

Air Products manages project risk in global ventures through its standardization and modularization

Fei Chen and Joe Voda explain the US company's LNG liquefaction offerings of various scales

Execution strategies incorporating standardized and modular solutions with proven liquefaction technology provide LNG plant developers a viable alternative to mitigate project risk, cost and schedule.

Developers of both greenfield and brownfield projects continue to evaluate such solutions when considering individual train sizes in the small and mid-scale range.

There are many factors to consider when evaluating the merits associated with standardized and modularized execution strategies to include production, process technology and project specific criteria.

There has been a renewed interest in small and mid-scale projects across the LNG industry. In the past, most LNG plants were designed to achieve economies of scale by employing the largest equipment that was proven at the time.

As the LNG industry continues to change, these factors are no longer the sole consideration of project developers. Most large and easily-accessible gas fields have already been developed. Many of the remaining undeveloped gas fields are smaller, offshore or remote. Additionally, energy price volatility has made traditional, large volume, long-term contracts increasingly difficult to secure.

Volumes

Finally, requirements for transportation fuel and energy peak shaving applications typically require smaller volumes with fluctuating demand profiles. As a result, the financial viability of new projects faces increased challenges, and project developers are looking for innovative solutions to meet the new market requirements.

As smaller plants do not benefit from the same economies of scale as larger plants, the primary focus has shifted towards low total installed capital. In addition, developers desire execution strategies that shorten their project schedules and accelerate time to on-stream to quickly monetize stranded gas. However, to be economically viable, a small-scale LNG plant must still minimize downtime, maintain maintenance intervals, and maximize

production similar to a large plant.

To accommodate these new market requirements, standardized liquefaction cycle and equipment configurations amenable to modularization have become highly desirable. The solutions described in this article may be applied to liquefying natural gas across a wide range of processing capacities but are specifically suitable for small and mid-scale train sizes.

Tradeoffs to consider

Liquefaction process cycles, proven or new, as well as equipment technology advancements developed with specific consideration for standardization and modularization, can play an important role in reducing CAPEX and schedule while also improving OPEX.

Nonetheless, there are tradeoffs that require consideration when developing standardized and modularized products.

Standard process and plant designs can reduce engineering time and manufacturing schedule while also achieving targeted plant availability through the use of proven designs. However, site specific conditions such as feed gas composition pressure, type of cooling medium and temperature can impact the reusability of the design.

In addition, the standardization approach may be different for plants of varying sizes or markets with careful evaluation necessary to determine whether to standardize individual equipment items, process modules or the entire plant.

Typically, standardization is inversely related to train size, with smaller train sizes achieving higher levels of standardization. Although standardizing the entire liquefaction unit may be less attractive for large trains, standardization of key equipment can still provide a benefit.

Modular design construction may reduce field labor costs and help mitigate construction and schedule risk, but the benefits may be partially offset by the extra structure associated with modules and the need to transport large modules from building yards to project sites.

