Ammonia Storage Tanks

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Ammonia has been stored as a liquid since ammonia production on an industrial scale began about 100 years ago. Ammonia was initially stored in pressurized systems, such as bullets and Horton spheres. Typically, spheres were used to store up to 2,000 tonnes. Today, atmospheric ammonia storage tanks are used to store up to 50,000 tonnes of ammonia at plant sites and distribution terminals.

Low-pressure ammonia storage has been widely accepted for two reasons. First, it requires much less capital per unit volume. Second, it is safer than sphere storage that uses pressures higher than atmospheric. With the large-scale industrial production of ammonia, it has become common to store ammonia at atmospheric pressure and at -33°C.

TYPES OF AMMONIA TANKS

The main types of atmospheric tanks operating at -33°C are:

- Single-wall steel tanks with external insulation [Figure 1]. Some of these tanks have concrete bunds surrounding the tank to contain the entire contents of the tank.
- Steel tanks with double walls and perlite insulation in between the walls are known as double-wall tanks or double containment tanks [Figure 2].

There are two types of double-wall, double-integrity (DWDI) tanks: those with insulation in annular space [Figure 3] and those with insulation on the outer tank [Figure 4].

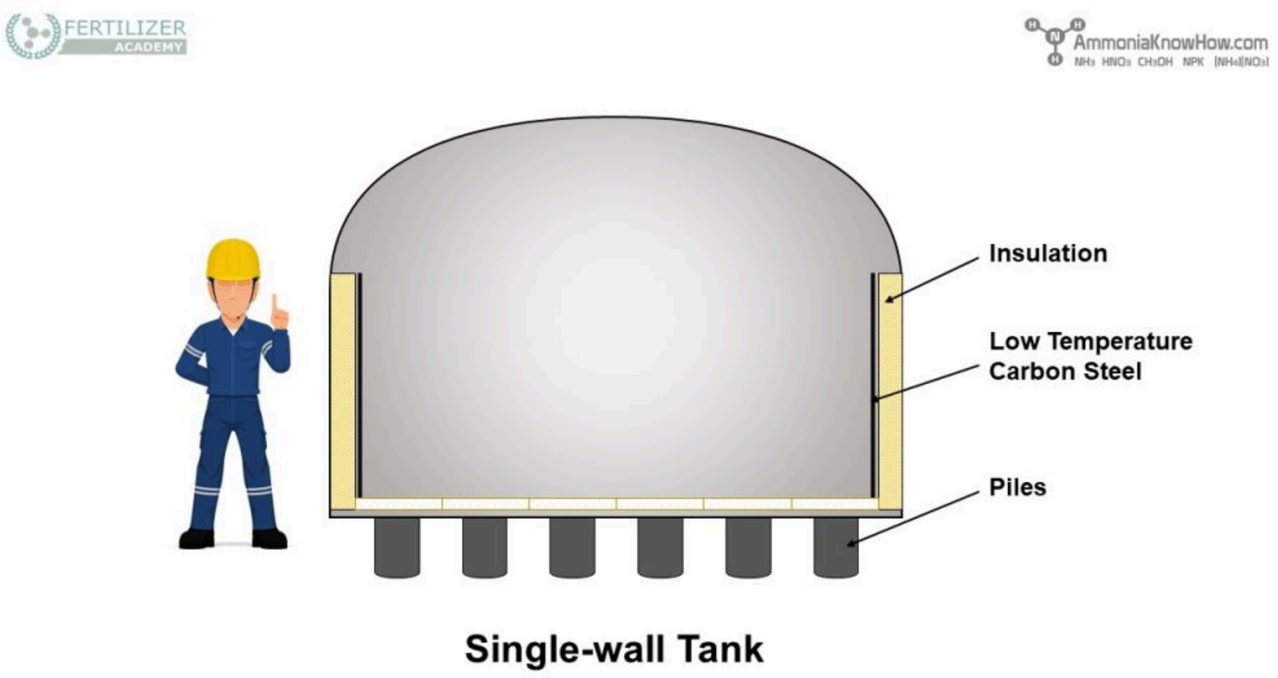

Figure 1

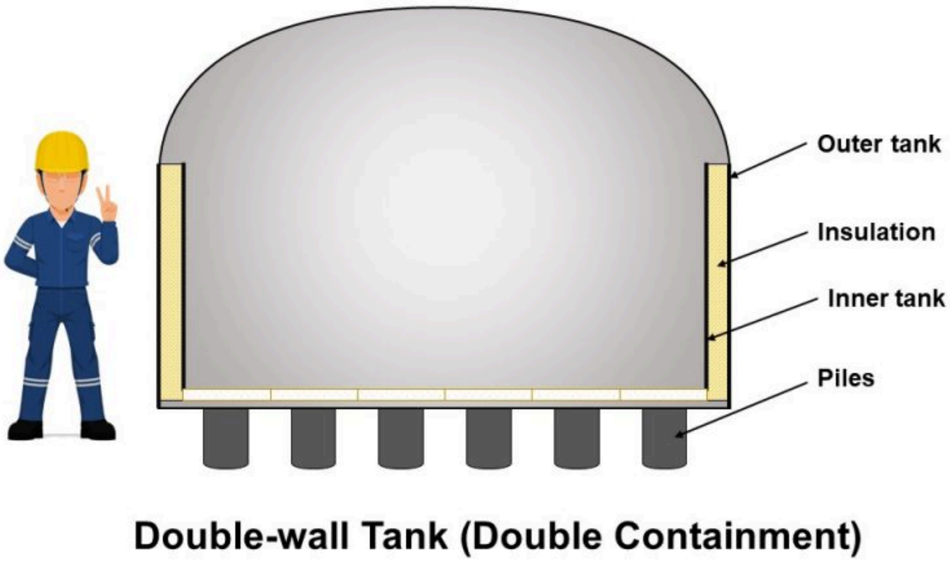

Figure 2

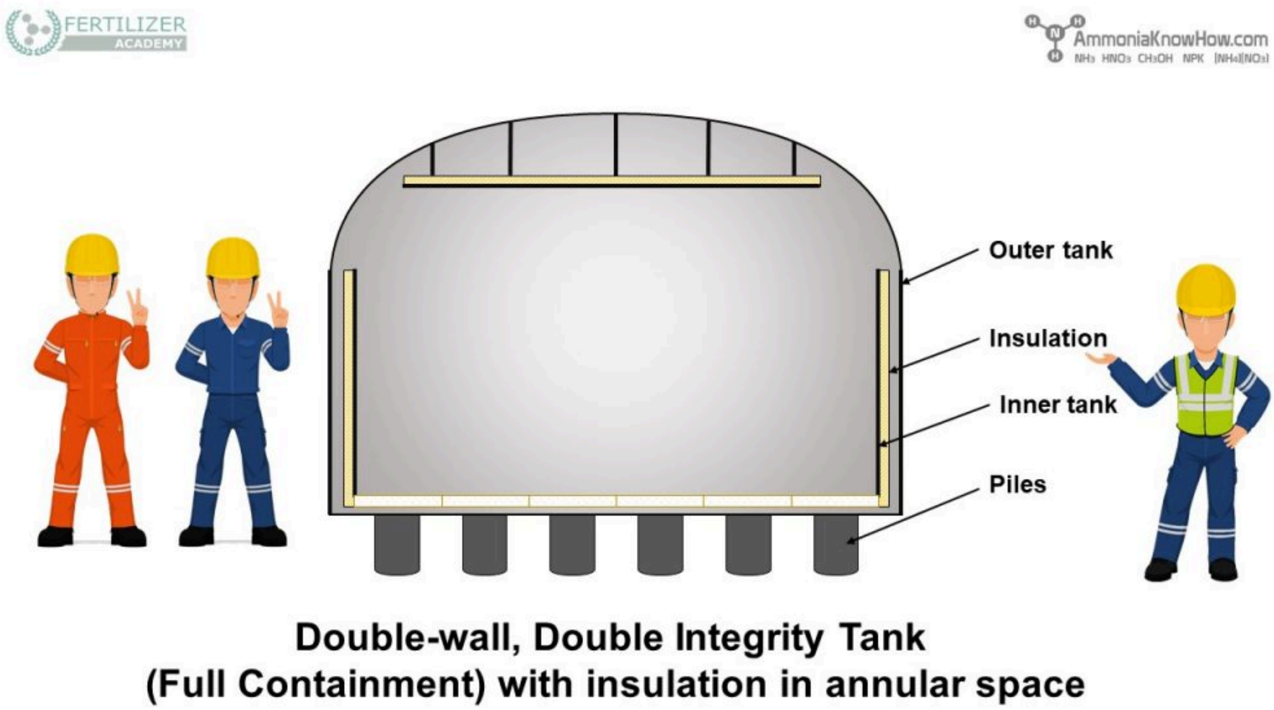

Figure 3

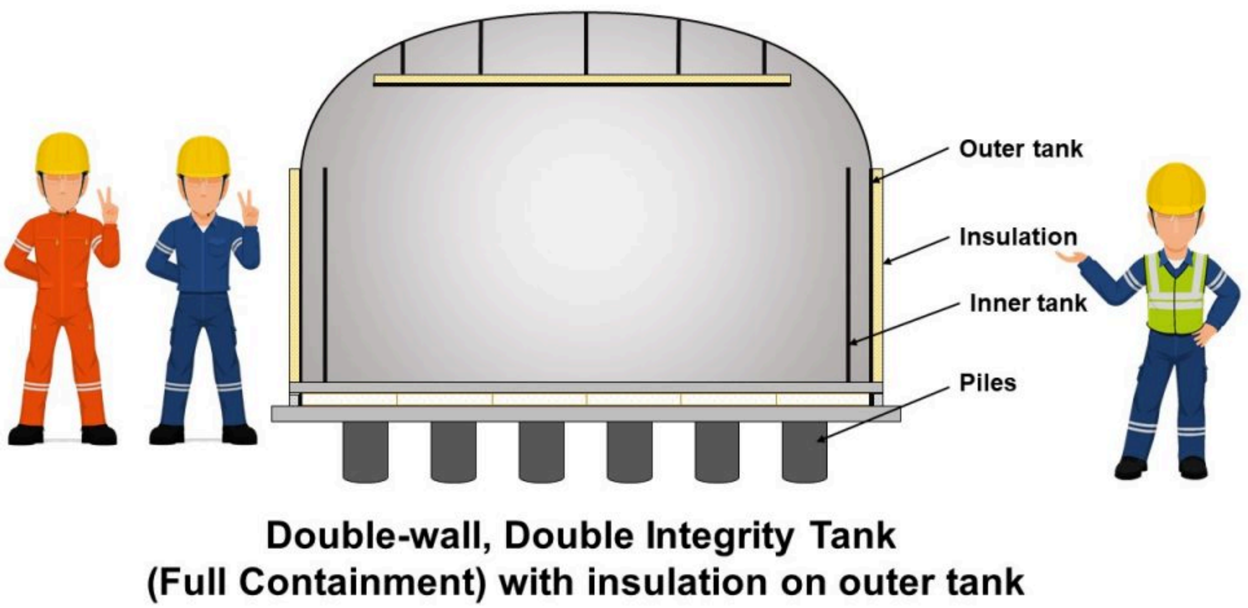

Figure 4

The DWDI tank with insulation on the outer tank can be operated for a longer time in an inner tank failure. The tank with insulation in the annular space needs to be decommissioned when the inner tank fails since its outer tank is not insulated. DWDI tanks with insulation in the annular space cost less than tanks built with insulation on the outer tank. Both of the double-wall style tanks are designed to contain the full contents within the inner tank and with the same construction material (low-temperature carbon steel).

In the figures, the different tank designs are shown standing on piles, generally the accepted standard for newly designed tanks. However, single-wall tanks have been placed directly on compacted soil/sand foundations that require under-tank heating coils (foundation heaters) to prevent frost lens and possible ground-heaving.

