MAXIMISE YOUR SMALL SCALE SAVINGS

Rick Vater, Barry Carbaugh, and Joe Zalac, Matrix PDM Engineering, USA, examine various factors that can have significant influence on the capital costs associated with small to mid scale LNG facilities.

Interest in small and mid scale LNG facilities continues to grow in the current market environment and, as such, it is more important than ever for owner/operators to look for ways to minimise the capital cost of engineering and constructing LNG facilities in determining its overall financial success.

Small and mid-size LNG facilities generally fall into three categories: peak shaving, bunkering, and occasionally small scale export facilities.

Peak shaving facilities are used to provide natural gas to distribution systems during periods of high demand. Historically, peak shaving facilities have been most commonly found in the Northeast of the US; however, recently the trend has been for new facilities to be built in the Southeast and the Southwest. The key elements of a peak shaving facility are liquefaction, storage, and vaporisation. Some peak shaving facilities do not produce LNG on site, but rather purchase LNG and have it delivered by truck. These facilities are often referred to as satellite peak shaving facilities.

LNG bunkering facilities provide LNG fuel to ships, locomotives, or trucks. Bunkering facilities for ships are commonly located along coastlines and often also function as small scale export facilities. Small scale LNG export terminals are being developed to provide LNG to electrical generation facilities located in Central America and the Caribbean, as well as other remote areas of the world. The key elements of these facilities are: liquefaction; storage; and ship, barge, rail, and/or truck loading.

Plot size and location

LNG facilities in the US are regulated by the US Federal Energy Regulatory Commission (FERC) and/or the Pipeline and Hazardous Materials Safety Administration (PHMSA). Projects involving interstate and international commerce are regulated by both FERC and PHMSA, while projects involving

intrastate commerce are regulated only by PHMSA. Both agencies enforce the regulation contained in Section 49 of the Code of Federal Regulations Part 193. These regulations address many aspects of the design of LNG facilities, including the siting of a facility. The federal regulations focus on protecting the public, and therefore require LNG facilities to be located on a large enough plot of land such that the effects of a major release incident are confined to the facility's property. Thus, the trade-offs between the costs of the property, the cost of hazard mitigation features – such as vapour fences – and the ease of obtaining permits and approvals needs to be considered. The safety evaluation also needs to take into consideration the proximity of residential areas, schools, and places where the public may congregate.

Other factors that need to be considered in choosing a site include proximity to natural gas pipelines, which can provide gas to the facility, and the proximity to roads, railways, and port facilities, as appropriate.

Ground surface elevation

Sites which meet the aforementioned requirements can sometimes be located in low lying areas. These areas can be subject to flooding from rainfall or from tidal storm surges, which usually require that the site be elevated or that levees be built. The earthwork associated with raising site elevations and/or building levees can add millions of dollars of cost to a project, while not enhancing the production capabilities of the facility, and thus can threaten a project's financial viability.

Figure 1. Generally, the single most costly item of equipment at an LNG facility is the LNG storage tank.

Figure 2. An LNG truck loading station.

LNG storage tank foundation

Generally the single most costly item of equipment at an LNG facility is the LNG storage tank. LNG storage tanks are available in various styles. The article titled 'Choosing the best containment' by Bob Watson, published in the March 2018 edition of *LNG Industry* magazine, provides useful information on selecting a style of LNG storage tank.

The element of an LNG storage tank that has the greatest amount of cost variability is its foundation. LNG storage tanks built on sites with good soil conditions can utilise shallow foundation designs. Conventional flat bottom, atmospheric, metallic, single containment LNG tanks can utilise ring-wall foundations, while flat bottom, atmospheric, full containment, concrete LNG tanks utilise a slab on grade foundation. Both styles of foundation employ under-tank foundation heating systems. These are the most cost-effective foundation solutions for their respective styles of tanks.

Sites with poor soil conditions will require deep foundations. The design of foundations for poor soil conditions becomes more challenging when high seismic conditions are present. In these situations, certain soil layers could experience soil liquefaction during a seismic event, which could result in excessive ground settlement. Deep foundation solutions include: driven piles, auger cast in-place piles, stone columns, rigid inclusions, and deep soil mixing. These solutions can significantly increase the cost of the LNG storage solution.

Tail gas disposition

Tail gas consists of boil-off gas (BOG) from storage, regen gas from pretreatment, and ethane-rich waste gas from liquefaction. It may be returned to the feed gas pipeline or sent to a tail gas pipeline, if available.

Depending on the composition of the blended stream, the pipeline tariff on heating value may be exceeded, resulting in financial penalties or denial of pipeline access. For feed gas with low ethane concentrations, diluting the tail gas with feed gas often lowers the heating value below the tariff threshold.

For higher ethane concentrations, operating the liquefier at a reduced rate will lower the amount of ethane-rich waste gas produced and extend the range for feed gas dilution.

At the highest ethane concentrations, nitrogen injection is required to lower the heating value below the tariff threshold.

