



# THE RIGHT SIZE SOLUTION

**Scott Mossberg, Bechtel Oil, Gas and Chemical, USA, and Douglas Ducote, Chart Energy and Chemicals Inc., USA,** discuss the benefits of mid scale LNG discovered by the two companies during a period of collaboration.

**B**echtel and Chart have been working together to develop a wide range of mid scale LNG liquefaction solutions using Chart's IPSMR® single mixed refrigerant process. During development and engineering, the team identified a number of features that provide mid scale solutions with advantages over traditional large scale LNG configurations. In this paper, the team leaders summarise the outcomes and explain how close matching to customer production needs, efficient plot utilisation, competitive liquefaction efficiency, improved maintenance and isolation combine to deliver favourable costs per tonne of LNG produced.

## **What is mid scale LNG?**

Traditionally, liquefaction plants were defined as peak shaving or baseload depending upon their function and capacity. Regardless of size, plants consisted of a single design to achieve total plant capacity, hence, particularly for the baseload model, as technologies and manufacturing capabilities improved, the trend has been towards ever larger capacities in order to realise economies of scale.

Rather than attempt a definition of mid scale LNG based on plant capacity, it is more accurate to introduce the word 'modular' and define 'modular mid scale LNG' as the process of achieving total plant capacity through multiple identical

liquefaction modules rather than a single custom plant. Typically, each liquefaction module is engineered to produce between 0.5 and 2+ million tpy of LNG and by maximising shop built standard equipment, modular mid scale LNG does not have the same risk profile and upward CAPEX price pressures as the baseload model.

## Matching customer production needs

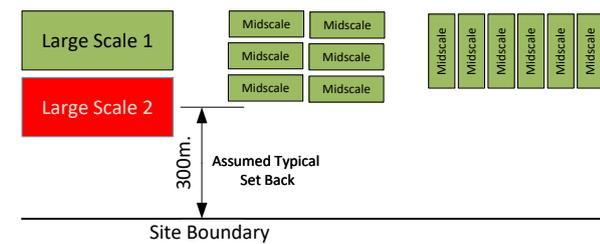
The first step in realising the benefits of mid scale LNG is selecting the 'right size' mid scale train capacity. Economy of scale is talked about frequently in the LNG world, and economy of scale applies for mid scale if the 'right size' of train capacity is selected. But economy of scale has limits. Beyond certain points, critical pieces of equipment (piping, valves, etc.) become more difficult and expensive to source, fabricate, ship and install. Trains that are too small or too large can miss the 'sweet spot' for efficiency and cost per tonne. The IPSMR® process can be configured for a cold box capacity of more than 2 million tpy utilising efficient brazed aluminium heat exchangers (BAHX) and can be easily configured for train capacities that match the owner's preferred gas turbine at site rated power output. IPSMR® cold box capacities can match the largest gas turbines currently in use for LNG production, and can match the capacity required for two aero-derivative gas turbines in parallel. This flexibility

allows the process to be ideally configured in identical, economical and efficient train sizes using standard, readily available components including compressor, gas turbines, pipe, fittings and valves. Additional trains are added in parallel to achieve total desired plant capacity. The customer can stage installation of the trains as additional liquefaction capacity is needed. Staged construction and startup can improve productivity and reduce rework as indicated below.

