

2.3.6.4 LIQUID AMMONIA VESSELS

Vessels in liquid ammonia service are susceptible to stress corrosion cracking (SCC) (see 3.3.2(b)) in areas of high stress. High strength and coarse-grained materials seem to be more at risk of SCC than are fine-grained or more moderate strength materials, although no commonly used steels appear to be immune to the problem. Postweld heat treatment of new or weld-repaired vessels or cold formed heads is beneficial in reducing the incidence of SCC. The presence of 0.2% minimum water in the liquid ammonia also inhibits SCC. Any leak should be thoroughly investigated and the necessary corrective action initiated.

a) Inspection of Parts and Appurtenances

- 1) Where existing openings permit, perform a visual internal inspection of the vessel. Look for any obvious cracks (very advanced SCC) and note areas that are subject to high stress such as welds, welded repairs, head-to-shell transitions, sharp interior corners, and interior surfaces opposite external attachments or supports. Alternatively, an internal inspection may be conducted from the outside utilizing suitable NDE, e.g., ultrasonic techniques.
- 2) If valves or fittings are in place, check to ensure that these are complete and functional. Parts made of copper, zinc, silver, or alloys of these metals are unsuitable for ammonia service and should be replaced with parts fabricated of steel or other suitable materials.

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a) Internal Inspection

- 1) Where existing openings permit, perform a visual internal inspection of the vessel. Look for obvious cracks (very advanced SCC) and note areas that are subject to high stress such as welds, welded repairs, head-to-shell transitions, sharp interior corners, and interior surfaces opposite external attachments or supports. ~~Alternatively, an internal inspection may be conducted from the outside using suitable NDE, e.g., ultrasonic techniques.~~
- 2) Fittings, such as liquid level gage floats and excess flow valves, should be removed or otherwise protected from power buffing or light sandblasting when preparing the interior surface of the vessel for inspection.

b) Examination and Detection of SCC

- 1) All interior welds and highly stressed areas shall be examined by the wet fluorescent magnetic particle testing method (WFMT) using an AC yoke for magnetization. Note that weld cracks are often transverse to the weld in orientation. It is extremely important to ensure that the NDE method used will disclose cracks in any orientation.

- 3) Fittings should be removed or otherwise protected from power buffing or light sandblasting when preparing the interior surface of the vessels for inspection.
 - 4) All interior welds and highly stressed areas should be examined by the wet fluorescent magnetic particle-testing method (WFMT) using an A/C yoke for magnetization. Note that weld cracks are often transverse in orientation. It is extremely important to ensure that the NDE method used will disclose cracks in any orientation.
 - 5) If cracks are discovered, a calculation must be made to determine what depth of grinding may be carried out for crack removal (without encroaching on the minimum thickness required by the construction standard or equivalent).
 - 6) Where possible, crack removal by grinding is the preferred method of repair. Since the stresses at the crack tips are quite high, even very fine cracking should be eliminated.
 - 7) Where crack depth is such that removal requires weld repair, a weld procedure should be employed that will minimize HAZ hardening and residual stresses. Whenever possible, weld repairs regardless of their size should be post-weld heat treated.
 - 8) Re-inspect by WFMT to ensure complete crack removal.
 - 9) It is not intended to inhibit or limit the use of other evaluation methods. It is recognized that acoustic emission and fracture mechanics are acceptable techniques for assessing structural integrity of vessels. Analysis by fracture mechanics may be used to assess the structural integrity of vessels when complete
- 2) If cracks are discovered, a calculation shall be made to determine what depth of grinding may be carried out for crack removal without encroaching on the minimum thickness required by the ~~construction standard or equivalent~~ original code of construction.
 - 3) Where possible, crack removal by grinding is the preferred method of repair. Since the stresses at the crack tips are quite high, even fine cracking shall be eliminated.
 - 4) Where crack depth is such that removal requires welded repair, a weld procedure shall be employed that will minimize HAZ hardening and residual stresses. ~~Whenever possible, Welded repairs, regardless of their size the depth of repair, should shall~~ be post weld heat treated. Any repairs required and associated post-weld heat treatment shall be completed in accordance with Part 3.
 - 5) ~~Re-inspect~~ Re-inspection by WFMT after welded repair is needed to ensure complete crack removal.
 - 6) It is not intended to inhibit or limit the use of other NDE evaluation methods. It is recognized that acoustic emission and fracture mechanics are acceptable techniques for assessing structural integrity of vessels. Analysis by fracture mechanics may be used to assess the structural integrity of vessels when complete removal of all ammonia stress cracks is not practical. If alternative methods are used, the above requirement that all cracks be removed, even fine cracks, may not apply.

