Handling Cold vs. Saturated LNG

Since 1941, when the first pilot LNG liquefaction plant was set up in Cleveland, US, the LNG industry has amassed a huge body of experience that has enabled the near perfect public safety record that it has earned. Today, the global LNG supply capacity has grown to more than 240 million tpy, with over 430 LNG carriers in operation, with a projected growth to approximately 350 million tpy by 2020.

In those early days of the industry, equipment was not available for handling LNG, so a new special equipment industry was born. These developments largely originated from the experience of a group of scientists and engineers based at California Institute of Technology (Caltech), who were involved with the early US aerospace industry.

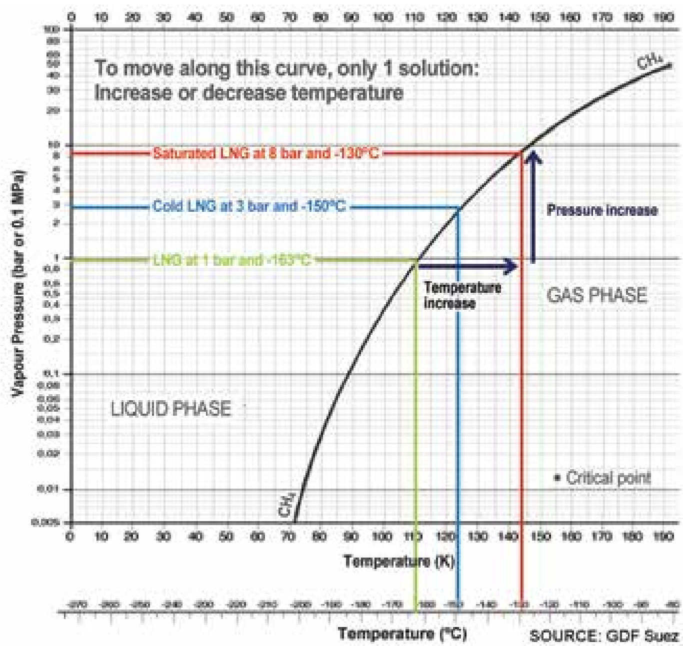

Figure 1

The LNG supply chain has been growing ever since with the latest new market segments being the small scale LNG plant and LNG as a transport fuel [Figure 1]. These developments have resulted in the introduction of new technologies and solutions over the traditional large scale LNG approach. The potential size of the 'direct consumer product' LNG fuel market varies greatly, with claims ranging from 80 million tpy to 240 million tpy. The most recent BP Energy Outlook 2035 predicts natural gas as a transport fuel to grow steadily at approximately 1.2% / year and to account for approximately 15% of the total demand growth during the period to 2035. This potential market size is predicted to be one of the key drivers in the growth of the overall LNG industry in the coming years. With growth and new development comes risk. The developers of this consumer sector will need to be cognizant of the damage that an incident, such as the Three Mile Island nuclear accident, could have on the growth of this valuable source of clean and economical energy.

Globally, LNG has been safely handled in large volumes over the last 40 years. Generally there are three types of LNG facilities (export, import and peak shave). These facilities are scattered throughout the world some times near population centers where natural gas is needed. This is compounded further by the prevalence of mobile facilities due to the smaller scale and resulting size. It should be noted that this excellent safety record has been largely based on 'cold LNG' (atmospheric pressure storage). [Figure 2]

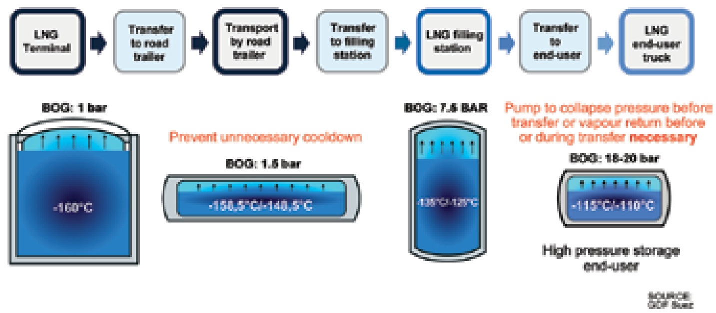

Figure 2 - High pressure increase from terminal to end-user, 3 transfers

From this perspective, a key difference between the traditional LNG approach and the practices being evaluated in the LNG distribution model is its adoption of the traditional industrial gas distribution infrastructure model as the basis for operations.