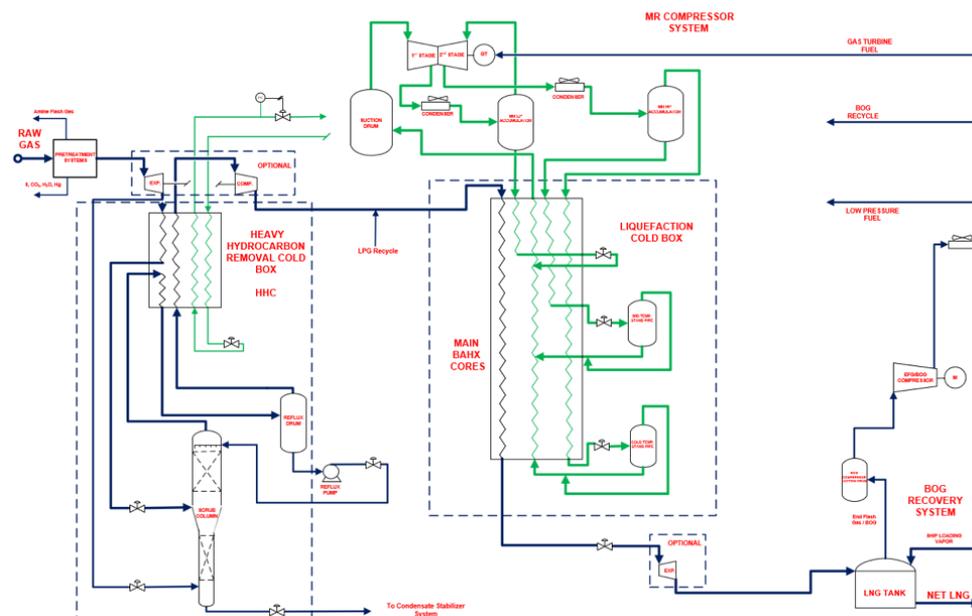
In addition to matching the gas turbine power output, LNG production goals can be met by adding optional equipment to the LNG facility to improve production, increase efficiency, reduce footprint and reduce cost per tonne. When feed gas pressure is high enough, an expander/compressor set, installed with the heavy hydrocarbon removal system, will boost back feed gas pressure to the liquefier from the pressure needed for heavy hydrocarbon separation and can significantly improve efficiency of the LNG process and result in increased LNG production with lower cost per tonne. In addition to expander/compressor sets, liquefier feed gas booster compressors can be an effective means of efficiently increasing LNG production. In fact, when feed gas pressure is low, horsepower added via a booster compressor is more valuable than horsepower added to the refrigeration compressor drive system. A feed gas booster compressor will almost always improve LNG production capacity and may also reduce cost per tonne even if efficiency is not improved.

Like other mixed refrigerant processes, IPSMR® can also benefit from the addition of liquid hydraulic turbines to the process. The economics of adding hydraulic turbines to the LNG run down line are enhanced with larger train sizes and higher liquefaction feed gas pressures. In many hot climates, the addition of turbine inlet air chilling (TIAC) may provide an economical option to not only increase LNG production and allow production ranges to span differences between gas turbines sizes, but also flatten out the production versus the ambient temperature curve.

Simplified methods of precooling of the feed gas and mixed refrigerant can also improve efficiency, LNG production



**Figure 1.** Example of how mid scale trains can be positioned in multiple configurations.



**Figure 2.** A typical IPSMR® liquefaction process.

capacity, plant footprint and cost per tonne. As always, evaluating the advantages of additional equipment in terms of cost per tonne is a necessary part of study work at an early stage of the project. When configured in similar fashion, the efficiency of the IPSMR® process can rival or outperform that of baseload technologies.

## Plot utilisation

A very important consideration in reducing the cost of LNG facilities is to reduce the plot space required per tonne of LNG produced. Chart and Bechtel have studied options to reduce plot space, maintain adequate

equipment spacing for safety and maintenance and minimise negative impact to LNG production capacity. Air cooler dimensions can significantly affect the plot space required for the inside battery limits (ISBL) layout and increase the cost of site work, concrete work, structures, piping, electrical and instrumentation. Chart's and Bechtel's standard practice is to optimise for reduced cost per tonne by iterating the process design for optimal BAHX cold box sizes and air cooler sizes, while maximising the efficiency of the refrigerant compressor. The process variables that most influence the size and efficiency of equipment are BAHX allowable pressure drop, minimum internal temperature difference and mixed refrigerant composition. The process variables that most influence air cooler sizes are allowable pressure drop and process temperature approach to the ambient temperature. Compressor polytropic efficiency is most influenced by the selected pressure ratio per stage and the total process flow. All the process variables mentioned are optimised as a complete system with the goal of minimising air cooler footprint with minimal effect on LNG production while meeting the customer's LNG production requirements.

Several different mid scale standard design solutions have been developed using the IPSMR® process that result in competitive footprints and have the same or lower ISBL plot area per unit of LNG production than typical large scale solutions. LNG trains can have various auxiliary systems located inside the train or located outside the train's battery limits depending on the feed gas, goals for future expansion or shape of the available site. Most large scale LNG trains can achieve LNG production per square metre of plot space in the range of 3.2 – 4.6 m<sup>2</sup>/tpd. The mid scale solutions developed typically include CO<sub>2</sub> and H<sub>2</sub>S treating, amine regeneration, dehydration, mercury removal, heavy hydrocarbon removal, condensate stabilisation and LNG liquefaction; yet are in the range of, or well below, 3.2 m<sup>2</sup>/tpd.

