LNG terminal expansion moves to forefront of contract tender action

Brian Eisentrout, Process Design Manager at CB&I Corp. presents a case study of the Trunkline LNG Lake Charles Terminal work

As the worldwide demand for hydrocarbon-based fuels continues to rise, liquefied natural gas has become a key source of energy in the Western hemisphere as there are no potential sources of pipeline gas that could meet all the demand.

Countries in Western Europe, as well as nations such as India, Mexico, China and Chile have built, or are planning to build, LNG import terminals, while countries such as Japan and Korea historically have relied on import terminals for their natural gas needs.

Given the current increase in natural gas consumption, an expansion of a completed LNG import terminal is almost inevitable.

This is because the infrastructure for receiving shipments – such as the marine facilities for ships, storage tanks, utilities for regasification and pipelines for delivery – is already in place.

In addition, expanding facilities that have already been in successful operation are more readily accepted by the public and regulatory officials.

To these stakeholders, an LNG import terminal is not an "unknown" – they are aware of and understand the risks, hazards and benefits involved.

As such, the economic benefits of the facility, coupled with a demonstrated track record of safe operation, make expansion an easier proposition to accept.

While each LNG terminal is designed and constructed differently, depending on the codes and standards of the particular region in which it is being constructed, the basic terminal design remains largely the same.

As an example of the design issues and perspectives facing terminal operators, I will concentrate on the issues that had to be addressed during the expansion of one of only four operating terminals in the US - the Trunkline LNG terminal at Lake Charles, Louisiana.

Design considerations

When planning a new terminal, it is imperative that the terminal developer considers the possibility that the terminal will need to be expanded in the future. Of the many design parameters that must be considered when building a new terminal, several are important from an expansion point-of-view.

Some of the most crucial issues that must be considered when building a new terminal are the siting and exclusion-zone criteria. Exclusion zones are defined as the area within a specified thermal radiation threshold created by design

The Trunkline LNG terminal, which was built in 1981, is located southwest of Lake Charles, Louisiana, about 40km (25 miles) from the Gulf of Mexico and accessible to carriers via the ship channel

exclusion zones are foremost in people's minds when it comes to their perception of terminal safety, evaluating the land area necessary for an expansion is critically important.

The larger the impoundment surface area, the larger the fire and hence, the larger the exclusion zone due to the radiation from the fire. If the siting criteria and exclusion zone requirements for a future expansion are addressed during the initial planning, the ease of permitting and installing an expansion will be enhanced.

The design of an exclusion zone is significantly affected by the LNG storage containment style. For instance, single containment tanks, which have earthen berm impoundments typically installed, require significantly larger exclusion zones than full or double containment tanks.

This is because the size of the impoundment fire, as well as the radiation that stems from it, determines the exclusion zone.

To reduce the exclusion zone for single containment tank impoundments, high dikes or concrete walls can be used to mitigate the radiation by reducing the impoundment surface area and hence, zone with single containment tanks.

Full containment tanks with concrete roofs have a much smaller exclusion zone since the impoundment is the secondary container and the only fire scenario would be a relief fire.

Codes & standards

Even if the roof was not considered to be containment and the design fire was a fire in the secondary container, the exclusion zone distances would be reduced significantly compared to single containment distances.

Other issues for consideration include potential changes in codes and standards. Designing to the limit of a code without some margin may, in the long run, limit the ability for a future expansion.

For instance, slight changes to the code could push the thermal radiation over the limits. In addition, storage tank capacities have steadily increased.

Several years ago, it might have seemed reasonable to make provisions for a future tank with a capacity of 100,000 cubic meters (m^3). Today, however, designs for tanks with capacities of 200,000 m^3 or more are being contemplated.

impoundment of a single containment tank or from the secondary container of a full containment tank – is the primary siting criteria for an import terminal.

Several issues concerning the properties of the LNG need to be addressed as well. Is the LNG to be received in the expansion area from a specified source or from several possible sources?

Does the terminal need to be designed to receive spot cargos? Is it currently being received in the expansion area? Many of these issues are dependent upon the condition and composition of the LNG being received, which have a significant impact on the expansion of the regasification facilities.

