American Tank & Vessel, Inc. &
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# Full Containment LNG Tanks - the Economical Choice

With global pressure on petroleum storage, it is as important as ever to make good, economic choices in your LNG/NGL storage selection. Often Full Containment storage systems can support better economics and similar schedules versus Single Containment or Double Containment systems. Each job and design case are unique, and the overall system needs to be designed for each project. However, on multiple occasions an outer concrete containment structure is a better economic choice and quickly becoming the new standard.

## FEED STUDIES LEAD TO FULL CONTAINMENT

The historical decisions, for outer concrete tanks and full containment, were supported by permitting, adjacent fire, local regulations and other design issues. Today, there is another list of reasons why Full Containment with an outer concrete tank should be considered for best practice and best economics. Over the last few years AT&V and its partners have led multiple projects from the FEED Study stage with Single Containment only to realize later that Full Containment had additional values and a better economic footprint than traditionally understood. Not considering Full Containment in the FEED Study, along with Single Containment can run up the cost due to the delays once it is realized as a benefit or necessity. Therefore, the safe and smart approach is to perform FEED Studies based on Full Containment with Single Containment as an option. This

will help avoid many of the extra FEED Study costs and delays that have been occurring.

Outside traditional considerations, it is important to also consider that Full Containment tanks have a high integrity design. In the event of an inner tank failure (or an inner tank "over-topping" event) caused by a seismic event or facility malfunction, the outer tank wall is designed to contain both the LNG liquid and vapor, as required by API-625, NFPA 59A-2016, and ACI 376-2011. This benefit provides the facility operator with the comfort of knowing that the entire tank investment is not jeopardized, and that a long shutdown (i.e. multiple years) may be avoided over a single event.

## LOWER COST WITH FULL CONTAINMENT

Full Containment tanks have a smaller thermal exclusion zone than Single Containment tanks because a Full Containment tank inner tank failure will result in 100% liquid containment in the outer tank, situated (typically) 3' outboard of the inner tank. In contrast, the dike wall of a single containment tank is typically located at more than 100' from the inner tank. As such, an LNG spill from the inner tank of a single-containment tank will spread over larger footprint (given that the outer carbon shell would immediately fail), resulting in a much larger thermal exclusion zone. With a Full Containment system, it is possible to:

- have a much smaller hazard footprint, which may eliminate the need to purchase/lease additional abutting land;
- eliminate costly earthen berms/dikes and an associated impoundment area;
- reduced annual costs for snow removal and maintenance of the impoundment area in northern climates;
- avoid (or, mitigate) wetland and other environmental impacts; and
- benefit from a much more efficient use of the land.

By eliminating the need for a large earthen/concrete dike wall, the Full Containment tank can be sited closer to the liquefaction/regasification facility, significantly reducing the cost of additional cryogenic and ambient pipe runs/racks.

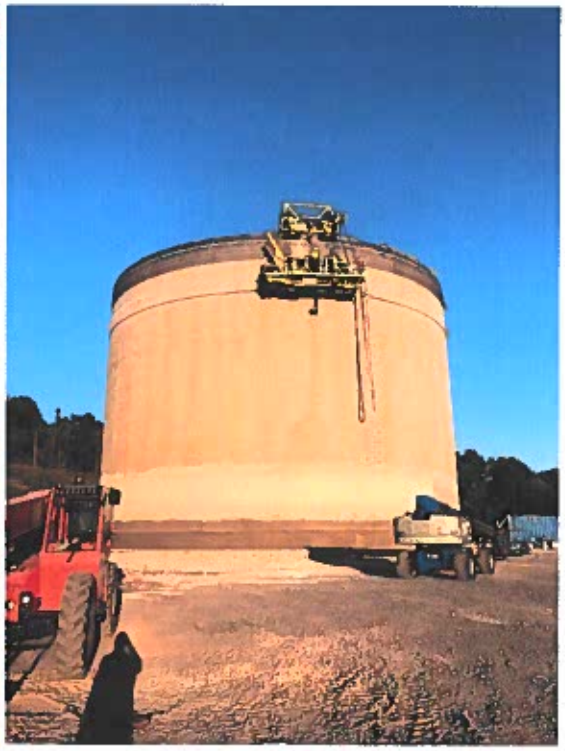

The concrete finish of a Full Containment tank minimizes coating maintenance of the outer tank. Maintaining a single-containment tank will cost the Client hundreds of thousands, if not millions of dollars each time the outer steel tank wall needs to be blasted, primed and repainted (ie, in a 50-year service life, a steel outer wall will need to be blasted and re-painted at least three times). Compared to a concrete outer wall tank where the finish (if applied) is purely aesthetic, the steel outer wall of a Single Containment tank MUST be coated/painted to extend its useful life.

