

# New trends in LNG storage

A decorative graphic on a teal background. On the left, a red paper airplane is positioned at the start of a dashed white line that curves downwards and then loops back to the right. On the right side, three white paper airplanes are arranged vertically, each with a dashed white line extending downwards from its tail. The overall theme is one of progress and forward movement.

**N**ew industry standards for low temperature and cryogenic storage have been developed over the past few decades. These include the design of double-wall storage structures, testing, utilisation of load bearing insulation systems, and air raising of field-erected tank roofs, which were led by CB&I.

The company continues to innovate LNG tank designs and project delivery models to reduce risk, improve project construction schedules, and optimise overall project economics for customers. These innovations include scalable tank offerings that meet customer storage needs over a wide range of tank capacities.

## **Mid scale: Modular LNG storage tanks**

Modular tanks provide the benefit of minimising the amount of site activities, shifting the majority of the tank construction work to a high quality, low-labour cost facility, within a well-controlled environment. This approach significantly reduces costs and helps advance the overall construction schedule.

The company has developed a mid scale modular tank design and execution plan for modularisation, delivery, installation, testing, and commissioning, which:

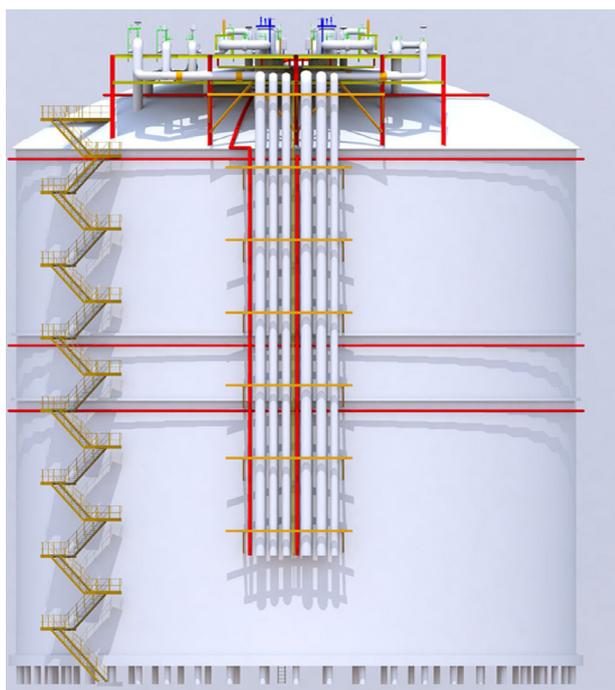
**Jeff Garrison, Yogi Meher, and Mark Butts, CB&I, explore how LNG storage tanks have developed with the changing industry.**

- Constructs tank module off-site in low-cost labour location.
- Transports the tank module including base slab/pedestal foundation, pump tubes, top platform, and topsides piping to grade to site.
- Installs the tank module on piles or prepared slab-on-grade.

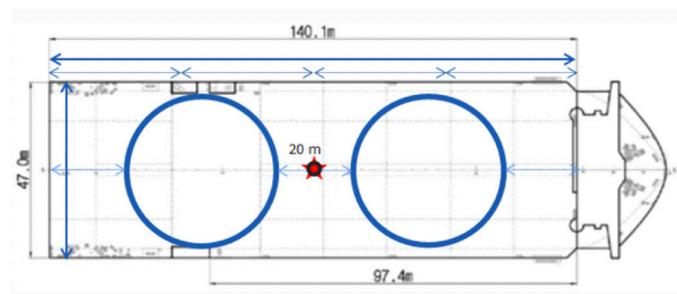
The tank is designed for wind, seismic, projectile, blast, and dropped objects loading.

## Modular transporting

Transportation is the key for delivering modular tanks of this size and configuration.



**Figure 1.** Elevation view of modular tank concept.



**Figure 2.** Shipping concept for two modular tanks.

**Table 1.** Nominal design conditions

Product	LNG
Net capacity	320 000 m <sup>3</sup>
SG	0.48
Design internal pressure	29 kPa
Maximum outer tank dia.	100 m

The company can provide transport of modular tanks by vessel or truck, transporting up to two tanks per open deck module transport vessel.

CB&I uses self-propelled modular transport (SPMT) for ground transport of its modular tanks, in which the tank/slab overhangs SPMTs due to narrow roads. This transportation method was developed to balance the load on all SPMTs and avoid overloading/cracking the base slab.

There are many things to consider when designing a modular tank built offsite, shipped to site and installed in its final location, including:

- Tank size based on height and weight limitation restrictions.
- Restrictions on road widths complicate the ground transportation.
- Balancing the loads on all SPMTs without cracking the slab.
- Specialised tank bottom insulation system designed for ground and sea transport.
- Maritime experts required to confirm the mid scale modular tank-imposed loads can be accommodated by the ship deck.