Condition, as used in this article, is the saturation pressure of the LNG delivered to the terminal. As the saturation pressure of the LNG cargo increases, the

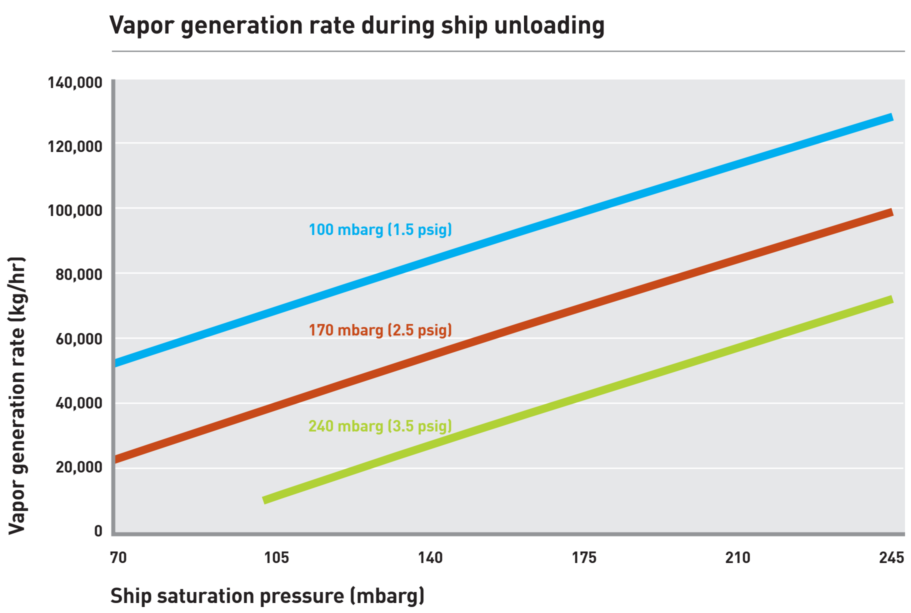

Figure 1: Relative vapor generation rates for typical containment tanks

vapor generated for a given unloading rate increases as well (see Figure 1).

Vapor generation

This figure gives relative vapor generation rates for typical single containment tanks, which have an operating pressure during unloading of 100 mbarg, (1.5 psig). Vapor generation rates are also given for typical full containment tanks, which have operating pressures of 170 mbarg (2.5 psig) and 240 mbarg (3.5 psig).

The vapor generation rates are representative of rates with no sendout, a methane content of 95.2 percent, a nitrogen content of 0.44 percent, and an unloading rate of 14,700 cubic meters per hour (m3/hr) into a single tank. Ship pump energy and heat leak are also included.

The graph shows that there are several advantages to having higher receiving tank pressure. But to unload LNG cargos with higher vapor pressures, additional vapor handling equipment is required.

Because the cryogenic compression needed to handle unloading vapor is expensive, it is important to compare adding compression to unload high saturation pressure LNG at full rate with not adding compression and unloading at a reduced rate to determine which is the optimal solution.

This comparison should evaluate such issues as the likelihood of high LNG saturation pressure; unloading delay, which would result in demurrage; and loss of product should flaring be necessary during unload. The storage tank operating pressure should also be examined.

Composition changes also have a significant effect on terminal facilities and equipment. The ability to recondense, vaporize and supply gas within pipeline specification is dependent on the composition of the LNG.

For example, higher nitrogen content can reduce the ability to recondense, while higher methane content could require additional vaporization equipment. Another issue that must be considered is rich LNG and whether it needs BTU correction.

This would require cargoes of differing compositions to be segregated for BTU reduction. This segregation could require additional storage or modification of the storage capacity to handle the volume of the potential LNG carrier. Ranges of typical LNG compositions and heating values are given in Figures 2 and 3. (see overleaf)

Another consideration is the increase in the size of LNG carriers to as much as 267,000 m^3 capacity. In addition to the obvious effect this will have on physical port facilities, the unloading rate from the ship may well increase, which could require larger and/or more loading arms.

An increased unloading rate may also increase the vapor generation rate, as well as the unloading duration. Plus, new LNG carriers have higher head pumps that can further increase the unloading rate through the existing piping.

Typical compositions

C1	90.37	88.60	84	84.79	92.79	95.05	87
C2	7.01	6.25	10	9.01	5.41	4.58	8.37
C3	1.32	3.50	2.5	3.25	1.37	0.29	3
i-C4	0.55		0.52	1.3	0.11	0.03	0.6
n-C4	0.00	1.50	0.89	0	0.21	0.02	0.6
i-C5			0.3	0.25		0.01	0.23
n-C5		0.05		0		0	0
n-C6			1.28			0.04	
N2	0.75	0.10	0.51	1.4	0.11	0.01	0.2