The natural insulating properties of the concrete outer wall of a Full-Containment tank may eliminate the need for water deluge systems to protect a tank wall from the heat of an adjacent fire of finite duration. The steel outer shell of a Single Containment tank cannot withstand the same heat-flux of an adjacent fire.

The concrete exterior wall of a Full Containment tank will withstand the effects of a breach in the cryogenic piping, whereas the outer carbon steel shell of a Single Containment tank would be severely damaged, rendering the tank inoperable. As such, expensive vacuum jacketed piping is typically required/warranted for single-containment pipe runs up the side of the tank.


Full Containment tanks also reduce annual client insurance premiums (including Builder's Risk policies) for the benefits provided by a Full Containment tank. Consider for the moment, the cost to the Client and its insurance carrier(s), in the event of a simple over-topping event (or external pipe breach), resulting in several years of down-time.

The Full Containment tank provides the maximum safety standard of any LNG or NGL storage system and is routinely chosen over Single Containment tank for the benefit of providing businesses/rate-payers with the knowledge that the chosen tank is state-of-the-art in terms of safely storing these liquids in areas near to the community it serves.



With a Full Containment tank, it is not necessary to include additional, and costly, deep foundation protection systems. With a Single Containment tank founded on deep foundations (driven steel or concrete piles, auger-cast grouted piles, drilled shafts, etc.) or on ground improvement (rammed aggregate piers, rigid inclusions, etc.), it is necessary to include a protective membrane on the piling elements to ensure foundation support in a spill scenario where the impoundment area surrounding the tank has filled with cryogenic liquid.

## FULL CONTAINMENT SUPPORTS FUTURE GROWTH

The choice of building a Full Containment tank (at an early stage) will provide the Client with a much-valued opportunity for storage growth (i.e. an ability to add another Full

Containment tank at some point in the future) as the Client's rate base/business and subsequent demand increases.

In the event that the Client chooses to increase the storage capacity of a facility to take advantage of excess liquefaction capabilities of the Balance of Plant systems, a Full Containment tank, with its improved thermal exclusion and vapor dispersion properties, will provide the Client with an opportunity to expand the calculated storage capacity (and thereby maximize the liquefaction capability) to a larger net-working volume and still keep the exclusion/dispersion zones on its property, with a smaller overall footprint.

Full Containment tanks have high resistance to external forces (windborne missile/object impact, light aircraft impact, adjacent fire, etc.) due to the complete reinforced concrete outer shell. Furthermore, this external force resistance can also be improved rather easily if there is a specific requirement by simply increasing the thickness of the shotcrete outer layer(s).

Utilizing the above analysis, many LNG tanks have been reconsidered and contracted as Full Containment with an outer concrete wall when initially projected to be Single

Containment steel tanks. Some of the benefits are hard to value, but there is enough economic benefit of precast, prestressed concrete LNG tank systems to support an economic decision for Full Containment.


## CONCLUSION

Full Containment LNG tank technology has changed a lot and so have the economics. Starting early and having support for analysis are key ingredients in optimizing the selection, schedule and savings. This is becoming a standard for many customers and detailed economic analyses on LNG tanks have been completed in as little as (4) weeks. Therefore, the process is becoming the new standard. With the intense pressure on defining better economics in the petroleum industry, there is no doubt that Full Containment storage with a concrete outer tank might be your answer and should be considered in all low-pressure LNG and NGL applications. In conclusion please consider note the following:

1. Execute FEED Studies with both Full Containment and Single Containment to avoid delays and to optimize economics.

2. Calculate CAPEX savings.

3. Calculate OPEX savings.
4. Calculate savings associated with insurance premiums.
5. Calculate savings from improved land utilization.
6. Calculate savings associated with minimization of plant layouts.
7. Calculate the value of having the potential ability to expand.
8. Calculate the value of added benefits associated with the overall integrity of a Full Containment tank.