THEN AND NOW

Final stages of dome roof assembly for an ammonia storage tank at a fertilizer facility in the Midwest.

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OUTLINE HOW THE DESIGN AND DEVELOPMENT OF AMMONIA FERTILIZER PLANTS HAS CHANGED SINCE THE LAST BIG NORTH AMERICAN BUILD.

It has been more than three decades since rising gas prices and price volatility sent North American fertilizer manufacturing offshore, shuttering many facilities and stopping new plant construction. Now, with the low cost of natural gas, North America is reshoring. But much has changed in the world in the years since the last big build. Regulations, technology, engineering and construction have all advanced. Owners and developers are experiencing more challenges in schedule, cost, public scrutiny and design complexities in expanding existing facilities, capturing ammonia as a byproduct from methanol production or constructing a new greenfield facility.

This article explores some of the changes made from then to now and the impact of those changes that can be encountered during design and development. The article is organised into five main areas: plant siting and layout, process equipment, storage tanks, fabrication and construction, and operation and maintenance.

Plant siting and layout

Additional offsite hazard analyses: Owners are now required to conduct offsite consequence analyses (OCA) for risk management programmes, required under the Clean Air Act (CAA). Facilities that manufacture, use or store toxic or flammable substances, such as anhydrous ammonia, above the specified threshold quantities in the Code of Federal Regulations (CFR) 40 CFR 68.130 are subject to this requirement. Individual states may also have additional requirements. These OCA need to consider the dispersion of ammonia vapour as a result of a spill and the effects felt offsite. The primary effect of these requirements is a more careful selection of potential sites to prevent them from being close to homes and businesses.

Chemical facility anti-terrorism standards: The US Department of Homeland Security (DHS) has classified anhydrous ammonia as a chemical of interest, which places facilities that produce or store it under the Chemical Facility Anti-Terrorism Standards (CFATS) regulations and guidance. Under these requirements, owners are required to have more fencing, surveillance and intrusion prevention systems.

Additional public relations efforts: With the heightened awareness of the risks associated with an ammonia facility, owners have placed an increased emphasis on public relations with the local communities where the facilities are located or are planned. These activities have included outreach to increase public awareness and education on plant operations, hazard notification and emergency response planning.

Figure 1. 50 000 t double containment ammonia tanks showing points of non-destructive examination (NDE) inspection to confirm quality construction.

Figure 2. Recently completed state-of-the-art global ammonia production facility in the Midwestern US.

Process equipment

Production rate increases: Ammonia production equipment and refrigeration sizing have increased. Plants being designed and constructed now produce 2000 – 3000 tpd, compared to 1000 tpd in the past. The larger facilities today are a result of the increased availability of low-priced natural gas feedstock and the increased demand for fertilizer and explosives used in mining.

Additional ammonia emission limits: Current US Environmental Protection Agency (EPA) and state regulations have placed limits on the overall ammonia emissions during normal operations from storage tanks and process equipment. As a result, owners have required the use of low leakage valves and equipment. This has also led to increased equipment redundancy in the plant design to avoid upset conditions, which would require sending product to the atmosphere or a flare.

Additional hazard detectors: Current facilities have an increased number of hazard detection systems to provide operators advance notice of potential leaks. These systems include low-temperature, flame presence and high concentration of ammonia vapour.

Storage tanks

Containment configuration: In earlier installations, low-temperature anhydrous ammonia storage tanks were often constructed with a single wall with an external sidewall insulation system and an internal insulation deck. Earthen dikes were provided to contain any tank leakage from leaving the site boundary. More recently, owners have moved from this single containment approach to a double or full-containment configuration, with a second outer tank with low-temperature rated material that can fully contain the contents of the inner tank in the event of a leak. With double containment, any vapour generated during the fill of the outer tank is released to the atmosphere. With full containment, this vapour is captured. While double and full containment tanks are more costly, the risk of releasing liquid or vapour offsite are much reduced. The overall size of the facility may also be reduced if the earthen dike system can be eliminated by the use of a full or double containment tank.

Capacity increases: Storage tank sizes have also grown from the 30 000 t (11.64 million gal.) size popular in the 1970s to now 50 000 t or more.

New material property studies: Since the late 1980s, stress corrosion cracking has been detected in some refrigerated storage tanks. As a result, additional studies have been performed into the materials typically used for storage tanks with the goal of preventing or mitigating this cracking. Owners have initiated structural integrity calculations to determine the maximum tolerable defect sizes in tank welds, using established fracture mechanics codes. With these sizes, acceptance standards for non-destructive examination (NDE) of materials and welds during fabrication and installation have been updated.