The fundamental concept underlying LNG safety is that this odorless, colorless, cryogenic liquid will neither vaporize nor burn when maintained at atmospheric temperature and refrigerated to below -161.4°C.

The LNG industry's excellent safety record is a result of several factors:

- The industry has technically and operationally evolved to ensure safe and secure operations. Technical and operational advances include everything from the engineering that underlies LNG facilities to operational procedures and the technical competency of people.
- Physical and chemical properties of LNG are such that risks and hazards are well understood and incorporated into technology and operations.
- The Standards, Codes and Regulations that apply to the LNG industry further ensure safety. An International framework of Standards and Codes regulate the industry. In some cases these regulations are being currently developed.

Industry Practices

Industrial gas practices are based on experience handling a product that is, in many cases, non-flammable. Therefore, transferring fluid by pressure building became common practice as industrial gas practitioners migrated to the LNG industry. In this process, the pressure within a storage tank or transport vehicle is allowed to rise up to18 bar at -110°C in order to permit the fluid to be drawn from the bottom of the tank when a valve is opened.

The adaptation of this high pressure transfer approach creates a number of added challenges compared to the pumped transfer approach. A heavier and more costly tankage is required for -110°C vs -160°C due to high pressure; lower densities SG 0.316 vs. 0.440 require larger storage tanks to achieve equal fuel heating value; and the risk of high pressure gas vapor releases is greatly enhanced in the case of tank rupture and during normal operational connections.

Early adaptations of high pressure storage have largely been due to the availability and competitive price of pressure building storage tanks and equipment. This was compounded further by the lack of availability of other LNG-specific low pressure storage designs of this scale. Additionally, it is possible that in some cases the builders/designers lack of familiarity with the suppliers of such LNG equipment played a role. New suppliers with an extensive LNG background are now entering the market, offering low pressure storage design options, specially adapted for this small scale market. As a result, more options are available for evaluation, which can be based on life cycle performance, especially in terms of the LNG delivered volumes, quality and safety, and not only on cost and availability, as may have been the case with the early adapters.

Some of the additional challenges identified in dealing with 'hot' and 'cold' LNG include the following:

- All large scale LNG plants and ships operating to date are dedicated facilities, which typically include 3 to 10 year project lead times, and are built by specialist engineering, procurement and construction (EPC) companies or shipyards with complex regulatory siting and approval processes. Small scale LNG plants, however, are generally mobile, standardized and commodity-driven in terms of budget, schedule and construction.

- Product transfers that demand high pressure will increase the temperature of the LNG and decrease the density and its associated fuel heating value, while increasing the risk of venting and, potentially, product loss.

- When tank pressure is maintained at a low level, as in a pumped transfer system, the entrained heat energy (known as enthalpy) is kept low and is not available to vaporize the fluid, thus decreasing the risk of unwanted emissions.

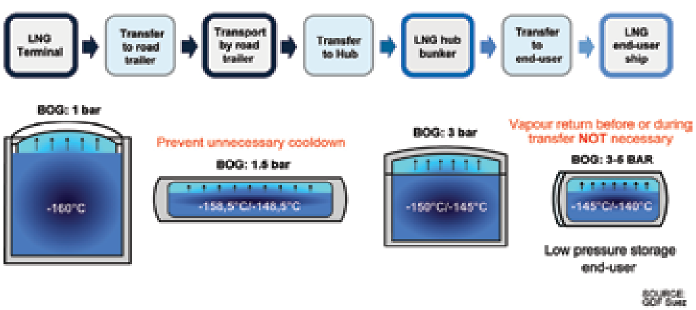

Figure 3 - Low pressure increase from terminal to end user, 3 transfers, pump needed

