A ample supplies of LNG have created a low price environment, which is expected to last through the end of this decade. At the same time, worldwide consumption of LNG continues to grow, with global demand expected to outpace supply sometime after 2021. According to projections by the Galway Group, the world could see a supply gap of 60 – 100 million tpy by 2025.

There are a number of planned LNG production projects that are vying to meet the future supply gap.
The timing and outcome of final investment decisions (FID), construction schedules, and plant start-ups hinge on the LNG owners’ and operators’ ability to address these important challenges, while also maximising plant performance and production. One place to find innovations that provide an advantage is in the pretreatment section.

**LNG pretreatment**

LNG pretreatment is a critical risk management function that can represent a meaningful portion of the capital and operating cost of an LNG plant.

In the area of technology innovation, more effective adsorbents are now available that increase the capacity to remove mercury and water with direct savings to capital and operating expenditures. To remove heavy hydrocarbons (HHCs) from lean gas feeds, a thermal swing adsorption (TSA) process has been developed that can selectively remove C\textsubscript{5+} hydrocarbons and BTEX with little pressure drop. This can provide up to 50% savings in lifecycle economics vs a cryogenic solution in large scale, baseload plants, and up to a 35% saving vs an integrated scrub column typically used in small to mid scale plants.

There have been two advancements in the area of delivery model innovation. Firstly, gas processing expertise can be integrated up front with automation and controls. Embedding the process knowledge in the control system and aligning the work processes in the flow scheme create a number of efficiencies that reduce project execution time and operating costs. Secondly, process technology can be delivered as modular equipment. Using a factory-built approach for pretreatment equipment – as opposed to a field-erected, stick-built approach – allows for faster fabrication and installation, predictable schedules, and excellent quality control.

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**Figure 1. LNG pretreatment flow scheme and advancements.**

To be successful, developers must overcome a number of project risks, challenges and complexities, including the following:

- Alignment of plant capacity with offtake commitments.
- Prediction and control of project costs and schedule.
- Treatment for more difficult and variable feedstocks.
- More stringent environmental regulations and product specifications.
- Maximisation of plant availability, reliability, safety and operating efficiency.
- Elimination of waste and by-product streams.
These advances in pretreatment create value for the owner/operator by reducing delays and enabling start-up sooner, lowering capital and operating costs, reaching target production quicker, operating the plant at superior performance, enhancing reliability, and realising faster return on investment (ROI).

LNG requires removal of contaminants to meet end product specifications and to avoid product blockages in the downstream heat exchanger equipment. The level of treating requirements varies according to the composition and variability of feed sources, the treated gas product specifications and local environmental regulations.

In front end gas processing purification and separation with conventional process flow schemes, the natural gas feedstock is first treated by removing mercury, H₂S, CO₂, and H₂O to extremely low levels in various gas purification steps. The feedstock is then treated to remove HHC compounds.

Figure 1 shows a conventional pretreatment flow scheme and summarises the benefits that correspond to each of the advancements described further in this article.

**Advanced adsorbents for mercury removal and dehydration**

For mercury removal, an operator may use regenerable or non-regenerable adsorbents (Figure 2). Non-regenerable adsorbent is used in a guard bed (GB) placed before the amine and dryer units. This is distinct from traditional mercury removal units (MRUs) that use activated carbon beds and can only be placed after the dehydration. A GB MRU can be placed before the dryers due to its resistance to water. Honeywell UOP’s latest adsorbent, GB-567, has double the adsorption capacity than the current GB-562HP and nearly three times that of the standard GB-562. This results in longer life, fewer reloads, and CAPEX savings due to less steel for a smaller vessel.

As it is regenerable, the HgSIV adsorbent can be added to the dryers, eliminating the need for a separate GB unit. The selection of either of these mercury removal sorbents depends on the financial objectives of the project.