## Project-specific engineering

CB&I's modular tank design allows each tank to be customised for project specific requirements:

- Tank design to be validated for site-specific seismic loading.
- Tank topside design to be based on project specific P&IDs.
- Foundation design for site-specific soil conditions.
- Resistance of steel outer container to site specific external hazards such as wind, blast, and projectile loading.
- Development of tank marine transportation under pressurised condition.

## Very large scale LNG storage tanks

In addition to mid scale solutions like the modular concept, the LNG industry also demands ever-increasing large scale storage solutions for 200 000+ m<sup>3</sup> capacity full containment tanks. CB&I has decades of experience providing large scale storage solutions, upscaling to ensure its full containment tanks are evolving to match industry needs. This has added substantial capacity over this time frame, with many tanks 160 000 m<sup>3</sup> and larger. Such examples around the world include large scale storage solutions located in Milford Haven, Wales, the UK; Quintana, Texas, the US; on Elba Island, Georgia, the US; and Barrow Island, Australia.

## Ever larger tank capacities

With experience gained over many decades designing and building some of the world's largest LNG tanks, CB&I has helped reduce LNG tank construction schedules by 30 – 40%. Reduced construction schedules translate to reduced project risk for facility developers and owners. With the industry moving to ever larger tank capacities, the company is leveraging its design experience with large tank sizes

and fast construction schedules to offer designs greater than 200 000 m<sup>3</sup>, even up to 320 000 m<sup>3</sup> in some cases. The purpose is to leverage advanced construction technology and schedule performance to offer the industry even greater economies of scale using the company's proven project delivery model. As the industry considers scaling tank capacity up to 320 000 m<sup>3</sup>, the company's focus is concrete full containment tank configuration as most appropriate for very large tank sizes, considering tank internal design pressures and other design requirements.

## Evaluation of risks for tank configuration

A full containment refrigerated liquefied gas storage tank system consists of an inner primary container designed to store the refrigerated product during normal operation, and a secondary liquid container designed to contain the product during an emergency leak from the primary liquid container. The primary container is composed of cryogenic steel suitable for the product temperature, while the secondary container is composed of either the same grade cryogenic steel or reinforced and prestressed concrete.

A full containment tank system as defined by API 625 shall have both primary and secondary liquid containers that are capable of independently containing the liquid product.

- The secondary container may need to resist external hazards such as an external explosion overpressure blast wave, projectile impact, or external fire.
- The secondary liquid container shall be capable of both containing the liquid product and controlling the vapour release in the event of product leakage from the primary liquid container.

## Compliance to codes and local regulations

A full containment tank system shall be compliant with facility and tank design codes as well as any local regulations. Typical codes that apply include:

- NFPA 59A – 'Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG).'
- API Standard 625 – 'Tank Systems for Refrigerated Liquefied Gas Storage'
- API Standard 620 – 'Design and Construction of Large, Welded, Low-pressure Storage Tanks'
- BS EN 14620 Parts 1 through 5 – 'Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C.'

## Tank design

Many factors drive the ability to design very large LNG tanks, including local environmental requirements such as wind and seismic loading, and operating requirements such as operating pressure. Factors can also include upset conditions such as adjacent tank fire and projectile and blast loading. With so many potential design considerations, the company's initial feasibility study for 320 000 m<sup>3</sup>

storage tanks is based on basic design conditions with a focus on constructability of large structures.

CB&I's research and development team completed design work to confirm a very large standard configuration full containment concrete LNG tank can be designed using current day code and standards requirements for the nominal design conditions defined in Table 1.

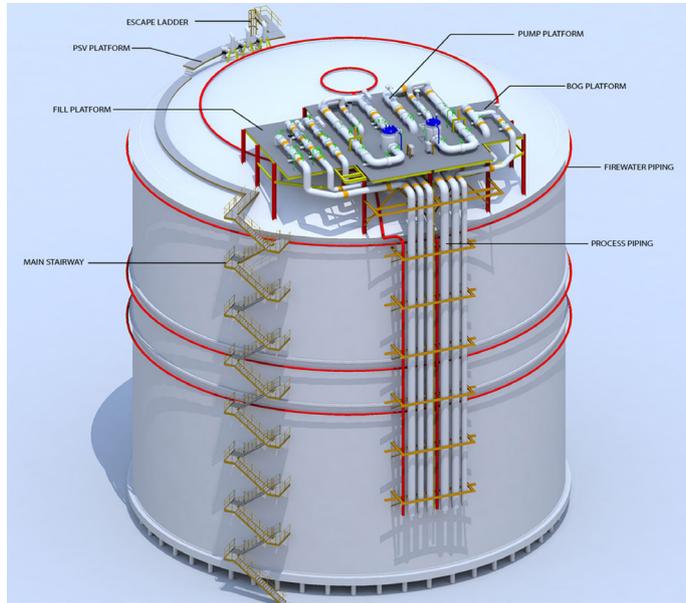


Figure 3. Rendering of modular tank concept.