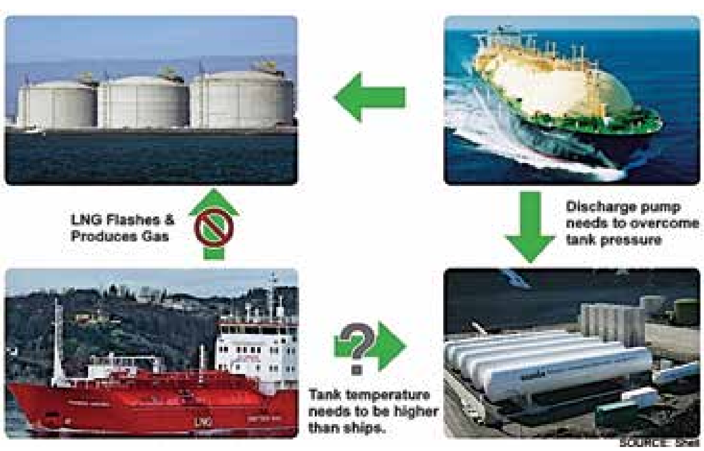

Figure 4

- Adherence to a zero emissions policy by maintaining a low pressure tank strategy helps to future-proof the facility owner's investment as emissions regulatory policy requirements escalate.

- The low pressure strategy simplifies LNG fuel transfer from tank to tank by ensuring that all tanks are always at a common pressure. [Figure 3]

- Where no such commonality exists, the standardization of handling practices, storage equipment and transfer devices is difficult, and limits interoperability when transferring fuel at different facilities. [Figure 3]

- High pressure end user storage demands that the vapor returns to storage and increases venting risks and heat loss to storage.

Figures 4 and 5 also show various fuel supply chain configurations.

A number of factors need to be considered when deciding whether to supply LNG by pumping, pressure transfer or both.

The inclusion of pumps and, in particular, submerged motor pumps (SMPs), is well proven when operating with either cold or hot LNG. The pumps are reliable, efficient and safe in all LNG applications. However, cold LNG pumping increases the flexibility of bunkering, product transfer, vaporizer feed and road/train/barge tankers cargo off-loading. This is especially the case where various interface conditions apply. [Figures 4, 5] SMPs also permit increased storage tank utilization and reduce transfer cycle time, which is critical in many of the LNG-fuelling cases, especially where bunkering is involved.

SMPs can also be used for pumping other natural gas liquids (NGLs), including some alternate fuels such as propane, butane, methanol and ethane, as well as downstream chemicals and petrochemicals (liquids such as ethylene, propylene, etc.) from the same tank, or mixtures of such products. SMPs are available in pot-mounted, in-tank removable (pump well) and fixed-in tank styles, thus providing the maximum flexibility with regards to installation and operation, whether inside or outside of storage tanks.

The adoption of a 'hub and spoke' or site liquefaction approach to the supply of LNG, together with a 'just-in-time' LNG capacity model, requires flexibility in order to be able to support either midstream or depot fuelling strategy demands. This type of flexibility, considering that the LNG can arrive either hot or cold, can only be achieved by ensuring that the SMPs are included at each critical interface where LNG is handled.

Field experience of early mobile storage and dispensing systems, which were originally only equipped with pressure transfer and had operational problems, has shown that pumps are necessary. Therefore, it is now prudent practice to supply both SMPs and forced vaporizers.

In the LNG-fuelling market, there is an ongoing debate on the adoption of dual-fuel vs full gas solutions due to loss of power concerns and issues. It is also recognized that redundancy in terms of LNG supply is necessary in order to safeguard against the loss of power due to fuel supply loss.

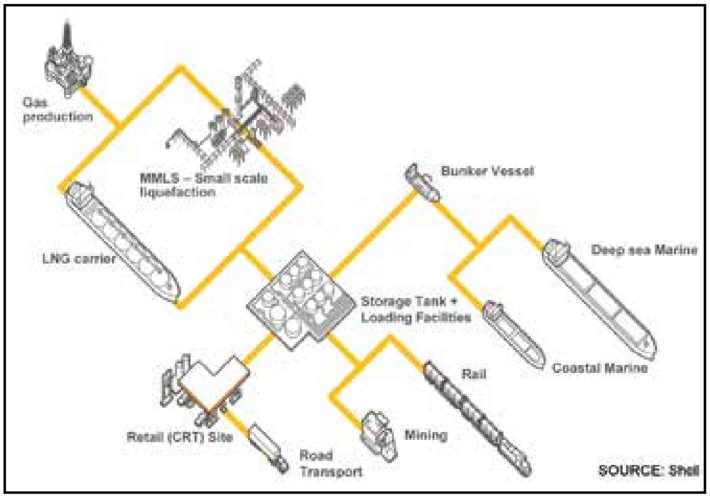

Figure 5

Another concern relates to what happens when the vehicle or mobile storage facility has to return to the depot or shipyard for undefined durations, or where maintenance must be carried out. Again, the inclusion of both SMPs, as well as forced vaporizers, provides the necessary options to ensure fuels can be offloaded safely and necessary works can be undertaken safely and expeditiously.