Therefore, the optimal level of standardization and the right balance

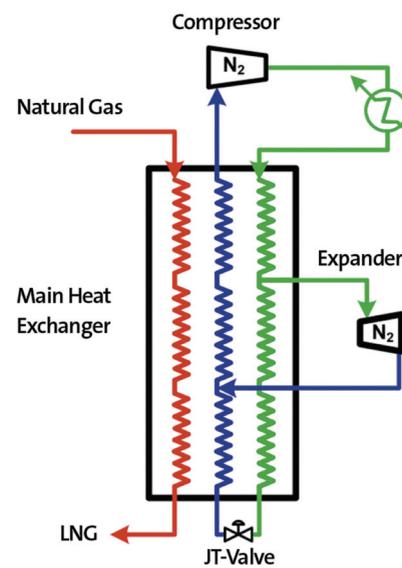


Figure 1: Simple N2 Recycle Process

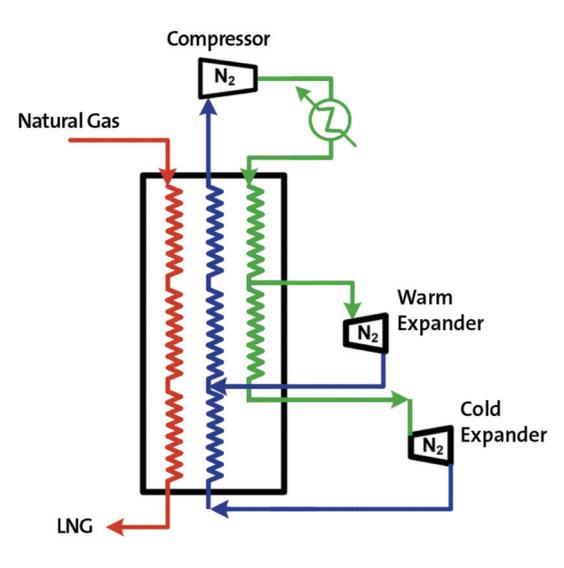


Figure 2: Two-stage N2 Expander cycle

between a modular or stick-built approach requires careful evaluation.

Standardized small scale

Low CAPEX and simple operation are often the most important considerations for small plant capacities (100 to 500 ton per day range). Standard designs using the simple to operate nitrogen refrigeration cycle (Nitrogen Recycle Process) using one nitrogen expander and one JT valve (Figure 1) is typically the most economic option.

The addition of a second expander (Figure 2) is a consideration when production approaches the upper limit of the range, as this improves the efficiency of a simple nitrogen expander cycle with a moderate increase in CAPEX.

The adoption of modular construction strategies for liquefaction plants in the

100 to 500 TPD range appears to be increasing.

Now, a small-scale plant may be developed by erecting multiple yard-built modules with inter-connecting piping and cables. There may be modules for gas receiving, pre-treatment, liquefaction, cooling and other peripheral equipment.

The liquefaction module is the core of the LNG plant and is further composed of two fully skidded sub-modules: a cold box module and a nitrogen compression/expansion module (Figure 3).

The cold box typically contains a liquefaction heat exchanger and process valves with the option for a heavy hydrocarbon rejection drum.

The nitrogen compression / expansion module includes a nitrogen recycle compressor, one or more nitrogen expanders and potentially integrated coolers.

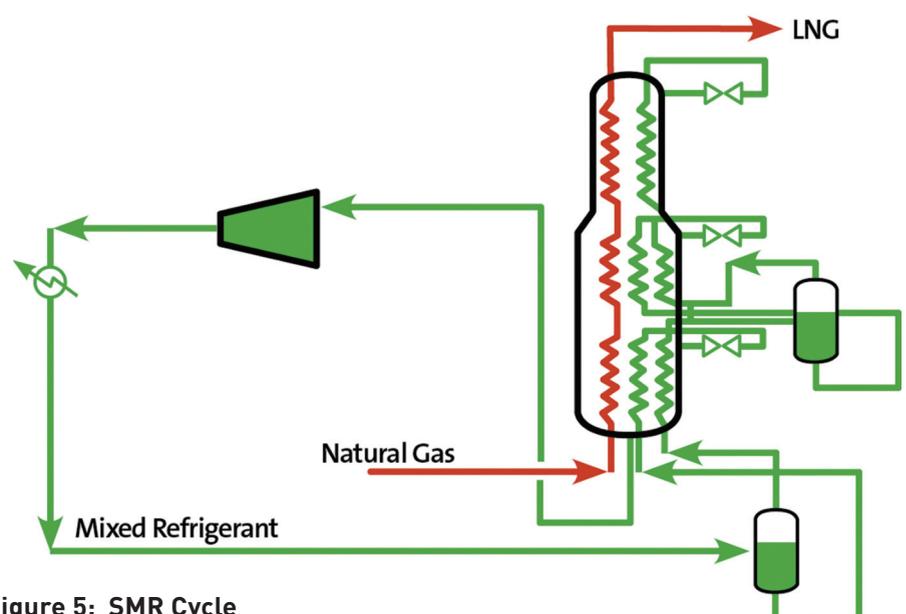


Figure 5: SMR Cycle

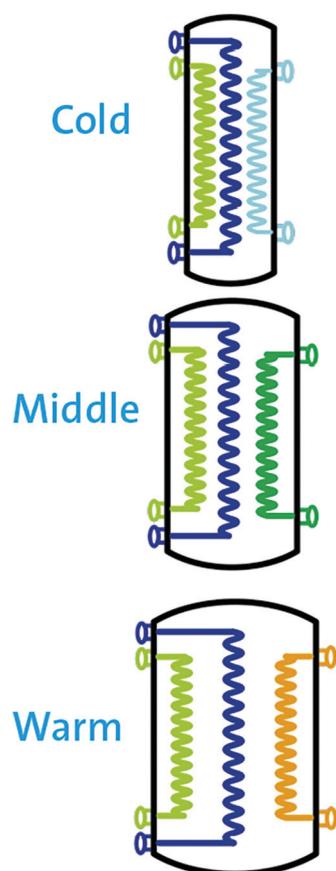


Figure 6: Coil Wound Heat Exchanger (CWHE) used as the Main Cryogenic Heat Exchanger (MCHE)

Each individual expander may be configured as a compander or be loaded on a common bull gear with the nitrogen compressor stages.