In addition to NDE and repair of liquid ammonia vessels that are susceptible to SCC, it is acceptable to use fitness for service evaluation methods to determine acceptability of a pressure retaining item to perform its intended function. These

removal of all ammonia stress cracks is not practical. If alternative methods are used, the above recommendation that all cracks be removed, even fine cracks may not apply.

b) Inspection of Insulated Vessels

- 1) Insulated pressure vessels can suffer from aggressive external corrosion that is often found beneath moist insulation. The Inspector should closely examine the external insulation scaling surfaces for cold spots, bulges, rust stains, or any unusual conditions in previous repair areas. Bulging or distorted insulation on refrigerated vessels may indicate the formation of ice patches between the vessel shell and insulation due to trapped moisture. Careful observation is also required where the temperature of insulated vessels cycle continually through the freezing temperature range.
- 2) The lower 1/3 to 1/2 and the bottom portions of insulated vessels should receive special focus, as condensation or moisture may gravitate down the vessel shell and soak into the insulation keeping it moist for long periods of time. Penetration locations in the insulation such as saddle supports, nozzles, or fittings should be examined closely for potential moisture ingress paths. When moisture penetrates the insulation, the insulation may actually work in reverse holding moisture in the insulation and/or near the vessel shell.
- 3) Insulated vessels that are run on an intermittent basis, or that have been out of service require close scrutiny. In general, a visual inspection of the external surfaces of insulated vessels should be conducted once per year.
- 4) The most common and superior method to inspect for suspected corrosion un-

methods shall be consistent with Part 2, Section 4.4, "Methods To Assess Damage Mechanisms And Inspection Frequency For Pressure-Retaining Items".

c) Inspection of Parts and Appurtenances

- 1) If valves or fittings are in place, check to insure that these are complete and functional. Parts made of copper, zinc, silver, or alloys of these metals are unsuitable for ammonia service and ~~should~~ shall be replaced with parts fabricated of steel or other suitable materials.
- 2) Check that globe valves are installed with the direction of flow away from the vessel.
- 3) Observe that excess flow valves are properly installed and in good repair.
- 4) Check that hydrostatic relief valves are installed in the system piping where required.
- 5) Piping shall be observed to be a minimum of Schedule 80 if threaded and Schedule 40 if welded. Seamless or ERW piping is acceptable. Type F piping shall not be used for ammonia service.
- 6) Fittings shall be forged or Class 300 malleable. Seal welding is permitted only with forged fittings.
- 7) The Inspector ~~should~~ shall note the pressure indicated by the gage and compare it with other gages on the same system. If the pressure gage is not mounted on the vessel itself, it should be ascertained that the gage is installed on the system in such a manner that it correctly indicates actual pressure in the vessel.
- 8) The Inspector shall note the liquid level in the vessel by observing the liquid level gage or other liquid level indicating device.

der insulation damage (CUI) is to completely or partially remove the insulation for visual inspection. The method most commonly utilized to inspect for CUI without insulation removal is by x-ray and isotope radiography (film or digital) or by real time radiography utilizing imaging scopes and surface profilers. The real time imaging tools will work well if the vessel geometry and insulation thickness allows. Other less common methods to detect CUI include specialized electromagnetic methods (pulsed eddy current and electromagnetic waves), and long range ultrasonic techniques (guided waves).

