

ANHYDROUS AMMONIA PRESSURE VESSELS IN THE PULP AND PAPER INDUSTRY

CRAIG REID

***THE GOVERNING OBJECTIVES SHOULD BE TO CONTROL FABRICATION
AND INSPECTION TO PREVENT OR MINIMIZE IN-SERVICE PROBLEMS
INCLUDING OVER-REACTION TO MINOR CRACK INDICATIONS.***

THE PURPOSE OF THIS ARTICLE IS TO ENSURE THAT PULP and paper operating companies, their engineering consultants, and inspection contractors are informed about stress corrosion cracking in anhydrous ammonia service. The information was written by a task group of the TAPPI Engineering Division Nondestructive Testing and Quality Control Subcommittee.

Bacteria in some activated sludge effluent treatment systems require supplementary food. In some cases, this food is provided by ammonia and phosphoric acid which are stored on the mill site. Ammonia is commonly stored as anhydrous liquid ammonia in carbon steel vessels at ambient temperature and 16 bar (250 psig) pressure. These vessels can be subject to stress corrosion cracking (SCC). SCC could cause release of ammonia, which is a hazardous chemical.

SCC of carbon steel vessels in anhydrous ammonia service is somewhat analogous to that experienced in continuous digesters. For example, the importance of stress relief during fabrication and of in-service inspection are common to both.

This article concerns storage in horizontal pressure vessels at ambient temperature, as this type of vessel is used in pulp and paper applications. Large refrigerated storage tanks are used for atmospheric pressure storage in the chemical industry.

HISTORY OF SCC IN AMMONIA STORAGE VESSELS

The history of SCC in carbon steel ammonia storage vessels was reviewed by Loginow (1) and is also briefly sum-

marized in a NACE Technical Committee Report entitled "Integrity of Equipment in Anhydrous Ammonia Storage and Handling" (2). In the 1950s, liquefied ammonia began to be injected directly into soil for fertilization. Failure of carbon steel storage vessels by SCC began to occur. These failures were unexpected since liquefied ammonia had been used for many years in the refrigeration, chemical, and metal heat treating industries without reported problems.

Investigation confirmed SCC to be the cause of cracking. Three recommendations were made in 1962 that still form the basis of modern codes:

- Pressure vessels should be fully stress relieved.
- Extreme care should be used to eliminate oxygen from ammonia systems.
- Ammonia should contain at least 0.2% water to inhibit SCC.

Loginow reported that adoption of these recommendations practically eliminated SCC in carbon steel vessels in the agriculture industry. However, in a recent Western Canadian survey SCC was found in 100 of 117 field storage vessels inspected by wet fluorescent magnetic particle testing (WFMT) (3).

Despite the above measures SCC continued to occur in road transport tanks constructed from high strength steels, in refrigerated storage vessels and in vessels which had been weld repaired but not subsequently stress relieved. An additional recommendation to limit steel tensile or yield strength was embodied in the U.S. and

British ammonia storage codes, respectively (4, 5).

- ANSI K61.1—Nominal tensile no greater than 70,000 psi (580 MPa)
- U.K. Code—Minimum specified yield strength shall not exceed 350 MPa (51,000 psi).

PRACTICAL CONSIDERATIONS

This article is concerned mainly with practical considerations important to pulp and paper mills already possessing anhydrous ammonia storage vessels or planning to fabricate such vessels. In view of the industry's experience with SCC in continuous digesters the governing objectives should be to control fabrication and inspection to prevent, or at least minimize, in-service problems including over-reaction to relatively minor crack indications. Guidance is available in the published codes and detailed information is available from some ammonia suppliers.

Fabrication

The two main objectives in fabrication should be to provide the most crack resistant vessel possible at reasonable cost and to ensure that an adequate inspection baseline is available for interpretation of subsequent in-service inspections.

ASME Section VIII Division 1 does not require stress relief for anhydrous ammonia storage pressure vessels unless the owner specifies a lethal service designation. The lethal service designation requires radiographic testing (RT) of all butt welded joints plus post weld heat treatment.

ANSI K-61.1-1989, "American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia," adds several requirements:

- Fabrication to ASME Section VIII Division 1 Table UW 12 at a joint efficiency less than 80% is *not* allowed.
- Inspection and testing under UG-90(c)(2) (multiple, duplicate pressure vessel fabrication) is *not* allowed.
- Steel used for pressure containing parts shall have a nominal tensile strength no greater than 580 MPa (70,000 psi).
- The minimum design pressure for ambient temperature storage shall be 16 bar (250 psig).
- Post weld heat treatment is mandatory and a furnace of sufficient size to accommodate the entire vessel is recommended. Welded attachments may be made to pads after post weld heat treatment.
- Horizontal vessels shall be mounted on saddles which extend over at least one third of the shell's circumference. Thermal expansion and contraction

shall be allowed for and means provided to prevent corrosion between the shell and the saddles.

The 1986 British Code "Storage of Anhydrous Ammonia Under Pressure in the United Kingdom" requires:

- Steel must have a specified minimum yield strength less than 350 MPa (51,000 psi).
- Weld filler must have minimal strength overmatch compared with the base plate.
- 100% magnetic particle inspection of *all internal* welds in order to provide a record against which all future inspections of the vessel can be assessed.
- No welding is permitted after stress relief without subsequent local stress relief.
- Concrete saddles are prohibited.
- Support must be on continuously welded steel saddles attached before stress relief.

Although the British Code does not state that magnetic particle inspection should be by WFMT it is generally agreed that WFMT is the most sensitive technique and should be used for inspection of ammonia storage vessels. All inspection should be performed by qualified technicians. SNT-TC-1A Level II is a recommended minimum.