Additional defect instrumentation: To further minimise risk of tank leakage, additional non-intrusive in-service inspection methods have been applied. Processes such as ultrasonic testing (UT), acoustic emission (AE) and electrical field signature method (FSM) have been employed both during construction, to establish a baseline, and while in service, to monitor changes from the baseline. Some of these new sensors, such as AE, have been installed permanently to provide owners with real-time on-going indications of potential tank problems.

Foundation designs: On earlier facilities, refrigerated ammonia tanks were supported by concrete foundations that were directly on-grade. To prevent frost heave of the foundation due to heat transfer from the liquid ammonia, heaters were embedded in the foundation to maintain a minimum safe temperature. This system works well as long as the heaters remain operational. To alleviate problems with heater failures, some owners have gone to elevated pile cap foundations, which have an air gap between the foundation and grade to prevent soil freezing.

Additional start-up instrumentation: With the increased emphasis on tank leak prevention, procedures for commissioning, decommissioning and re-commissioning have been updated to ensure careful and uniform cooling or warming up. This increased temperature uniformity minimises tank thermal stresses and development of leaks. To ensure this uniformity, additional temperature sensing elements are now installed on the tank floor and sidewalls for continuous monitoring.

Additional start-up purging: An additional risk factor for stress corrosion cracking is the presence of oxygen. Procedures for commissioning, decommissioning and re-commissioning have been updated to ensure the efficient removal of oxygen during start-up. Current practice is to purge the completed tank with gaseous nitrogen until the measured oxygen in the discharge gas is less than 4%. In the past, this was only done to 8%. The next step in the commissioning process is to purge with ammonia gas until the measured oxygen in the discharge gas is less than 0.5%. In the past, this was not monitored.

Fabrication and construction

Additional records: Construction documentation requirements have increased. Detailed records are kept of the quality inspection activities during tank construction and fabrication. In particular, material toughness properties provided by suppliers on material test reports are carefully maintained with traceability to locations in the completed tank.

Operation and maintenance

Process safety management: The US Occupational Safety and Health Administration (OSHA) has issued requirements for process safety management in 29-CFR-1910.119, which requires owners to have programmes in place at each facility to manage the workplace hazards associated with chemicals, such as anhydrous ammonia. As discussed previously, this has led to the addition of more hazard detectors and control systems to monitor tanks and process equipment for leaks and other problems. In the design phase, this has also lead to an increased emphasis on process hazards analyses (PHA) and conducting hazards of operation (HAZOP) studies with the design team and with operations personnel. With these studies, the designs are reviewed to ensure that adequate safeguards are in place to mitigate failures of equipment and sensors.

Additional in-service inspections: After commissioning and start of commercial operations, plants now have instituted increased plant programmes to evaluate the mechanical integrity of process vessels and storage tanks in service. This has resulted in periodic inspection of the refrigerated storage tanks for leaks, unanticipated displacements and other problems. Tank anchor straps are also being inspected for coating failures and corrosion. The performance of the tank external insulation systems are also being monitored using thermographic mapping, which shows cold areas that may be indicators of future problems.

For plants that have them, foundation heaters under the base of the tank are also being regularly reviewed for proper operation. This typically involves checking the resistance and power consumption of these electrical resistance heaters.

Regular operability tests of the installed safety equipment are being performed. This includes storage tank emergency shut-off valves, automated valves on process lines and safety relief valves. Tank and process sensors are also being checked for functionality, including level, pressure, temperature and flow elements.

Summary

In general, recent anhydrous ammonia facilities have a greater emphasis on preventing, detecting and mitigating the effects of leaks and on preventing offsite releases that could affect the public. While this has increased the facility construction and operating costs, the hazards to plant personnel and the public have been reduced.

Owners and operators that have been producing anhydrous ammonia during the past 30 years, even during periods of high natural gas prices, have become aware of most, if not all, of these changes. The abundance of low-cost natural gas today has fuelled the resurgence of anhydrous ammonia production in North America, creating the opportunity to construct or expand ammonia production facilities. Developers and owners that have not recently constructed or revamped a facility or who may not have the necessary experience are encouraged to retain the services of a reputable consultant and/or engineering firm that is knowledgeable in today's requirements and understands the history of existing facilities to ensure compliance and reliable operations. WF

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