- 5) There are also several methods to detect moisture soaked insulation, which is often the beginning for potential CUI damage. Moisture probe detectors, neutron backscatter, and thermography are tools that can be used for CUI moisture screening.
- 6) Proper surface treatment (coating) of the vessel external shell and maintaining weather tight external insulation are the keys to prevention of CUI damage.

c) Gages and Pressure-Relieving Devices

- 1) The Inspector should note the pressure indicated by the gage and compare it with other gages on the same system. If the pressure gage is not mounted on the vessel itself, it should be ascertained that the gage is installed on the system in such a manner that it correctly indicates actual pressure in the vessel.
- 2) See 2.5 for the inspection of safety relief devices (pressure relief valves) used to prevent the overpressure of liquid ammonia vessels. Pressure-relief devices in ammonia service shall not be tested in place using system pressure. Bench **A07** testing is required.

d) Inspection of Pressure Relief Devices

- 1) See Section 2.5 for the inspection of safety pressure relief devices (~~pressure relief valves~~) used to prevent the overpressure of liquid ammonia vessels. Pressure relief devices in ammonia service shall not be tested in place using system pressure. Bench testing or replacement is required, depending on the type of pressure relief device used is required.
- 2) The Inspector shall note the replacement date marked on those vessel safety valves and piping system hydrostatic relief valves requiring replacement every five years.

e) External Inspection of Insulated Vessels

- 1) Insulated pressure vessels can suffer from aggressive external corrosion that is often found beneath moist insulation. The Inspector should carefully examine the external insulation scaling surfaces for cold spots, bulges, rust stains, or any unusual conditions in previous repair areas. Bulging or distorted insulation on refrigerated vessels may indicate the formation of ice patches between the vessel shell and insulation due to trapped moisture. Careful observation is also required where the temperature of insulated vessels cycle continuously through the freezing temperature range.
- 2) The lower ~~1/3 to 1/2~~ one-half and the bottom portions of insulated vessels should receive special focus, as condensation or moisture may gravitate down the vessel shell and soak into the vessel insulation keeping it moist for long periods of time. Penetration locations in the insulation or fireproofing such as saddle supports, sphere support legs, nozzles, or fittings should be examined closely for potential moisture ingress paths. When moisture penetrates the insulation, the insulation may actually

work in reverse holding moisture in the insulation and/or near the vessel shell.

S7.8 ACCEPTANCE CRITERIA

The acceptance criteria for LPG vessels is based on successfully passing inspections without showing conditions beyond the limits shown below.

S7.8.1 CRACKS

Cracks in the pressure boundary (heads, shells, A07 welds) are unacceptable. When a crack is identified, the vessel shall be removed from service until the crack is repaired by a qualified repair organization or permanently retired from service. (See Part 3, Repairs and Alterations).

S7.8.2 DENTS

- a) Shells
The maximum mean dent diameter in shells shall not exceed 10% of the shell diameter, and the maximum depth of the dent shall not exceed 10% of the mean dent diameter. The mean dent diameter is defined as the average of the maximum dent diameter and the minimum dent diameter. If any portion of the dent is closer to a weld than 5% of the shell diameter, the dent shall be treated as a dent in a weld area, see (b) below.
- b) Welds
The maximum mean dent diameter on welds (i.e., part of the deformation includes a weld) shall not exceed 10% of the shell diameter. The maximum depth shall not exceed one twentieth of the mean dent diameter.
- c) Heads
The maximum mean dent diameter on heads shall not exceed 10% of the shell diameter. The maximum depth shall not exceed one twentieth of the mean dent diameter. The use of a template may be required to measure dents on heads.

- 3) Insulated vessels that are run on an intermittent basis, or that have been out of service require close scrutiny. In general, a visual inspection of the external insulated surfaces of ~~insulated~~ vessels should be conducted once per year.
- 4) The most common and superior method to inspect for suspected corrosion under insulation damage (CUI) is to completely or partially remove the insulation for visual inspection. The method most commonly utilized to inspect for CUI without insulation removal is by x-ray and isotope radiography (film or digital) or by real time radiography utilizing imaging scopes and surface profiles. The real time imaging tools will work well if the vessel geometry and insulation thickness allows. Other less common methods to detect CUI include specialized electromagnetic methods (pulsed eddy current and electromagnetic waves), and long range ultrasonic techniques (guided waves).
- 5) There are also several methods to detect moisture soaked insulation, which is often the beginning of CUI damage. Moisture probe detectors, neutron backscatter, and thermography are tools that can be used for CUI moisture screening.
- 6) Proper surface treatment (coating) of the vessel shell and maintaining weather tight external insulation are the keys to prevention of CUI damage.

f) Acceptance Criteria

The acceptance criteria for liquid ammonia vessels are based on passing inspection without showing conditions beyond the limits shown below.

