 30 - 50 ppmv	<0.1 ppmv
C8+ removal	N/A	<0.5ppmv	<0.5 ppmv
Regen gas flow (% Fresh feed)	5 - 7%	10 - 15%	7 - 15%
Cycle time (min.)	960/1440 (higher with variable cycle time <2000	60 - 500	200 - 500
Lifetime cycles (4 years)	Approximately 1500 (longer lifetime with variable cycling)	>4000	>4000
Adsorbent type	Molecular sieve	Silica gel	Silica gel + Molecular sieve
Regeneration	Temperature ramp-up	Fast heating	Fast heating

Note: *X can be 1, 2, 3 beds

gas is pre-heated and is then sent to a regeneration gas heater to heat it up to the required regeneration temperature. Heating is performed in a counter-current (upward) direction. As the hot gas passes up through the bed it desorbs the adsorbate, takes it into the vapour phase, and carries it out of the bed. The spent regeneration gas is then cooled to condense desorbed moisture and hydrocarbons, which are collected in a three-phase regeneration gas separator. The effluent regeneration gas is then routed through a regen recycle compressor to increase its pressure, and is mixed with the sweet gas stream upstream of the sweet gas chiller. The vapour is sent back to the adsorbing tower(s). After flowing down the adsorbing bed(s), the conditioned gas is routed to the cryogenic stage.

The majority of the adsorbent bed consists of specially developed aluminosilicate gel materials that perform bulk water removal and removal of C8+ and aromatic hydrocarbons to the cryogenic specification (Figure 7). The bottom of the bed consists of a molecular sieve material specially developed for robustness. An optional top layer can be added as a guard against carry-over from the upstream AGRU amine system. The simultaneous removal of HHCs and water in a single unit makes this approach both economical and effective, providing greater reliability and flexibility for changing feed gas conditions.

The novel aspect to the development of the dual-purpose TSA technology was the need to combine the short-cycle HRU process with the long-cycle molecular sieve dehydration process. The characteristics of the different systems are presented in Table 2.

For LNG plants fed with lean gas, alternative line-ups with less capital-intensive methods for HHC removal that are tailored for the conditioning of lean feed gases must be considered. The TSA HRU technology offers many benefits compared to more conventional arrangements for HHC removal, and BASF's TSA HRU technologies are well proven. The step-change technological advance of combining the HRU and the DeHy unit into a single, dual-purpose adsorption unit that simultaneously removes HHCs and water to cryogenic specifications, enhances the CAPEX efficiencies for new projects and provides a cost-effective retrofit option to existing plants. **LNG**

To learn how BASF developed the technology and proved its capabilities, read the remainder of the article by visiting www.lngindustry.com

References

1. SIMONETTI, T., NARAYANAN, M., BLADANET, C., Technip; CHEN, F., OTT, C., Air Products and Chemicals, Inc., "Innovations in Small to Mid-Scale LNG Plants," 26th World Gas Conference, June 2015.
2. SMITH, T., DOONG, S., UOP Honeywell, "Selective C5+ Removal for Lean Feed Gas," *LNG Industry*, February 2016.
3. SCHMIDT, W., CHEN, F., OTT, C., Air Products and Chemicals, Inc., "Advances in Removing Heavy Hydrocarbons from LNG Liquefaction Feed Gas," Gastech, September 2018.
4. HEYWOOD, M., UHE, M., Spirit Energy Ltd; ECKARDT, T., GREENE, M., RACHER, R., WYATT, R., BASF, "North Morecambe Onshore Gas Terminal Adapts to Changing Feedstock," *Oil and Gas Journal*, October 2020.