The goal is to achieve a high level of standardization for the individual equipment as well as the liquefaction modules while also retaining sufficient flexibility to accommodate project specific variables when needed with limited adjustment to the process and equipment design.

For example, with no or minor changes, the equipment and module design can work with electric motor or gas turbine drive and air cooled or water-cooled applications while remaining adaptable to varying feed gas compositions and

design codes. The nitrogen recycle process is an established refrigeration technology with significant industry references and relatively low capital expenditure.

This process is quick to start up and shut down and is easy to ramp up or down production. If desired, stable operation below 50 percent turndown from nameplate capacity is achievable.

Since nitrogen is used as the only refrigeration component, it is safe and environmentally friendly, and minimizes the cost and on-site management of the refrigerant.

For mid-scale LNG plants where efficiency is a consideration in the process selection, the single mixed refrigerant (SMR) process is often justified.

The SMR process requires fewer pieces of rotating equipment and is well proven in the small to mid-scale LNG range. Typically, the refrigerant consists of a mixture of hydrocarbons and nitrogen optimized to achieve the best efficiency (Figure 5).

For plants developed using SMR technology, standardization may focus more on the equipment level, including the mixed refrigerant compressor and the main cryogenic heat exchanger (Figure 6). The equipment may be designed to handle relatively large ranges for capacity, cooling medium type and temperature.

However, when it comes to variation in feed gas composition among different projects, flexibility in the overall process cycle design must also be considered as the difference in heavy hydrocarbon (HHC) concentration and light components (e.g. nitrogen) concentration in the feed gas may require the application of different impurity removal technologies to avoid freezing in the