LNG fuel was originally supplied to low pressure LNG engines (up to 18 bar) through vaporizers by pressure transfer only (i.e. by supplying pressurized vapor to the top of the tank and supplying LNG to the vaporizer from the bottom). Pressure transfer was also used from a suction pot to the high pressure pumps for the high pressure LNG engines (400 bar).

There were multiple problems with the strategy of only using pressure transfer for these mobile applications, including the following:

- When extraneous conditions create an environment in which the LNG fuel is agitated with significant liquid sloshing action, or the gas pocket is affected by spraying, the gas pressure can collapse in the supply tank or suction pot.
- Without tank gas pressure, LNG fuel flow stops.
- The warming effect of a gas layer can reduce the holding time capability of the tank, which can be accelerated further by LNG evaporation due to LNG contact with warm walls. Holding time requirements are key considerations especially in Type C storage tanks where no cooling provisions are available typically to help manage the boil off gas (BOG). This is still a major concern for operators of this type equipment.
- For high pressure engine applications, when pressure transferring fuel at elevated temperature, suction instability or net positive suction pressure (NPSP) problems will result. The resulting cavitation problem will inhibit or stop the high pressure pump/engine operation.
- Such cavitation in the high pressure reciprocating pumps will lead to premature failure and high maintenance costs, making the high pressure pump system unreliable and expensive to operate.
- LNG tank pressure is increased and heat accumulates in the tank. This causes an increase in BOG and makes re-fuelling/bunkering operations more complicated.

The problems associated with pressure transfer are eliminated by using only SMPs in either the LNG supply tank or in an intermediate (suction pot) tank prior to the low pressure vaporizer or high pressure pump system. Some of the problems resolved include the following:

- Replacing the pressure builder coil with an SMP will minimize the heat accumulation in the supply tank or the high pressure pump system by sending the pumping energy out with the fuel flow, thus ensuring that the LNG fuel is always handled cold. This also ensures that the tank pressure remains at a low increment over atmospheric (usually 1.2 to 1.55 bar) pressure for membrane type tanks or is properly sub-cooled for the high pressure systems.
- Practical experience has shown that pressure builders have been unable to overcome unforeseen troubles with system resistance, elevations and back pressures. Pumps are required, regardless of the pressure builders, in order to start the process of pressure building, whereby liquid needs to be pumped from inside the storage tank out through the top of the tank to an external vaporizer. The pressure builder has also struggled to be able to fully unload the contents of tanks, which must be considered as cargo losses. Pressure transfer is known to have limited operational boundary and pressure decay causes loss of transfer capacity. As such, bunkering and other transfers take longer than expected and can end in short cargo deliveries. This is critical especially in high volume bunkering operations where fill time is critical to the overall facility operational and contractual requirements.
- A removable in-tank SMP mounted inside the storage supply tank ensures that the pump is always ready and doesn't require special cool down periods with excess BOG nor prolonged charging periods before operating. This practice allows for an immediate start up and eliminates an initial surge of BOG during any cool down operation.
- The proven reliability of in-tank LNG SMPs has been demonstrated at over 20,000 hr mean time between overhaul (MTBO) in thousands of installations on various mobile platforms in marine and land-based environments.
- Removable in-tank SMPs are able to be removed from service for maintenance without gas freeing or unloading the storage tank. These pumps are proven to offer in excess 99.5% availability as these systems are proven for mobile applications both onshore and offshore.
- Installation configurations are now available from pump suppliers such as ACD LLC for removable SMP installations, such that the cargo liquid can be completely removed during normal operation.
- The interior of the storage tank is a non-classified area per NFPA 59A/NFPA 70. As such, the mounting of SMPs does not require any explosion certification. The use of seal-less SMPs removes the risk of fire and explosion with either warm or cold LNG by eliminating emissions.

The strong safety record of the LNG Industry is not without its price. Several accidents have occurred over the years including those in Cleveland (1944), Staten Island (1973) and Cove Point (1979). It is critical that safety stays at the forefront of decision making, and that there must be no complacency in dealing with LNG. The intense commitment to learning from such incidents has led to the following practices being adopted as standard in the industry:

- Storage tank applications exclusively use in-tank SMPs. This eliminates the need for tank bottom penetration, and puts in place the 'over the top pumping standard' (i.e. no tank liquid nozzles are located below the tank liquid level).