One pulp and paper company has added the following requirements for fabrication of such vessels:

- Incorporation of a "corrosion allowance" of at least 1.6 mm (1/16 in.) to permit minor defect chasing during in-service inspections and to provide a margin against pitting which may occur if water is allowed to enter an out of service vessel.
- All weld toes profiled by grinding prior to wet fluorescent magnetic particle testing (WFMT). All WFMT indications greater than 1.6 mm (1/16 in.) to be removed by grinding before post weld heat treatment.
- Shear wave ultrasonic testing (UT) of nozzle-to-shell welds permitted if RT is judged impractical.
- WFMT to be repeated after final hydrotest test of the vessel and the report retained by the owner.
- Vessel to be dried completely after hydrotest test and nitrogen padded until filled with ammonia.

Adoption of these additional requirements should ensure the vessel delivered is of known documented quality.

Valves, piping, and fittings

Both the ANSI and U.K. codes address piping, valves, and fittings. A detailed summary is beyond the scope of this article, but some points are worth noting.

- ANSI K61.1 requires all nonrefrigerated ammonia piping to meet the requirements of ANSI/ASME B31.3 "Chemical Plant and Petroleum Refinery Piping."
- The U.K. Code states copper and copper bearing alloys shall not be used.

ANSI/ASME B31.3 requires a minimum of 5% of piping welds be radiographically tested. Valves and other apparatus should be rated for ammonia service and should not contain copper or copper alloy components.

In one case, a nickel rupture disc corroded to failure at its periphery due to formation of an ammonia solution at a gasketed joint exposed to the weather.

In-service inspection

Vessel entry. Liquid or gaseous ammonia is hazardous and in some jurisdictions release of ammonia vapor to the atmosphere is prohibited by law. Vessels must be properly purged by water and/or steam. Detailed procedures for vessel purging and entry are available from ammonia suppliers (6).

Inspection procedures. The ANSI standard does not address in-service inspection but does state weld repair or alteration must conform to the current edition of the National Board Inspection Code (NBIC).

The 1992 edition of the NBIC includes nonmandatory guidelines for inspection of liquid ammonia vessels (7). These guidelines recommend:

- Power buffing or light sandblasting as surface preparation for inspection
- All interior welds be examined by WFMT.
- Cracks should be removed by grinding without encroaching on the minimum thickness required by ASME Section VIII and the original design.
- Weld repairs, regardless of size, should be post weld heat treated wherever possible.

Light grinding does increase the sensitivity of WFMT compared to sandblasting or power buffing (8). For example the NBIC mandates grinding as surface preparation for deaerator inspection. The omission of grinding in the guidelines for ammonia vessel in-service inspection may be due to concern that rough grinding may produce residual stress sufficient to initiate SCC in anhydrous ammonia service. If welds have been properly profiled for WFMT on initial fabrication, then grinding for in-service inspection should not be needed.

The NBIC guidelines also state that other inspection methods such as acoustic emission or ultrasonics may be used and that fracture mechanics may be used to assess the integrity of vessels where complete removal of cracks is not practical.

Normally the only corrosion that occurs in anhydrous ammonia vessels is due to water ingress during out of service periods. Shallow pitting, however, has been found in the bottom of some vessels beneath oily deposits. The source of oil is presumed to be from compressors used to handle the ammonia.

In view of concerns over air contamination due to vessel entry and residual stress imparted by grinding nonintrusive inspection, techniques like acoustic emission and UT could be considered by vessel owners. The British Code does not mention nonintrusive inspection of ambient temperature pressure vessels but does state that, if acoustic emission is to be used for spherical storage vessels, a reference base should be taken during initial hydrotesting. Nonintrusive inspection is being used in other industries (9).

Vessel refilling. Safety procedures should be established for refilling a vessel that has been emptied for inspection. It is also very important to purge the vessel of air to prevent the occurrence of SCC. Detailed instructions are available from ammonia suppliers (10). If a vessel is not to be returned to service immediately after inspection, then care should be taken to dry it and possibly nitrogen-pad it depending on the time it will remain out of service.

Inspection frequency. Neither the ANSI document nor the NBIC deals with inspection frequency. The British Code recommends the following:

- WFMT inspection of 100% of all internal butt welds within the first three years of service
- WFMT re-inspection within 2 years if significant defects are found
- Subsequent to no significant defects being found, any subsequent inspection should include WFMT of all Tee junctions and 10% of the total length of butt welds
- In no case should the subsequent examination interval exceed 6 years.

It is apparent from the above that latitude can exist for in-service inspection techniques and frequencies. Each owner should determine inspection frequency in conjunction with the appropriate authority. Some jurisdictions require a 3-year inspection frequency.

SUMMARY

The use of carbon steel pressure vessels for storage of anhydrous ammonia in the pulp and paper industry could be a non-event or deteriorate into a cycle of inspection and repair. This article has highlighted major concerns related to SCC. There is a wealth of additional information available on all considerations related to

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these vessels from the ANSI and British Codes, the NACE document, ammonia suppliers, and the current technical literature. The American Institute of Chemical Engineers (AIChE) holds the annual AIChE Ammonia Safety Symposium aimed at finding ways to safely manufacture, transport, and store ammonia and related chemicals. The proceedings of these symposia are published by AIChE. It is recommended that any owner of such vessels keep

aware of current expertise. TJ

Reid is materials and corrosion section head with MacMillan Bloedel Research, 4225 Kincaid St., Burnaby, BC, Canada V5G 4P5.

Task group members: Craig Reid; R.S. Charlton, Levelton Associates Consulting Engrs.; R.C. Faloon, MQS Inspections Inc.; and W. E. Boudreau, Belle Testing Inc.

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