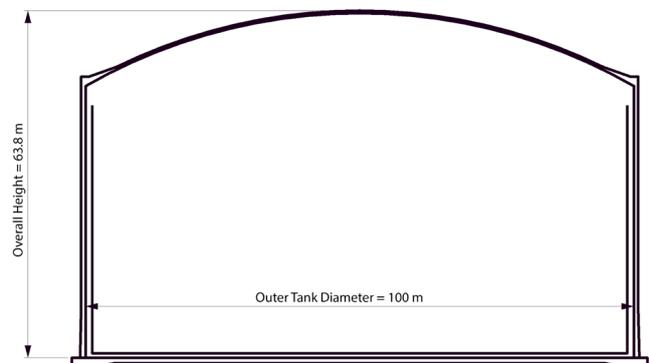


Figure 4. Conceptual geometry of 320 000 m<sup>3</sup> LNG tank.

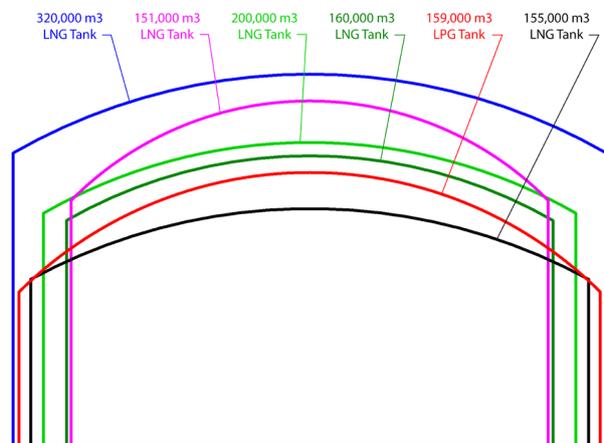


Figure 5. Comparative sizing of large low temperature and cryogenic tanks.

## Conceptual 320 000 m<sup>3</sup> LNG tank

The conceptual geometry for 320 000 m<sup>3</sup> storage is a natural extension of CB&I's experience with very large diameter tanks coupled with experience building very tall structures. This experience allows the company to combine these diameters and heights in the same structure to achieve 320 000 m<sup>3</sup> storage. Some of the company's experience in constructing large low temperature and cryogenic (LT&C) tanks includes:

- Two 151 000 m<sup>3</sup> full containment concrete LNG tanks, Quintero Bay, Chile, with an outer tank diameter of 80.4 m.
- Five 155 000 m<sup>3</sup> full containment concrete LNG tanks, Milford Haven, Wales, the UK, with an outer tank diameter of 94 m.
- Four 159 000 m<sup>3</sup> double wall full containment steel LPG tanks, Juaymah, Saudi Arabia, with an outer tank diameter of 98 m.
- Three 160 000 m<sup>3</sup> full containment concrete LNG tanks, Yuedong, China, with an outer tank diameter of 82 m.
- Two 180 000 m<sup>3</sup> full containment concrete LNG tanks, Barrow Island, Australia, with an outer tank diameter of 87 m.
- Three 190 000 m<sup>3</sup> full containment concrete LNG tanks, Isle of Grain, the UK, with an outer tank diameter of 90.8 m.

- Two 200 000 m<sup>3</sup> full containment concrete LNG tanks, Gulf Coast, the US, with an outer tank diameter of 89.8 m.

## Construction technology for large structures

Evaluations on constructability must consider both diameter and height. The main constructability issues include air raising a large diameter roof, concrete placement on such a large roof, and environmental loads, such as wind, for some locations.

The company's Construction Technology group ensures customers benefit from the latest technology, equipment, and construction methods across our global job sites. This group also maintains relationships with major construction equipment suppliers to assure an efficient flow of supplies and minimal downtime.

This group is instrumental in CB&I's ability to design and construct large tanks, including this 320 000 m<sup>3</sup> conceptual design.

## Conclusions

CB&I's latest innovations in LNG storage tank design offers a modular double steel full containment tank in an effort to minimise the amount of site activities, shifting the majority of the tank construction work to a high quality, low-labour cost, well-controlled environment. The company continues to innovate scalable tank offerings so as to meet customers' needs for large LNG storage exceeding 200 000 m<sup>3</sup> all the way up to 320 000 m<sup>3</sup>. CB&I continues to innovate the LNG storage tank designs to offer scalable and modular options to customers to help improve the schedule and economics. **LNG**