SELECTING THE RIGHT MID-SCALE LNG SOLUTION with CHART’s IPSMR® PROCESS TECHNOLOGY

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Introduction

Chart has worked with several EPC contractors, equipment and module manufacturers and liquefaction plant owners to develop a wide range of mid-scale LNG solutions using Chart’s IPSMR® process. Of special note is the work done with Bechtel Oil, Gas and Chemicals, Inc. to optimize solutions and standardize designs. During development and engineering, a variety of both expected and unexpected benefits have been uncovered that provide mid-scale solutions advantages over the traditional large-scale LNG configurations. Some of these benefits include the ability to better match with customers production needs, efficient plot utilization, competitive liquefaction efficiency, reduced process complexity, improved maintenance and low cost per tonne; with low cost per tonne always important.

Ability to Match Customer Production Needs

The first step in realizing 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 sizes, critical pieces of equipment, piping, valves, etc. become more difficult and expensive to source, fabricate, ship and install. Trains that are too small can increase cost per tonne and miss the “sweet spot” for efficiency or trains that are too large can miss the “sweet spot” for cost per tonne. Chart’s IPSMR® process can be configured with each cold box capacity of 2+ MTPA and IPSMR®+ can be configured for 3+ MTPA per train, utilizing Chart’s largest and most efficient brazed aluminum 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 aeroderivative 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, subject to safe working distances between trains, as additional liquefaction capacity is needed. Staged construction and start-up 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 feed gas pressure to the liquefier above the reduced pressure needed for heavy hydrocarbon separation. This 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 can be 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 overall 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 LNG capacities 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 but help to span production differences between gas turbines sizes. TIAC also helps to flatten out the production versus the ambient temperature curve.

Simplified methods of pre-cooling of the feed gas and mixed refrigerant using IPSMR®+ can also improve efficiency, LNG production 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 with optional equipment, the efficiency of the IPSMR® or IPSMR®+ process will rival or outperform that of base load technologies.

Figure 1: Typical IPSMR® flow diagram

Plot Utilization

A very important consideration in reducing the cost of LNG facilities is to reduce the plot space required per tonne of LNG produced. Chart, with Bechtel and others, including IOCs, have studied options to reduce plot space, maintain adequate equipment spacing for safety and maintenance and minimize negative impact to LNG production capacity. Air cooler dimensions will significantly affect the plot space required for the ISBL layout and potentially increase the cost of site work, concrete work, structures, piping, electrical and instrumentation. Chart’s standard practice is to optimize for reduced cost per tonne by iterating the process design for optimal BAHX cold box sizes and air cooler sizes while maximizing the efficiency of the refrigerant compressor. Given the feed gas composition and pressure, the process variables that most influence the size and efficiency of the liquefaction 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 flow rate. All the process variables mentioned are optimized as a complete system with the goal of minimizing air cooler foot print with minimal effect on LNG production while meeting the customer LNG production requirements. As the IPSMR® process licensor and supplier of the BAHX and air coolers, Chart has complete access to technical experts for these critical components. The result is a very efficient process with minimized ISBL foot print.
Working with Bechtel, several different mid-scale standard design solutions have been developed using the ISPMR® 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 meter of plot space in the range of 3.2 - 4.6 square meters per production tonne per day. The Bechtel mid-scale solutions currently developed typically include CO₂ and H₂S treating, amine regeneration, dehydration, mercury removal, heavy hydrocarbon removal, condensate stabilization and LNG liquefaction. These typical mid-scale solutions can be in the range of, or well below, 3.2 square meters per production tonne per day.

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

When siting LNG facilities, various codes and standards often apply. To protect the public, overpressure hazards, flammable vapor-gas dispersion limits, thermal radiation, and noise calculations are performed by the EPC contractor. These will often require large separation distances between public space and the hazards, as well as other onsite restrictions for locating 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 midscale facility. Smaller inventories of hazardous liquids can also provide smaller separation distances.