Ningxia China 1000 TPD SMR trains



LNG Train in Indonesia

Figure 10: Modularized or field erected mid-scale LNG trains

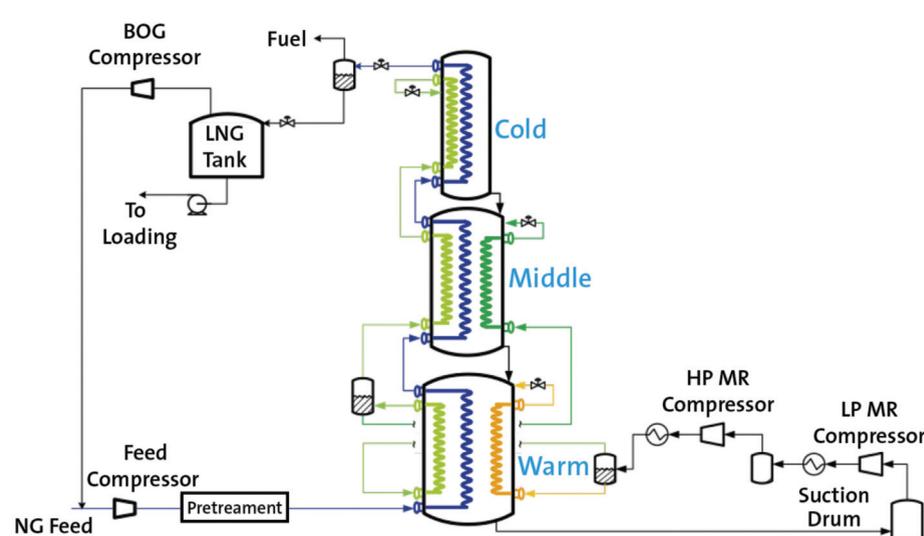


Figure 7: SMR cycle with standard MCHE, base configuration

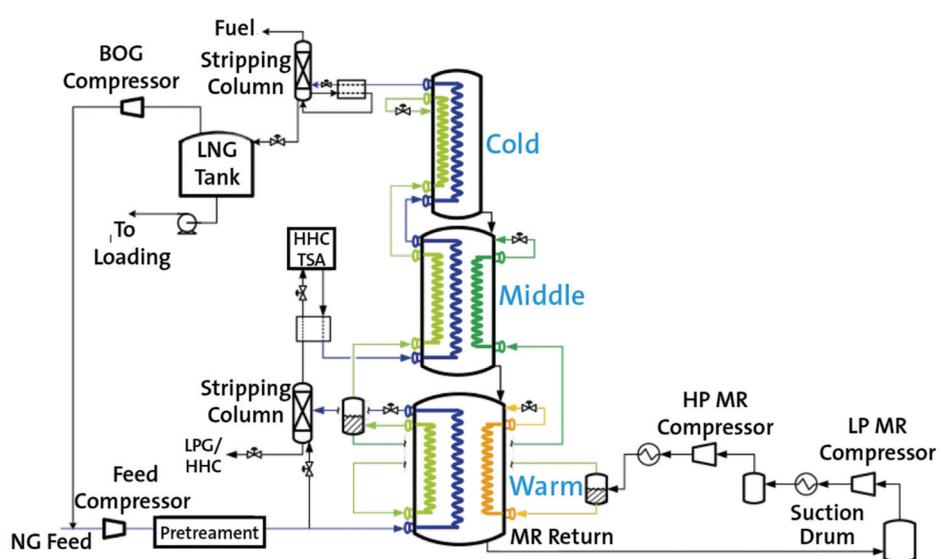


Figure 8: SMR cycle with standard MCHE, integrated HHC removal TSA and nitrogen stripper

equipment and meet the LNG product specifications.

The standardized MCHE design (Figure 6) needs to be adaptable to multiple cycle configurations to retain the necessary flexibility to meet each project's specific requirements for heavy hydrocarbon removal and nitrogen rejection.

If the feed gas contains very low HHC and nitrogen concentrations, the SMR liquefaction cycle can be configured to have only the three sections (cold, middle,

and warm) of the MCHE in a row (Figure 7, base configuration).

In this configuration, the feed gas is first cleaned up to remove acid gases and water, and then cooled and liquefied in the MCHE prior to being sent into the LNG storage tank.

If the feed gas contains a high HHC concentration and needs to reject nitrogen, an HHC removal TSA and an HHC stripping column may be integrated collectively with the warm section of the



Figure 11: Mid-scale 1350 TPD SMR train

standard MCHE design to ensure both alkane HHCs and aromatic HHCs are effectively removed, and a nitrogen stripping column may be placed downstream of the cold section of the MCHE to reject nitrogen (Figure 8).

Depending on the project criteria, the standardized solutions should also have the flexibility to be integrated into the contractor's preferred execution strategy whether it be modularized or field erected.

For example, the three sections of the MCHE may be contained in three separate shells to allow for ease of transportation and more flexibility in optimizing overall module and piping design. On the other hand, the three sections of the MCHE can be placed into a common shell to reduce inter-connecting piping and plot space.

Overall, the goal is to achieve a high level of standardization for the individual equipment to support modular or field erection strategies while retaining the necessary flexibility to integrate various

impurity removal schemes for higher efficiency and robust operation.

Similar to the requirement for small-scale LNG, the standard design for the MR compressor and the MCHE should work with electric motor or gas turbine drive and air cooled or water cooled at most global locations. The coil wound type of MCHE is proven to be well suited for standardization with the benefits of this type of heat exchanger summarized in Table 1.

Standardization - from equipment level to plant level: In addition to standardization at the equipment level and process module level, it is often beneficial to achieve a certain degree of standardization at the plant level.

Figure 12 shows a typical plant layout superimposed with a process flow diagram for a mid-scale LNG plant. Material and energy flows are categorized into natural gas, refrigerant, LPG (liquid petroleum gas) and utility.