Ethane removal

Shale gas production often results in the composition of pipeline gas feeding an LNG facility containing from 3.5 mole % to as much as 11.5 mole % of ethane feeding the LNG facility. This ethane must be removed, along with heavier hydrocarbons, to prevent freezing in the liquefaction heat exchanger and to keep the ethane concentration in LNG rundown to storage from exceeding product quality limits ($\leqslant$ 3 mole %). To remove the ethane and heavy hydrocarbons, a distillation column is added to the cold box.

Once removed, the ethane and heavy hydrocarbons must be processed by the facility. With little or no ethane present, heavy hydrocarbons alone can be trucked from the facility.

At best, without additional cooling, an ethane-rich waste stream is in a saturated liquid state. Options for disposal include flaring, supplementing the facility's fuel gas system, and sending to a tail gas pipeline. Depending on the facility's mode of operation, a combination of any of the three may be needed.

These options require that the ethane be vaporised. Depending on the operating pressure of the tail gas pipeline, a pump ahead of the vaporiser or a compressor downstream of the vaporiser may be necessary.

BOG disposition

BOG is generated within an LNG storage tank by the combined effect of heat transfer from the ambient environment into the stored LNG, through normal tank operations such as loading and unloading LNG, and as a consequence of the strategies applied to maintaining tank pressure. Smaller LNG tanks can often present more challenges than a large import or export tank in the management of BOG.

Figure 3. Fired heaters provide the energy needed to vaporise LNG at a peak shaving facility.

Heat leak and its contribution to boil-off is an unavoidable consequence of storing a saturated product at a liquid temperature that is cooler than the ambient environment. For LNG storage tanks, the use of high performance insulation systems, especially in the case of larger tanks where the volume to area ratio is high, can provide significant benefits in terms of helping to limit boil-off of LNG from heat leak to 0.05% or less of a full tank's mass per day. Starting at tank sizes with around 1 billion ft^3 of equivalent storage (approximately 12 million gal.) a 0.05% boil-off may become impractical and heat leak percentages of 0.07%, 0.10%, or as high as 0.15% for a 1 million gal. tank may be expected. Operators of smaller tanks should be aware of this when considering product loss in their OPEX analysis.

The larger percentage of heat leak boil-off associated with smaller tanks should not be misunderstood as a large mass flow of BOG. As indicated, the heat leak boil-off is expressed as a function of the mass of product lost compared to a full tank, so the mass flowrate can be quite low for tanks with a small amount of maximum capacity. This can present a challenge when selecting a BOG handling system, as other tank behaviour that contributes to boil-off may not scale similarly. For instance, unloading LNG from a trailer into a tank is generally going to be executed at the same rate regardless of tank size. A warm truck can generate a substantial amount of BOG due to flashing upon pressure let-down. For example, an LNG trailer unloading liquid at -240˚F at 200 gpm may generate 3000 lb/hr of boil-off vapour. For a large storage tank this does not present much of a problem as heat leak alone from a 1 billion ft^3 tank can be on the order of 1200 lb/hr and a BOG compressor with a 4:1 turndown would be suitable. Turndown is the ratio of the maximum operating capacity of an item of equipment to its minimum operating capacity. A 1 million gal. tank on the other hand may have boil off, even at 0.15% per day, that is as low as 200 lb/hr, requiring a BOG system with a 15:1 turndown. Generally, operation of a compressor package at the low end of its turndown is inefficient and yet, as heat leak boil-off is nearly continuous and unloading operations can be intermittent, an operator of a small LNG tank may find that inefficient use of a large compressor package would be normal rather than the exception. Alternatively, strategic combinations of BOG compressors may work to provide more efficient solutions. For example, the use of a smaller holding compressor for heat leak and a second larger compressor intended for unloading operations, or multiple smaller 33% capacity units, would provide better solutions than larger 100% capacity machines.

Other process operations may present challenges when considering BOG generation for a small tank when compared to a large tank. Trailer unloading or the operation of an LNG pump can generate a significant amount of boil-off vapour while spilling back into the tank. A small tank outfitted with large capacity, high-pressure pumps will face the same challenges with compressor selection as trailer unloading operations.

Barometric events, scenarios defined by rapid external pressure changes generally linked to a significant weather event, can result in BOG generation as the liquid is conditioned to a new saturation pressure, while trying to hold tank gauge pressure. The effect of barometric events does scale with tank size and should be treated in the same way regardless of tank size. Rather than tank size, consideration for how to handle a barometric event has more to do with the tank design pressure. A 4.0 psig tank has more capability of tolerating a rise in gauge pressure due to a barometric event than a tank with a low design pressure that has little choice but to attempt to keep pace with the changing external pressure. Unfortunately, a 4.0 psig tank design is generally limited to full containment concrete tank designs, which have rarely been selected for small facilities due to higher capital costs. Consequently, a smaller tank designed with a lower design pressure may have to prioritise more BOG capacity for barometric events than a tank designed with a higher design pressure.

Conclusion

There are numerous challenges that need to be overcome in the development of small and mid scale LNG terminals. Significant saving in project costs can often be achieved by involving a qualified engineering team in the early stages of the development of a project. Where speed to market is important, shortened project development times can be accomplished by utilising a full-service contractor who can take the project from concept to completion. **LNG**

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