Innovative storage solutions to meet growing demand

Brian Wiese, CB&I, USA,
explores how innovations in liquid nitrogen (LIN) tank design are unlocking larger capacities and offering valuable lessons for the energy storage sector.

As hydrocarbon storage infrastructure evolves, operators are increasingly seeking larger, more efficient tanks to reduce footprint, optimise costs, and improve operational reliability. While liquid nitrogen (LIN) is most commonly associated with industrial gas applications, it plays a critical role in the energy storage sector, providing inerting and purging for facility safety systems, as well as providing feedstock for hydrogen energy processes.

At the same time, advances in cryogenic storage design are being driven by demand from other industries, most notably semiconductor fabrication. New processes require an increased volume of LIN to support modern cleanliness requirements as well as to meet the required low temperatures for certain parts of the process and provide an extremely dry and oxygen-free environment. Traditional LIN tank configurations cannot effectively meet this need, creating an opportunity to advance the technology solutions applied to LIN storage. In turn, this can offer valuable lessons for LNG, ammonia, and other cryogenic hydrocarbon storage applications.

This article explores how next-generation LIN storage solutions are overcoming legacy design constraints to achieve unprecedented scale, and what these innovations could mean for the future of cryogenic storage across the hydrocarbon sector.

Typical LIN tank configuration

LIN is stored at -320°F under low pressure, typically ranging from 2 to 5 psig. A typical LIN tank (see Figure 1) consists of a double-wall, double-roof tank with a stainless steel inner tank and a carbon steel outer tank. Both the inner and outer tanks are anchored to resist the uplift from the internal pressure. To help keep the LIN at temperature, the inner tank rests on load-bearing

cellular glass insulation, and the annular space for the shell and the roof are filled with perlite insulation. The inner tank has external stiffeners to resist the pressure from the perlite. Process piping is installed in the annular space adjacent to the inner tank, enabling effective insulation while protecting the piping from external environmental conditions. The tank is typically elevated on a 'table top' foundation that is 10 to 12 ft above grade. The foundation is designed as either piles that end in a pile cap or as a double-slab concept with columns separating the two slabs. The elevation provides liquid head to the external pumps.

Held back by legacy

Historically, LIN tanks were designed such that they could later be converted to liquid oxygen (LOX) tanks. The prevailing thought was that this design would give owners flexibility to respond to increased LOX demand in the future, but the demand never materialised. However, the LOX-related design requirements have continued to be applied to LIN tanks by being carried forward in today's specifications.

The dual design aspect of LIN tanks required that they meet the more stringent requirements to store LOX. Namely, this meant that anything containing organic (combustible) materials could not be used in or around the tank. While oxygen does not combust, it does act as an accelerant if there is a fire present. Some examples of this impact are:

- Fibreglass insulation had to be replaced with more expensive and less effective ceramic insulation because of the flammable glue binders in the former option.
- Asphalt interleaving in the cellular glass load-bearing insulation had to be changed to more expensive and difficult to handle fibreglass woven cloth.

Another impact of these legacy design criteria is that a resilient blanket could not be used to reduce the external pressure from the perlite insulation. Over time, the perlite pressure grows, easily exceeding 100 lb/ft^2, leading to tanks requiring extensive internal stiffening, often necessitating a stiffener at every ring. These examples of legacy constraints have limited flat-bottom LIN storage tanks to a maximum capacity of approximately 10 000 m^3 (2.64 million gal.).

Charting a new path

CB&I recently completed the construction of a LIN storage tank with a capacity of 22 400 m^3, making it the largest LIN storage tank in the world. The tank supports a new semiconductor fabrication facility in Texas, US. Previously, CB&I had constructed a 10 000 m^3 LIN storage tank that was considered the world's largest. To achieve this drastic increase in storage volume for a single LIN tank, CB&I collaborated with the LIN supplier to solve the many challenges necessary to make this tank a reality. CB&I's expertise in design and construction of large cryogenic storage tanks, such as LNG and ammonia tanks, provided the foundation for developing innovative solutions that enable larger-volume LIN storage.

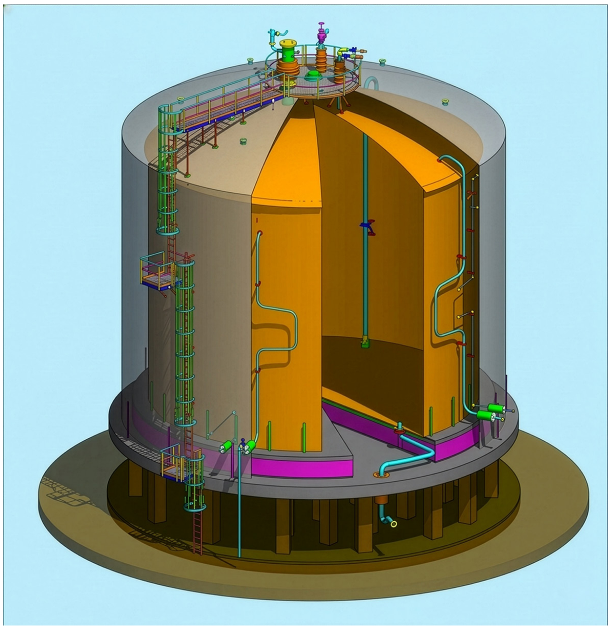

Figure 1. Typical LIN tank configuration.