Single-wall tanks were built at many sites in the past, but the current practice, based on quantitative risk assessment (QRA), recommends that DWDI tanks be used for bulk storage to achieve an As Low As Reasonably Practicable (ALARP) risk level. Note that the failure rate for DWDI full containment tanks is nearly one-hundredth of the rate for single-wall tanks, based on HSE UK's failure rates; Purple Book /SGS 3 published by VROM, Netherlands; and the Failure Rates Handbook by Belgium. Atmospheric ammonia tank standards are still evolving. For example, risk assessment was not previously included in the above-noted standards. API 625, which cross-references to API 620, states that the tank purchaser should conduct a risk assessment to determine the tank configuration.

Tank design, installation, and operation should comply with the best available operating procedures based on HAZID, HAZOP, bow-tie analysis, and similar process risk evaluation tools. The design of individual storage tanks and their associated ancillary equipment can vary. Items requiring systematic attention during a tank's lifetime include relief valves, nozzles, drainage systems; roof, wall, bottom insulation; piles and foundation (elevation surveys); tank integrity inspection (especially weld joints); acoustic emission testing (AET), piping inspection; and fitness-for-service assessment.

TANK DESIGN AND SAFETY ASPECTS

The following design features are recommended for high-integrity ammonia tanks:

- The atmospheric ammonia storage tank should be of double-wall, double integrity type with insulation on the outer wall and be designed for 14 kPag internal pressure.
- The tank should be designed, fabricated, erected, and tested following the generally accepted standard, API

- The tank should be erected on an elevated piled concrete slab foundation to prevent the ground from freezing below the tank because this design would negate the potential damage of the foundations, or the tank itself, due to frost heave. The top of the concrete slab should be at an elevation of about two meters above the surrounding area.
- The foundation and tank should be designed to withstand a full hydrostatic test of the tank. Both inner and outer tanks should be hydro-tested. The tank design should accommodate thermal changes and minimize induced bending stress in the shell.
- For installation in a region of seismic activity, seismic analysis of the tank and associated pipework should be carried out.
- The design should include the required allowances for cyclonic wind and earthquake conditions per country standards.
- The design should be suitable for a marine environment.
- Drain lines are to be provided with both for the inner and outer tanks.

TANK MATERIALS

The inner and outer steel tanks should be all-welded construction and fabricated from normalized carbon-manganese steel. API 620, Appendix R, lists acceptable materials for tank construction, code designations, and material properties. Materials for atmospheric ammonia tanks should be selected to satisfy the requirements specified in the design code. The standard type of material is low temperature, certified carbon-manganese steel, impact-tested at or below -40°C. Welding and any Charpy V-notch testing should be carried out to meet the tank plate's quality requirement and the welding procedures at the tank design conditions.

The supporting/load-bearing rings underneath the tank; walls should be a treated wood (lignostone) or equivalent type of material. Treated wooden blocks are preferable to Perlite concrete blocks for insulation at the bottom of the tank. The outer tank anchoring material should be identifiable against mill certificates giving chemical analysis and mechanical properties. Any components welded directly to the tanks should be fabricated from the acceptable materials listed in API 620, Appendix R. All nozzle / manway welds in the lower plates should be post-weld heat treated (PWHT) and stress relieved to remove residual stresses from the welding process. No hard stamping of materials is allowed because it causes stress.

PRESSURE RELIEF

At a minimum, at least two pressure relief valves and two vacuum relief valves are recommended for each atmospheric storage tank to protect against overpressuring or vacuum conditions that might occur. The relief valves' design configuration should allow anyone valve to be removed for examination or maintenance without losing the protection of the tank. An isolation valve between the tank and each relief valve and a mechanical linkage system should be incorporated so that only one valve can be isolated at any time (a Nederlock / Castel Key system can also be used). Relief valves and safety devices should be sized according to the requirements of API 2000.

A permanent vaporizer to maintain tank pressure as one additional layer of protection is recommended in case of a low-low pressure scenario to avoid air ingress that could cause the potential for stress corrosion cracking (SCC). An emergency shut-off valve in the liquid supply line is needed to activate an alarm on high-high pressure in the tank.

INSTRUMENTATION

Tanks should be fitted with three independent level and pressure indicators. An independently activated high-level, the shut-off valve should close the feed to the tank at a very high level in the tank (a two-out-of-three level transmitter safety instrumented system).