For dehydration units, the company’s UI-94 adsorbent offers increased strength and extended life. The UI-900 was introduced with an even greater adsorption capacity than previous adsorbents, while still maintaining the good strength attributes of UI-94. When used in a reload application, this adsorbent improves operations, including longer adsorption time, fewer cycles, longer life, and reduced energy consumption. In new units, it enables smaller vessel sizes, thus reducing CAPEX (steel) and OPEX (energy).

**HHC removal for lean feed gas**

LNG owners and operators want an operationally simple and feed-gas-flexible process plant that will consistently protect the main heat exchanger from downtime (de-riming), resulting from HHC freeze-up. Technologies on the market can effectively remove HHCs if the feed gas is rich (Figure 3). However, pipeline gas, particularly in North America, is increasingly lean due to unconventional gas production and high value natural gas liquids (NGL) being recovered in midstream gas plants. Lean feed gas may contain less than 2 gal. of NGLs per thousand cubic feet of gas (GPM) or a Mol% of less than approximately 0.261. Traditional methods to treat lean gas and remove HHCs, such as scrub columns, expansion, and condensation, may have higher economic lifecycle costs, reduce plant capacity, and/or complicate operations by requiring external NGL imports into the plant.

SeparSIV™ is a highly selective multilayer temperature swing adsorption process to remove C₄+ HHCs. Similar to a dehydration unit, this is a regenerable system. An adsorber vessel (or vessels) purifies the gas on-stream, while a regeneration vessel (or vessels) is fed clean, heated regen gas to purge the HHCs. The regen gas is cooled to condense the HHCs in a separator drum. The vessels cycle between adsorption and regeneration. A three-vessel, modular SeparSIV equipment unit is depicted in Figure 4. This unit has a nominal capacity of 200 million ft³/d with turndown capability of 50%.

In addition to HHCs, the unit removes BTEX to <1 ppmv, water, and traces of other contaminants, such as glycol, greases and amines (if present). The system is flexible enough to cope with varying feed compositions by adjusting the cycle time for...
Overhead view of a mid scale LNG plant with 3/d modular unit has been lean. Execution reduces automation project schedule. A 200 million ft³/d was estimated to save up to 50% in lifecycle cost vs a cryogenic LNG plant layout using modular separation (SeparSIV) unit.

Regeneration or the cooling temperature of the regen stream. It can also remove low concentrations of other contaminants including CO₂ and/or mercaptans.

The unit is energy efficient because it avoids the significant reduction in pressure drop and cooling load typically experienced with cryogenic options. In a large scale LNG project, a traditional hydrocarbon removal unit (HRU) may be a turboexpander or Joule-Thomson (JT) valve placed after the dehydration unit. The expander method drops the temperature of the hydrocarbons by reducing the feed pressure significantly. This method requires a distillation column to separate the liquids from the gas and also requires a compressor on the back-end to recompress the gas back to a level that enables the heat exchanger to run efficiently.

SeparSIV, by contrast, is an adsorption process with very little pressure drop. In addition, only the regeneration gas is cooled to precipitate the HHCs. This can reduce compression and/or cooling load, which can result in significant cost savings. For example, a baseload export LNG project in the US having a capacity of 810 million ft³/d was estimated to save up to 50% in lifecycle cost vs a cryogenic solution (CAPEX savings up to 30% and annual OPEX savings up to 75%).

In small to mid scale LNG projects, a traditional HRU includes a scrub column that may be integrated with a mechanical refrigeration unit for precooling the gas or a slipstream from the cold box. This option is cheaper than the turboexpander, but it introduces several levels of complexity for operators, especially when the feed gas is lean. In addition to the moderate level of pressure drop necessary to operate below the critical pressure, the performance of the scrub column is challenged by an insufficient amount of NGLs to create the reflux necessary to remove the heavy components. This results in operability and reliability issues.

SeparSIV removes such issues and is available as a skid-mounted, modular package for faster delivery and easier installation in small to mid scale LNG projects. A 200 million ft³/d modular unit has been estimated to save up to 35% in lifecycle costs compared to an integrated scrub column.