The feed gas from a pipeline goes through the receiving facility and meter

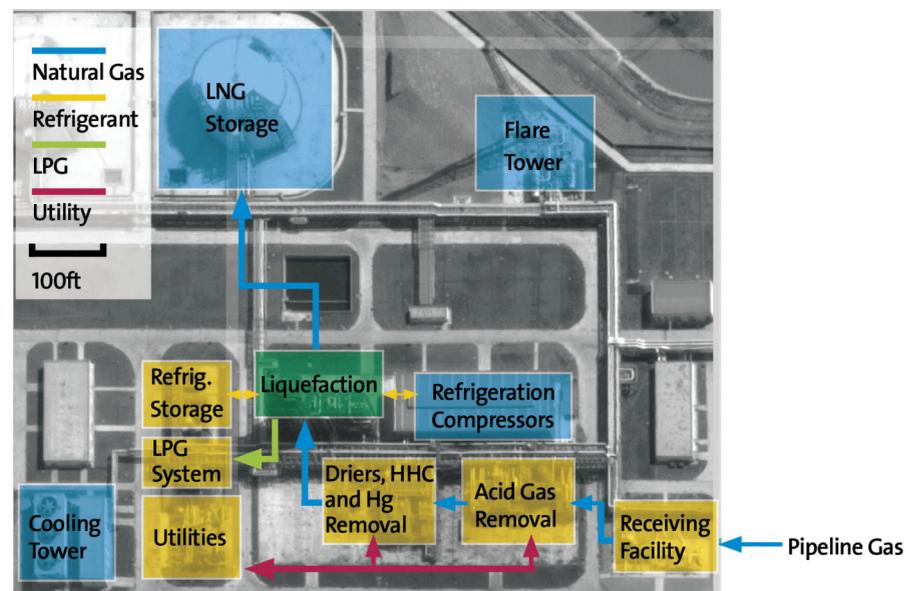


Figure 12: Typical mid-scale LNG plant flow diagram and facility layout

station before entering the acid gas removal unit, the dryer, the HHC removal unit, and the mercury removal unit and arrives at the liquefaction system where it is cooled and liquefied to produce LNG. The heavy end of the feed gas is processed to make LPG product and stored in the LPG storage system.

The utility unit provides the heat duty required for front-end system regeneration, while the refrigeration compressors together with the refrigerant storage system and cooling tower provide the cooling duty for the natural gas liquefaction. Each discrete process unit and its equipment can be standardized constructed using a modular or stick built approach.

Standardizing the plant layout can provide additional benefits including the potential for increased reuse of engineering documents such as plot plans, 3D models, civil design, risk and site hazard analysis, and construction strategies.

Conclusion

When exploring options for small or mid-scale LNG train sizes, it is important to understand the objectives for a successful project. The economics of small-scale LNG projects typically benefit from lower capital cost and shorter schedule.

These constitute unique constraints that require project developers to work closely with EPCs and process licensors to identify the best technology and execution strategy.

Innovations in process cycles, equipment design, enriched standardized product portfolio and modularization strategies open doors to achieve project objectives.

Although the planned individual train capacity may be smaller than the typical baseload train, the magnitude of the overall investment itself still warrants appropriate due diligence to guarantee a successful return over the life of the plant. ■

For more information, please contact Air Products at +1 610-481-4861 or email, info@airproducts.com

Features	Description	Benefits/Advantages			
		Reduce OPEX	Improved Revenue	Safety	Environmental Friendly
High Availability & Reduced Downtime	CWHE with external containment allows continuous operation even in the unlikely situation of tube leaks thus delaying any necessary repair to a scheduled shutdown.	●	●		
Reduced plugging risk	CWHE design and tubing reduces the probability of plugging/blockage.		●	●	●
High Efficiency	Refrigeration system with multiple cooling streams increases overall liquefaction efficiency. Closely matched temperature profiles within MCHE provide high performance and efficiency.	●	●		●
High Adaptability	Proprietary thermo data base facilitates a design whereby the selected refrigerant mixture/ components provide flexibility to accommodate fluctuations in feedgas composition. Depending upon plant configuration, refrigerant components can be extracted from feedgas or sourced locally.	●	●		
High Operational Flexibility	Multiple cooling streams increase operational flexibility, especially for fluctuating feedgas composition, daily and seasonal ambient temperature change. Ease of turndown with stability during shortage of feedgas.	●	●		
High Robustness & Reliability	CWHE with tube-in-shell design provides high resistance to thermal stresses/shock and ensures good vapor-liquid distribution.	●		●	●
External Protection	CWHE with external pressure shell provides added measure of protection in the event of an unlikely natural gas leak thus mitigating unnecessary releases into the atmosphere.		●	●	●
Multi-Bundle Design	CWHE multiple bundle design (e.g. pre-cooling, liquefaction, and sub-cooling) can ease transportation constraints.			●	

Table 1: Benefits of Air Products' Mid Scale Coil Wound Heat Exchanger Units (CWHE)