Figure 2: Example of how mid-scale trains can be positioned in multiple configurations. Complements of Bechtel Oil, Gas and Chemicals, Inc.
The ability to rotate the ISBL as in the figure above can be beneficial. In some cases, high volumes of refrigerants can make one side of the plant have larger over pressure hazard or flammable dispersion limit for safe distances. In other cases, the site wind direction may favor a particular air cooler configuration to prevent hot air recirculation. Furthermore, the smaller equipment sizes of mid-scale trains means that there is less volume involved in hypothetical releases.

While any one of these factors may not be the controlling factor at a particular site, having these options on configurations, orientation, and spacing can provide optimal utilization from the available space on a site.

**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 and IPSMR®+ is configured with 2 refrigeration compressors and 1 gas turbine driver per 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 which are interdependent. Depending on the configuration of the large-scale facility the LNG production loss with a single gas turbine loss can exceed the percentage of refrigeration turbine power that is being supplied by that gas turbine. An IPSMR® or IPSMR®+ plant is designed to have multiple identical trains with one gas turbine driver in each train. When a single turbine trips, the production loss is equal to the percent of power lost since the refrigeration system in each train are independent of each other. The same scenario also applies to capacity losses during maintenance as turbines can be maintained one at a time. Keeping peak man power lower, and resources available for other need 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 without concern about balancing power requirements between the different gas turbines in each refrigeration system. With IPSMR® and the single gas turbine driver, 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 and of course, individual trains can be shut down.

Another significant advantage of Chart’s IPSMR® mid-scale LNG design is that the process uses fewer pieces of equipment than most other large-scale designs, especially less rotating equipment. 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 and maintenance cost, 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 with Chart’s Heavy Hydrocarbon System

One of the additional benefits of Chart’s mid-scale technology offering is the simplicity of Chart’s 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 typically installed in a Cold Box. Both the liquefaction and HHC cold boxes, are completely shop assembled, wired, and pressure tested process module, which significantly minimizes 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 is not dependent on either LNG or the condensate system 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, minimizing the product flow to the condensate system and maximizing product flow and BTU content of the LNG. The design maximizes LNG product value and minimizes 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, off take needs, or other constraints, selecting 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 life cycle with engineering, mid-scale LNG plants can often have only a single refrigeration system, resulting in reduced 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 organizations 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, optimizing 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.

When construction, commissioning, and start up are staged properly, there are additional benefits to the project when multiple trains of midscale plant designs are used. In all three phases, teams must spend time learning about the facility and working together, 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 from one train to the next 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 and be more productive.

As a result, using the standardized IPSMR® designs has a shorter construction schedule over larger-scale plants due to standard designs, lower equipment counts, and the benefits of duplication.
Simplified maintenance and isolation

Having fewer 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 high pressure mixed refrigerant compressor casing on the drive shaft, a barrel compressor and layout configuration can be utilized 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.

Figure 3: Example of low cost and operational friendly compressor layout. Complements of Bechtel Oil, Gas and Chemicals, Inc.

Conclusions

When the “right size” standard mid-scale solution is selected utilizing the Chart’s IPSMR® process technology, the benefits are significant. The Chart mid-scale LNG solution is a very efficient mixed refrigerant process, rivaling base load efficiency when coupled with Chart’s highly efficient and largest BAHX, Hudson air coolers and Chart’s heavy hydrocarbon removal system. Chart’s mid-scale LNG solution features minimum equipment count, minimum complexity, brazed aluminum heat exchangers 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.

About the author
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With more than 40 years of experience in cryogenic gas processing, Doug Ducote is a multi-disciplined, highly respected figure in the LNG, refining, petrochemicals, and gas processing fields. A co-inventor of Chart’s IPSMR® LNG process, Doug’s current responsibilities are centered on process configuration and simulation associated with commercialization of the IPSMR® process technology, particularly regarding modular, mid-scale LNG liquefaction.

He holds a Bachelor of Science Degree in Aerospace Engineering from Louisiana State University.