Figure 2 : Range of LNG Compositions

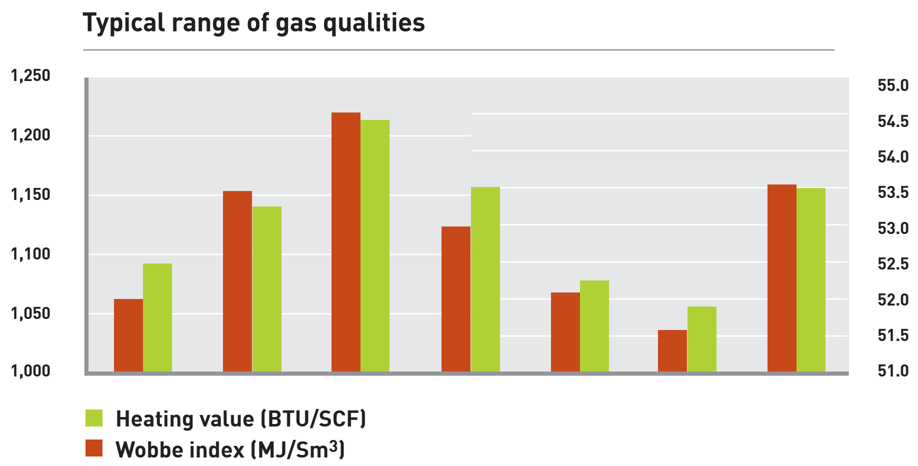

Figure 3 : Heating value and Wobbe index

The overall storage must also be evaluated, as the ability to unload 100 percent of a carrier's capacity is needed. Another element to keep in mind is that the physical size of the unloading dock may prevent loading arm modifications or additions.

All of these issues must be factored into the overall terminal design, especially if there is a high possibility that the terminal will need to be expanded in the future.

LNG source

When considering an expansion, the first question should be whether the LNG supply is going to remain the same. If not, it is crucial to find out what the future LNG composition could potentially be. If the future composition has higher heavies constituents (i.e. rich LNG), BTU correction may be required.

BTU correction may be accomplished in several ways, including LNG blending, dilution with air or nitrogen, gas mixing, or heavies removal.

Blending may require additional storage so that cargos can be segregated into different storage tanks. While the addition of new storage for the sole purpose of blending may not be economically justified, the available existing storage can be segregated where allowable, which could be the most economical solution.

Air and nitrogen dilution of the natural gas are also viable BTU reduction methods. Because air dilution requires a relatively large air compressor that represents a significant capital expense despite only being used sparingly, an option for air injection is to rent or lease a readily available engine-driven air compressor for dilution when it is required.

One drawback to air dilution, however, is the injection of oxygen, which is detrimental to the operation of many pretreatment systems of downstream peakshaving facilities. Oxygen conversion during molecular sieve regeneration may reduce the life and capacity of the molecular sieve.

Nitrogen injection is also a viable dilution method. Nitrogen could be injected while LNG is in the liquid form or after regasification.

Because injection after regasification would require a large volume of nitrogen, an air separation plant or other capital intensive facility would be needed to produce the quantity required.

By the same token, injection prior to regasification would require the production of nitrogen in cryogenic form, which, if not available in quantity, would necessitate the installation of an air separation plant. Nitrogen injection while the LNG is in liquid form would also require liquid nitrogen storage onsite.

BTU content

Mixing of the terminal's high BTU content outlet gas with the relatively low BTU content of an adjacent pipeline is also a viable option for BTU reduction.

Depending on the flowby of the adjacent pipeline and the BTU content of the terminal gas, this may be an easy method of using high BTU gas.

Obviously the higher the flow and the lower the BTU content of the flowby gas, the easier it is to maintain pipeline specification for BTU content in the mixed gas. As such, minimum flow in the flowby gas must be taken into account.

Additional design considerations for handling rich LNG include whether to increase the horsepower of the pumps and/or the pressure of the piping systems. For a given pump head, more horsepower is required to pump a new supply of LNG that is richer than the design LNG.

If the pump has the available horsepower in the installed motor, the potential is to create excessive pressure. Pressure created by the pump discharge is the head multiplied by the density of the fluid pumped.

The higher the density pumped, the greater the pressure created. Pump upgrades for the higher density fluid, as well as restricted pump flow, are possible methods of managing the rich LNG.

After considering the potential LNG compositions, the second question should be what the condition of the LNG will be when it's delivered to the terminal. Should the LNG supply for the expansion come from a more distant or remote location, it could have a higher vapor pressure at the delivery point, which would require additional design considerations.

Significant to this evaluation is the consideration for accepting a variety of spot cargos. Options include designing for a worst-case LNG vapor pressure or selecting a lower vapor pressure as the limit.

However, selecting the worst case will result in the highest investment in capital equipment, such as a compressor and/or recondensers.

Investment

The increase in vapor handling required will ultimately determine the investment. If cargos with vapor pressures exceeding the design limits of the terminal are received, there are several methods of accommodating them.