Automation that captures process knowledge

Integrating automation solutions with the pretreatment process expertise has several advantages, including designing the automation system sooner and optimising it for the plant design. This helps LNG development projects avoid delays from re-work later and optimises pretreatment operations for improved equipment life, higher utilisation and yields.

Honeywell Process Solutions (HPS) has invested in templates with extensive input from Honeywell UOP experts to improve the quality and consistency of the graphics for the distributed control system (DCS) and the instrumentation for advanced process control (APC). In addition, operating procedures are embedded in the DCS and the operator training simulator (OTS), which includes Honeywell UOP reactor models, real world scenarios, and workbooks.

With this integrated approach and its lean execution of automation projects (LEAP) model, HPS can accommodate early data from Honeywell UOP and later data from engineering, procurement and construction (EPC) packages (Figure 5). The automation system connects to the equipment using a Universal I/O module, which allows a de-coupling of design and fabrication of controls equipment, thus removing automation from the critical path of the project.

Regarding APC, measurement points are included in the pretreatment piping and instrumentation diagrams (P&IDs) so that they can be implemented during plant construction. This enables faster APC implementation after start-up. The pretreatment design is correlated and already embedded in the APC solution. This enables difficult-to-measure properties to be calculated more easily, allowing the plant to run without violating constraints.

Modular delivery of pretreatment equipment

Traditionally, an EPC has been responsible for designing customised pretreatment operations, with the assistance of process technology providers for each of the unit operations. This approach exposes the plant owner to the risk of cost escalation due to change orders. However, modular fabrication and delivery offers a predictable, repeatable and cost-effective approach. Figure 6 shows an overhead view of a mid scale (200 million ft³/d) LNG plant layout using modular pretreatment equipment. In this approach, the gas processing technology supplier works directly with the client/operator to determine the optimal amine, dehydration and HRU design and then supplies the solution as skid-mounted, modular equipment at a firm, fixed price. The EPC still plays an important role in this approach, but
the advantages of having pretreatment modules factory-built include the following:

- **Reduced cost and schedule:** assembly work is done in the shop at lower hourly labour rates in a controlled environment (no weather delays), and prior to field move in, while permits are being secured. Equipment units are skid-mounted and shipped by truck or barge – even to remote locations – ready for installation.

- **Efficient fabrication and superior quality:** equipment, piping, and instrumentation are more readily available in the shop located closer to supplies and can be fully tested prior to shipment to the field.

- **Technology provider maintains single point responsibility for performance of equipment.**

Modular equipment can provide lower CAPEX than field-erected equipment for plant capacities up to 800 million ft$^3$/d. This is due to reduced engineering, project management, field labour and the use of a repeatable design. Single trains are easily modularised up to 400 million ft$^3$/d. Multiple trains can often be sequenced or ‘numbered-up’ to process higher flowrates more cost-effectively than a single train stick-built unit. Numbering-up units for higher capacities is an effective strategy to manage risk and cash flows by expanding plants in stages with identical, consistent train designs as product sales opportunities grow over time. If additional demand does not materialise, the owner avoids having sunk investments into unwanted capacity.

**Summary**

LNG continues to be an attractive way to monetise onshore and offshore gas reserves, and more LNG will be needed to meet future supply requirements. While production facilities face significant pressures to reduce risks, costs, and schedules, the industry is changing to effectively deal with these challenges. Suppliers are responding with advances in technology and novel approaches to project execution, with benefits that include the following:

- **Greater capacity and efficiency of contaminant removal to protect downstream equipment from mercury, acid gases, water, and HHCs.**

- **Significantly shorter project schedule and lower costs by integrating and optimising automation with expert process technology.**

- **Single-source systems engineering with elimination of delays due to multiple interfaces.**

- **Modular equipment delivery and installation to reduce project schedule and cost overruns.**

**References**