- Removable pump installation configuration allows for the maintenance of pumps without gas freeing and entering the storage tank. The system is simple to operate and the crews / operators can be easily trained to perform these tasks safely and efficiently.

- Improved Net Positive Suction Head (NPSH) properties, which use special inducer designs, enhance storage utilization, handle marginal liquid conditions and can more effectively deal with possible 'water hammer' pressure surges during the starting of high flow pumps.

- Low level starting capability optimizes inventory management and allows for the re-starting of pumps, even at low tank levels.

- Dual process feed through for electrical and instrument supply to SMPs and generators provides hermetic gas-tight seals, which stop any possible migration of gas from inside the process to the outside supply side. The power, or instrument, cables inside the tank are connected to the solid bus bar, thus breaking any gas migration pathway. The two termination header seals are designed for the same pressure and temperature that would exist in the instance of a failure of the primary termination header seal. The space between the two termination headers is monitored to detect failure of the primary termination header and to provide alarmed protection against possible gas migration.

The industrial gas/small scale LNG model will benefit by identifying opportunities to standardize its own practices through the establishment of industry practice groups of system designers and pump buyers. Some possible outcomes include:

- A standardized product range of pumps (valves, compressors, etc.), specially designed to provide optimum performance, safety, reliability and efficiency in the flow and pressure range common to these systems.

- A standardized documentation package that minimizes the interface discussions and the engineering hours.

- The design, documentation and certification packages should be such that the project engineering work and planning approval works can be carried out by the owner/operator or a local contractor without the need to involve larger engineering firms.

- The standard equipment design should be capable of interfacing with many configurations of both process piping and storage tanks.

- The product range should include a complete pump system that reflects a 'plug and play' philosophy, whereby hardware and software interfaces are minimized, clearly identified, and a single point of contact and responsibility exists.

- The equipment should be available for quick delivery after purchase order (PO) in a matter of weeks not months.

- The equipment must be competitively priced and reflect the best value for money in terms of safety and proven reliability, while, at the same time, ensuring that the lowest available total life cycle costs are achieved.

- The equipment should come with international third party type certifications for the complete system, reflecting compliance with major design codes and classification society rules.

- The equipment should be designed for installation and operation in accordance with international facility design codes such as NFPA 59A/70.

Some of the key points when specifying LNG mobile storage and regasification equipment include the following:

- Only SMPs should be been adopted for all land and offshore applications, providing zero emissions pumping and eliminating the leakage of flammable gas and liquid.

- A zero emissions policy that can help ensure safest possible solution while simultaneous operations occur (i.e. loading of fuel, cargoes or passengers).

- In-tank removable pumps with higher overall efficiency pumps means less heating of the liquid used for cooling the motor.

- Ensure only In-tank removable SMPs with special motor coolant return line features for routing the motor coolant liquid from the motor to re-inject and mix with the pump discharge flow. Once it is mixed with the pump discharge flow, it leaves the storage tank inside the pump well or discharge pipe, where it travels to the top of the tank, and is routed outside through the process piping. This feature eliminates the effects of BOG production during operation of SMPs as all liquid is pumped outside of the tank with the pump discharge. There is no heating effect from SMP operations.

- Only pump products that are type certified by third party agencies, such as Lloyds Register, Bureau Veritas, DNV GL and ABS, are specified for critical applications.

- It is important to insist on variable speed SMPs with the ability to ramp up pump delivery pressure as required in order to break down the high vapor pressure in the different delivery storage tank conditions.

- Pump suppliers should provide complete pump systems, ensuring a single point of contact and responsibility to the system designers and end users.

- SMPs must be able to operate at high speed (i.e. super synchronous up to 10,000 RPM are provided to ensure lowest CAPEX and OPEX costs).

Careful consideration should be given to the many aspects of LNG product delivery conditions and equipment selection in order to ensure that the safest, most versatile and reliable system is selected. The inclusion of SMPs in your LNG transfer scheme is a tried and proven solution to these types of critical applications. The system must meet all current statutory compliance requirements, while protecting the end user against future emissions policy legislation.

For further information, go to www.acdcom.com.

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