The primary design challenge involved the stiffening of the inner shell against the perlite pressure. With a tank diameter of 117 ft and a height of over 86 ft, the perlite pressure would exceed 150 lb/ft^2. Conventional stiffening would have necessitated thicker rings and multiple stiffeners on several of the upper rings. CB&I identified a resilient blanket solution that was acceptable to the client, allowing the perlite pressure to be reduced by more than 80%. While this configuration eliminated the majority of the stiffeners and allowed thinner shell plates to be used, it introduced a secondary complication. To use the resilient blanket, the inner tank stiffeners were required to be installed on the inside of the inner tank, instead of the customary exterior arrangement used to facilitate cleaning (how CB&I addressed the cleaning issue is discussed later in this article).

Another design challenge involved the roof selection and the placement of the roof at height. Typically, LIN tanks use a lap-welded, self-supporting dome roof for both the inner and outer tanks, with each roof placed using a crane. However, the size of this tank required a different solution that involved ring girders and radial rafters. Additionally, the reach of a crane required to lift and place such a large and heavy roof made the traditional installation method impractical. CB&I designed the inner roof to have externally framed girders and rafters fabricated from stainless steel to meet the temperature requirements for LIN service. The outer tank was designed with internally framed rafters and girders made from carbon steel.

To install the roofs at the top of the tank, CB&I used a variation of its roof air raise method. In 1960, the company developed the air raise method that allows large dome roofs to be fully constructed inside the tank shell while at grade. The area under the roof is then pressurised, pushing the roof to the top of the shell. The difference with this tank is that there were two roofs to install: the inner roof and the outer roof. The solution is a 'piggyback' air raise. First, the inner roof was constructed at grade, inside the inner tank (see Figure 2). Temporary supports were placed on top of the inner roof, and the outer roof was then constructed, as shown in Figure 3. Special care had to be taken to ensure that the stainless inner roof did not receive carbon contamination from the outer roof construction. The roofs were air-raised together in a safe and seamless operation. In-fill pieces were then used to complete the section between the portion of the outer roof that was air-raised and the outer shell. Once the outer roof was completed and was fully supported by the shell, the temporary supports between the two roofs were removed.

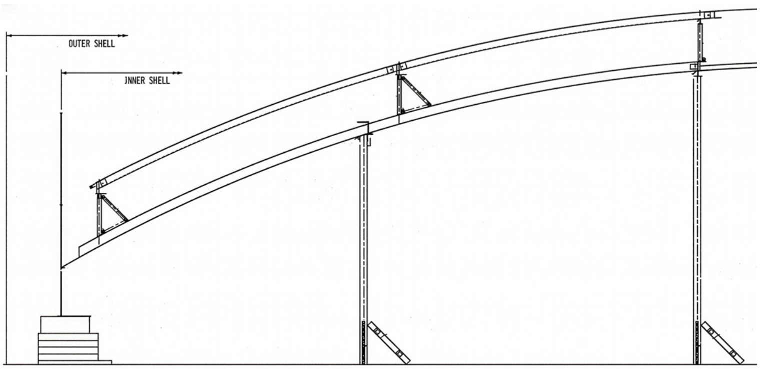

Figure 2. 'Piggyback' concept.

Figure 3. Temporary roof supports.

Clean, elevated

Traditional LIN tanks have always demanded an elevated level of cleanliness above what is required for other cryogenic stored liquids. The typical cleaning procedure involves the following process:

- Mechanical cleaning to remove large debris.
- Solvent cleaning to remove oil/grease deposits.
- Detergent cleaning.
- Potable water rinse.
- White light inspection for any visible contaminants.

Current semiconductor fabrication processes require a more stringent cleaning procedure and acceptance criteria. Ultra-pure and ultra-clean LIN is critical to ensure proper operation of the entire facility. Accordingly, elevated cleanliness requirements are necessary for all associated LIN storage. A black light inspection must be performed after the white light inspection. If the black light fluoresces on anything, it must be cleaned again. Additionally, the amount of fibres left behind from the cleaning cloths is a concern. For high-purity applications, the acceptance criteria require fibres to be smaller than 1 mm in size and total residue to be less than 50 mg/m^2 of the cleaned surface, which is half the amount typically permitted. CB&I successfully demonstrated to the client a cleaning methodology that met these strict requirements.

Conclusion

Larger LIN storage tanks provide a cost-effective solution for new semiconductor fabrication plants and allow for a smaller overall footprint and reduced land use. However, new technology solutions must be implemented to make the storage tank feasible.

There has been a shift in storage solutions to accommodate larger volumes of LIN. It is important for clients and owners to work with knowledgeable partners as they navigate the changes necessary to meet this demand and move beyond legacy LIN tank design and construction requirements.

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