The ship unloading rate could be reduced to a rate that allows the terminal vapor handling equipment to manage the load, which would have a significant impact on the schedule.

As an alternative, the unloading rate could be maintained while the excess vapor is flared or vented. This is not a desirable option but may be usable in a one-of-a-kind situation. Storage tank bottom filling also has been demonstrated as an effective vapor suppression method.

Under normal procedures, a cargo of rich LNG would be top filled to release the energy into the fluid as flash gas; however, if the cargo is bottom filled in the terminal storage tanks, the flash gas generation is suppressed.

Bottom filling must be closely managed to prevent rollover. Usually, the unloading compression equipment is operated for several days after the ship is unloaded to remove the excess energy in the storage tank.

In addition, high vapor pressure in cargo tanks will result in high vapor generation rates. This can be managed by either increasing the size of the vapor handling equipment or reducing the vapor generation rate, which can be achieved by either bottom filling the LNG tanks or unloading at a reduced rate.

Whenever throughput is increased, a review of berth availability and the storage capacity needed to meet production demands is required.

This is because the inventory available will be depleted in a shorter amount of time with the increased throughput. As such, berth availability will need to be higher. If berth availability is limited or cannot be increased, additional storage would be a way to maintain production obligations.

An additional consideration when expanding a regasification terminal is whether to reduce fuel use/costs. If fired equipment is used, as is typical in submerged combustion and fired indirect vaporizers, approximately 1.5 percent of the terminal throughput is used as fuel.

Nearby or associated power plants can provide the heat for vaporization. In warm climates, ambient air and seawater are available heat sources that can be readily expanded.

Even the terminal's own power generation can be a source of vaporization energy, particularly in cases where the terminal is not dedicated to a power plant or water heat source and it must have a back-up heat source.

Case Study of Lake Charles Expansion

The original plant capacities were:

- Single ship unload at 10,000 m^3/hr
- Three single containment LNG tanks - 95,000 m^3 each
- Sendout capacity: 5.46 million tons per annum (mmtpa), or 750 million standard cubic feet per day (mmscfd), using seven submerged combustion vaporizers (SCV)
- Sendout delivery pressure: 48-103 mbarg (700-1,260 psig) to 0.6-meter (24-inch) diameter pipeline

An enhancement completed in 2000 increased the sendout capacity to 7.28 mmtpa (1,000 mmscfd). Each SCV capacity was raised to 1.14 mmtpa (150 mmscfd). The most recent expansion further increased the continuous sendout capacity to 13.1 mmtpa (1,800 mmscfd) and the peak sendout capacity to 15.9 mmtpa (2,100 mmscfd).

This expansion was performed in two phases, with three in-service dates for the expansion facilities. The Phase 1 expansion of the continuous sendout capacity to 8.73 mmtpa (1,200 mmscfd) was completed in September 2005, with the additional storage placed in service in April 2006.

The Phase 2 expansion was completed in July 2006. Additional terminal work is currently under way, which will allow BTU correction by extraction of the heavier components from the rich LNG.

Expansion system design

Although some carriers that berth at Trunkline LNG have had vapor pressures exceeding 170 mbarg (2.5 psig), this pressure was determined to be an appropriate design pressure.

Plus, the chances of ship vapor pressure routinely exceeding 170 mbarg (2.5 psig), while possible, are not likely. This pressure was arrived at by a suitable compromise that allows the terminal to unload using spare vapor handling compressors rather than additional compressors used solely for ship unloading.

Although simultaneous ship unloading was originally contemplated, it was determined that simultaneous unloading at design conditions was not merited. Thus, if two ships were to arrive at the terminal simultaneously with cargos at the design limit, they would be unloaded sequentially.

If the vapor pressures of both ships were low, however, their unloading could be overlapped to the capacity of the vapor-handling system. Additional provisions included in the terminal expansion were to design the new pumps and upgrade the existing pumps to pump rich LNG.

The potential pressure generated by the rich LNG and the horsepower required to pump it served as design parameters for the new pumps.

The addition of storage also had an effect on the exclusion zones required. The existing storage tanks are 90,000 m^3 capacity with space allotted for an additional 90,000 m^3 tank. Had a tank of equal size been added, with an impoundment dike and the same dimensions as the existing tanks, there would have been little to no effect on the exclusion zones.

In actuality, the storage tank required for the expansion was 140,000m^3, and the resulting impoundment size required was significantly larger. To mitigate the larger exclusion zone required by the larger surface area fire, the impoundment height was increased three meters (10 feet).

The resulting reduction in surface area reduced the exclusion zone to a manageable size, similar to that of the existing storage tanks.