ELECTRICAL

Tanks should be fitted with earthing bosses, and tanks over 30 meters in diameter should have three earthing bosses. The earthing bosses should be constructed of austenitic steel for the studs and washers and protected copper conductor strips to prevent ammonia contact. Earthing bosses need to be evenly spaced around the tank. Adequate lighting should be provided for personnel.

PIPING

INSULATION

External insulation should be covered with a continuous flat aluminium vapour barrier. Single profiled sheets for the aluminium vapour barrier must not be used. A specialist insulation designer must evaluate external insulation procedure and design to ensure no water ingress that would allow ice to form on the tank shell or the base, potentially causing heaving. The ambient temperature for the design of the insulation system is a maximum temperature of 50°C and minimum temperature of minus 40°C.

TANK NON-DESTRUCTIVE TESTING (NDT)

The primary NDT used on the NH3 tank throughout its life should be the acoustic emission (AE) test method. The tank design should include all permanent fittings/modifications required to minimize time and disruption during set-up and testing. The tank should be installed with waveguides for AE tests during initial fabrication. The initial AE test must be conducted at the hydrotest stage to fix any construction defects before placing the tank in service. A second AE test also needs to be carried out during the first fill of liquid ammonia into a new tank.

Following the hydrostatic and AE tests, water should be held in the inner tank at the height equivalent to the maximum operating level for seven days to ensure that future foundation settlement does not occur. The constructor inspection test plan (ITP) should also include witness points during construction.

GENERAL REQUIREMENTS

The stairway to the top of the tank should be a spiral type, with a separate standalone access tower. Platforms with access from the main stairway should be provided to ensure necessary maintenance access. The design and coverage of this platform should consider the safety of personnel working in the platform area.

AMMONIA STORAGE FACILITY

A layer of protection analysis (LOPA) study should be used to determine the following safety instrumented functions:

- Remote shut-off valves are provided on the liquid ammonia main inlet and outlet line to/from the ammonia storage tank.
- The refrigeration system should be based on recognized and proven industrial compressors.
- An auto-mode-controlled compressor would facilitate tank pressure control during loading/unloading.
- A review of stand-by equipment for critical duties and utilities are required.
- The design should take into account a closed vent and drain system for ammonia.
- Redundancy in critical instrumentation and control is required.
- Thermal relief valves must be installed on the ammonia lines if a possibility of blockage or heat ingress exists.
- Any fugitive ammonia emissions should be minimized. Ammonia venting from relief valves or maintenance activities must be piped back to the ammonia storage tank.
- Any venting of ammonia to the flare should be avoided or minimized.
- An ammonia leak detection system in the storage area is necessary.
- Lightning protection and earthing protection for the tank is mandatory.
- Emergency power to one of the refrigeration holding compressors to maintain tank pressure during a power failure is required in the design package.
- A flare is needed for controlled venting under extreme emergency situations.
- A wind direction indicator is suggested.
- Emergency plant lighting is necessary.

COMMISSIONING

- Purge the tank with nitrogen until the discharge gas' measured oxygen is less than four per cent (vol.).
- Purge with ammonia vapour until the tank's oxygen is less than 0.5 per cent (vol.).
- Cool the tank down to as low as possible by injecting liquid ammonia at a cooling rate of less than 2°C/hour, preferably using a spray system.
- Measure the temperatures in the tank away from the gas inlet.
- Take samples from the ammonia liquid in the tank and analyze them for water and oxygen.

DECOMMISSIONING

- Empty the tank to the absolute minimum liquid level.
- Evaporate the remaining ammonia in a way that ensures uniform and slow heating, not exceeding 2°C/hour.
- Purge with warm ammonia until all liquid ammonia is removed.
- Remove the ammonia gas in the tank by purging with nitrogen and not with air to prevent an explosive mixture.
- To prevent environmental issues, flare all the ammonia-vapour-containing streams.
- Remove the nitrogen atmosphere by purging with air until the oxygen content is greater than 19 per cent. If ammonia is still measured in the gas phase, breathing equipment must be used when entering the tank.
- Residual oil remnants may require additional cleaning methods and additional personnel safety requirements and equipment.

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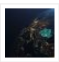
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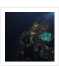
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