A benefit of being able to hold the area per production steady while using smaller production trains is the additional flexibility it provides while optimising a site layout. When optimising land utilisation on any particular site, LNG production is just one of many things to consider. Overpressure hazard footprint, flammable vapour-gas dispersion limits, thermal radiation hazard noise impact and site drainage, all have equally large effects on the overall availability for site utilisation.

When siting LNG facilities, various codes and standards can often apply. To protect the public, overpressure hazard, flammable vapour-gas dispersion limits, thermal radiation and noise calculations are performed. These will often require large separation distances between public space and the hazards, as well as other onsite restrictions for locating other key equipment. Since the LNG plant itself will often have several points within the ISBL that can impose large separation distances, some land may not be able to be fully developed. If a large scale plant cannot fit, there are often multiple solutions with a mid scale facility. Smaller inventories of hazardous liquids can also provide smaller separation distances.

## Operational benefits

Multiple trains of mid scale liquefaction can provide production efficiency benefits to the operator of the liquefaction facility. Typically, an IPSMR® mid scale liquefaction train is configured with one compressor and

gas turbine per liquefaction train. As previously highlighted, a larger total plant capacity is achieved by installing multiple identical trains. Large scale plants are configured with multiple compressors/gas turbines in series and sometimes in parallel as well. For comparison, a typical large scale plant may consist of one train with two, three or more compressor/gas turbine sets with multiple different compression services and refrigeration systems dependent on each other. Depending on the configuration of the large scale facility, the LNG production loss with a single turbine loss can exceed the percentage of refrigeration turbine power that was being supplied by that gas turbine. An IPSMR® plant is designed to have multiple identical trains with one compressor/gas turbine service in each train. When a single turbine trips, the production loss is equal to the percent of power lost since the compressor/gas turbines do not rely on each other. The same scenario also applies to capacity losses during maintenance as turbines can be maintained one at a time, keeping peak manpower lower and resources available for other necessary activities, if required.

Multiple trains of mid scale liquefaction can provide operational flexibility for the plant owner as well. It may be possible to dedicate trains of liquefaction to specific investors, gas supplies or storage tanks to provide contract flexibility for the plant owner.

The fundamental design of the IPSMR® refrigeration system is simple, with no concern for balancing power requirements between the different gas turbines in each refrigeration system. With IPSMR® and the single compressor/gas turbine service, simple process and gas turbine controls automatically adjust to the power available for changing ambient conditions.

Multiple trains of mid scale liquefaction offer enhanced turndown flexibility as well. Chart's experience is that each individual train of liquefaction can be turned down to approximately 30%, with 50% as the normal stated turndown.

Another significant advantage of IPSMR® mid scale LNG design is that the process uses fewer pieces of equipment than most other large scale designs, especially less rotating equipment. As already mentioned, IPSMR® uses a single compressor/gas turbine refrigeration service per train. In addition, the process also eliminates the need for mixed refrigerant pumps, pump skids and pump related valves and controls to further reduce plot space, operating cost, maintenance and plant design complexity. The reduced rotating equipment count, which sets the largest spare part count in the liquefaction train, also reduces spare parts inventory requirements.

## Design simplicity of the heavy hydrocarbon system

One of the additional benefits of Bechtel and Chart's mid scale technology offering is the simplicity of the heavy hydrocarbon removal system (HHC) for LNG service. In a typical arrangement, each liquefaction train is paired with a 'heavies' removal system including a scrub column, heat exchanger assembly and reflux drum, all installed in a cold box. Both the liquefaction and HHC cold boxes are completely shop assembled, wired and pressure tested process modules, which significantly minimise field construction. The HHC system may also include a reflux pump skid or expander/compressor set or possibly a booster compressor

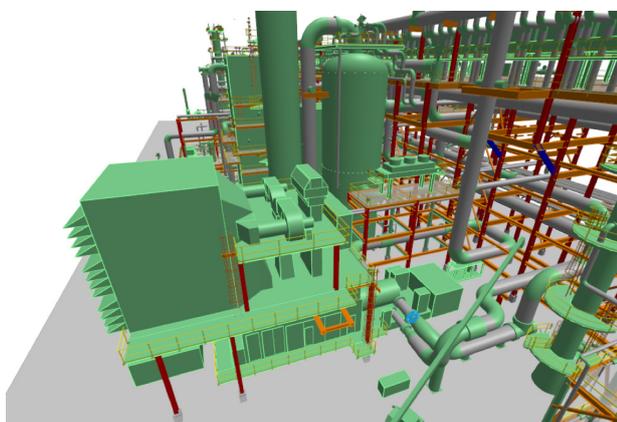
depending on the feed gas composition, pressure and desired LNG production.