Mixing is the method currently used by the terminal to maintain pipeline quality gas. The 41-kilometer (26-mile) pipelines that receive the terminal output inject the gas into a main transmission line with high flowby. A heavies extraction plant is in the planning stages, which will enable the terminal to provide pipeline quality gas without having to mix with the pipeline.

The expansion also included the following equipment and system modifications:

LNG unloading system A second unloading dock was added with the ability to handle 160,000m³ vessels. A second recondenser was added to handle the additional vapor generated by the larger vessels. No additional vapor handling was required as simultaneous unloading from the two docks is not planned.

Sendout system modification Seven original sendout stage pumps were modified to provide higher flow and head, and seven new high-capacity second stage sendout pumps were added. In addition, seven new SCVs were installed, each with a capacity of 1.14 mmtpa (150 mmscfd). Additional water treatment was added for new vaporizers. The 41-kilometer (26-mile) pipeline used to carry terminal output to the natural gas transmission system was expanded to include a second, 0.8-meter (30-inch) diameter line.

One 140,000m³ LNG storage tank was added with the ability to unload a cargo direct from the new dock into the tank – independently of the existing three tanks.

Support utilities Existing terminal firewater, utility water and instrument air systems were expanded for the new facilities. The existing terminal control systems, including separate distributed control, fire detection and emergency shutdown systems, were expanded for the new facilities. Fuel gas and high expansion foam systems were also expanded.

In terms of facility security, there were several hundred construction personnel who needed access to all areas of the terminal.

To control and manage their access into sensitive areas, each person was identified using photo IDs and magnetic key cards. Hazardous areas were controlled by daily work permits. When plant operations in an area created an additional hazard, work in those areas was suspended.

Communication

While planning the expansion, a large number of interfaces was organized between plant and construction personnel, as well as between existing equipment and new equipment. Where possible, duplicate equipment was used to reinforce operation of the new equipment.

The expansion piping installation, for instance, required a single plant shutdown and deinventory of the terminal piping. Around 30 critical piping tie-ins were made during the shutdown.

The deinventory required the installation of a temporary flare (the terminal does not have a flare) to dispose of gas that could not be removed and compressed into the pipeline. An additional 150 piping tie-ins were made in the terminal that did not require a full shutdown.

Each piping tie-in was treated as its own project and had its own schedule, material summary, safety review and installation procedure. Although these piping tie-ins did not require a terminal shutdown, they did require restrictions or modifications to the terminal operations for a short period. To minimize this disruption, each tie-in was treated as a turnaround with an hour-by-hour schedule.

The expansion of the terminal control systems included using existing terminals, slots and cable, as well as adding distributed controls.

Lessons learned

The expansion of terminals in the US and elsewhere has generated several universal principles that can be applied to all import terminal expansions.

But because each terminal has a unique physical location and supply contract, they need to be studied on an individual basis. Physical proximity to LNG supply sources, transmission pipelines at the receiving terminal, supply sources and consumers should all be considered when determining whether to accept spot market cargos.

Composition or condition changes must also be examined because additional terminal equipment may be needed to handle these spot market cargos.

Likewise, if the expansion facilities will be supplied with LNG from a different source, the condition and composition of that LNG must be considered and evaluated.

Siting of the expansion is another significant issue that must be considered. Allowances for land area and possible technology changes likewise should be taken into consideration.

Expansion facilities should have minimal interface with existing facilities. Using existing control system hardware, for example, exposes the terminal operations to potential shutdowns whenever construction personnel are in the cabinets. Interface work during ship unloading is not recommended, and electrical distribution systems should be as independent as possible.

Expansion planning is critical, particularly in instances where LNG carrier schedules and gas nominations change from hour to hour. The interfaces organized with aging equipment and hardware need to be carefully managed with contingencies for leaks, malfunctions and failures.

Failure of a specific piece of hardware should not affect the interface and tie-in. Procedures and personnel need to be available to complete the necessary work even if some components have failed, and spare parts and materials that can be used as a workaround also need to be readily available.

Not to be ignored is the additional manpower needed from both the operating staff and the construction staff during the installation. Approximately 10% more staff is needed on the operating side to manage the interface with the construction personnel in regards to permitting, special operating procedures and tie-ins. The construction staff also needs personnel to manage manpower safety, permitting development of tie-in procedures and contingency plans.

And while the basic design for most import terminals remains largely consistent, expansions can be very complicated and challenging.

As such, they require proper planning, as well as experienced guidance that can identify ways of improving performance and efficiency. These qualities are crucial to any expansion and will ensure that the project is successfully executed. ■