The reflux for the scrub column is entirely provided within the HHC module and does not rely on either the condensate system or LNG to supply reflux. This is especially valuable when the HHC must be designed for lean gas compositions. One of the other significant features of the Chart HHC design is that it is specifically designed to only remove freezing components from the feed gas, minimising the fraction of non-freezing components to the condensate system and maximising flow and Btu content of the LNG. Complemented with Bechtel's condensate stabilisation system, the design maximises LNG product value and minimises the size of the condensate system.

## Benefits of duplication at all phases of the project

In some cases, where building large scale trains does not fit the owner's economic model, offtake needs or other constraints, selecting from multiple mid scale standard designs may be a better fit and comes with multiple advantages, at many levels of the project, especially when duplicated multiple times.

Starting at the beginning of the project lifecycle with engineering, mid scale LNG plants can often have only a single refrigeration loop, with a smaller overall equipment count. On a large scale plant with multiple complex refrigeration loops, unique designs need to be completed for each loop and pressure level of refrigerant. From the EPC contactor point of view, this means process design, physical layout, piping and pipe stress, controls and wiring all need full detail design. Procurement organisations and equipment suppliers are affected as well. The equipment designs, drawings, fabrication and testing all need to be coordinated, reviewed and delivered. Consider the case of a refrigeration compressor where sizing, optimising efficiency, rotor dynamics and design review can all take considerable time and effort. The design and setting up of a test stand for a compressor alone can cost millions of dollars. Reducing the number of unique pieces of equipment that need to be designed, shipped, installed, commissioned and maintained is often the easiest way to keep costs low. This is especially beneficial with IPSMR® where efficiency is not significantly compromised and 'right size' mid scale trains are possible.



**Figure 3.** Example of low cost and operational friendly compressor layout.

When construction, commissioning and startup are staged properly, there are additional benefits to the project when the mid scale plant is duplicated and standard designs are used. In all three phases, teams must spend time learning about the facility and each other, in order to become effective and productive. Time spent building these teams and working collaboratively helps to keep productivity high. Being able to transition the teams onto the next train of the project allows the next train to start with great momentum. Also having already completed the identical task on the first train, teams will already be familiar with the work ahead, have a better understanding of the finished product, will make fewer errors and be more productive.

## Simplified maintenance and isolation

There are other simplification benefits of only having a single refrigeration loop, compared to multiple refrigeration loops. Multiple refrigeration loop systems tend to use one refrigerant to cool the other refrigerant, as well as the feed gas. These cross-cooling points add additional equipment to the process. For operating companies that have zero energy isolation requirements, isolation of this equipment can either mean de-inventorying more refrigeration sections or additional isolation points to minimise refrigerant losses. Using the single refrigeration loop naturally has less equipment and isolation points required. Zero energy isolations are accomplished with fewer valves per refrigeration loop.

Having a single multi-stage compressor casing to provide all the process compression requirements offers additional design benefits when designing the compressor layout. Compressor layout design often has competing factors for the optimal design. For operational ease, typically a bottom nozzle split casing compressor may be chosen. In many cases, this allows for the compressor rotor section to be accessed and replaced, without removing the piping or dismantling other parts of the plant. The downside of bottom nozzle compressors is the need to be elevated. This comes with an increased cost. Top suction compressors avoid the upfront cost of the elevated platform for the compressor, but will require piping to be removed when the design requires more than one compressor casing in the compressor string. But with only a single compressor casing on the drive shaft, a barrel compressor and layout configuration can be utilised to keep the compressor at grade and still be able to remove compressor internals, or replace the dry gas seals, without the need to remove any piping.

## Conclusion

The result of Bechtel and Chart's collaboration is the basis for a mid scale LNG solution with minimum equipment count, minimum complexity, BAHXs and cold box modules for liquefaction and heavies removal. This mid scale approach facilitates low cost installation and short schedule durations including self-performed modular fabrication, easy adaptation to plot space requirements, simplicity of operation and robustness for varied feed gas compositions and pressures and varying ambient temperatures. **LNG**