1) Cracks

Cracks in the pressure vessel boundary (heads, shells, welds) are unacceptable.

When a crack is identified, the vessel shall be removed from service until the crack is repaired by a qualified repair organization or the vessel permanently removed from service. (See Part 3, Repairs and Alterations).

2) Dents

When dents are identified that exceed the limits set forth below, the vessel shall be removed from service until the dents are repaired by a qualified repair organization or the vessel permanently retired from service.

a) Dents in Shells

The maximum mean dent diameter in shells shall not exceed 10% of the shell diameter, and the maximum depth of the dent shall not exceed 10% of the mean dent diameter. The mean dent diameter is defined as the average of the maximum dent diameter and the minimum dent diameter. If any portion of the dent is closer to a weld than 5% of the shell diameter, the dent shall be treated as a dent in a weld area, as shown in (b) below.

b) Dents in Welds

The maximum mean dent diameter on welds (i.e., part of the deformation includes a weld) shall not exceed 10% of the shell diameter. The maximum depth shall not exceed one-twentieth of the mean dent diameter.

c) Dents in Heads

The maximum mean dent diameter on heads shall not exceed 10% of the shell diameter. The maximum depth shall not exceed one-twentieth of the mean dent diameter. The use of a template may be required to measure dents on heads.

3) Bulges

- d) When dents are identified which exceed the limits set forth in these paragraphs, the vessel shall be removed from service until the dents are repaired by a qualified repair organization or permanently retired from service.

S7.8.3 BULGES

a) Shells

If a bulge is suspected, the circumference shall be measured at the suspect location and several places remote from the suspect location. The variation between measurements shall not exceed 1%.

b) Heads

- 1) If a bulge is suspected, the radius of curvature shall be measured by the use of templates. At any point the radius of curvature shall not exceed 1.25% of the diameter for the specified shape of the head.
- 2) When bulges are identified that exceed the limits set forth in these paragraphs, the vessel shall be removed from service until the bulges are repaired by a qualified repair organization or permanently retired from service.

S7.8.4 CUTS OR GOUGES

When a cut or a gouge exceeds 1/4 of the thickness of the vessel, the vessel shall be removed from service until it is repaired by a qualified repair organization or permanently removed from service.

When bulges are identified that exceed the limits set forth below, the vessel shall be removed from service until the bulges are repaired by a qualified repair organization or the vessel permanently retired from service.

a) Bulges in Shells

If a bulge is suspected, the circumference shall be measured at the suspect location and at several places remote from the suspect location. The variation between measurements shall not exceed 1%.

b) Bulges in Heads

If a bulge is suspected, the radius of the curvature shall be measured by the use of templates. At any point the radius of curvature shall not exceed 1.25% of the diameter for the specified shape of the head.

4) Cuts or Gouges

When a cut or gouge exceeds 1/4 of the thickness of the vessel, the vessel shall be removed from service until it is repaired by a qualified repair organization, a fitness for service analysis is performed, or the vessel permanently retired from service.

5) Corrosion

a) For line or crevice corrosion, the depth of the corrosion shall not exceed 1/4 of the original wall thickness.

b) Isolated pits may be disregarded provided that their depth is not more than the one-half the required thickness of the pressure vessel wall (exclusive of any corrosion allowance), provided the total area of the pits does not exceed 7 sq. in. (4500sq. mm) within any 8 in. (200mm diameter circle, and provided

S7.8.5 CORROSION

- a) Line and Crevice Corrosion
For line and crevice corrosion, the depth of the corrosion shall not exceed 1/4 of the original wall thickness.
- b) Isolated Pitting
Isolated pits may be disregarded provided that:
- 1) Their depth is not more than one-half the required thickness of the pressure vessel wall (exclusive of corrosion allowance);
 - 2) The total area of the pits does not exceed 7 sq. in. (4500 sq. mm) within any 8 in. (200 mm) diameter circle; and
 - 3) The sum of their dimensions along any straight line within this circle does not exceed 2 in. (50 mm).
- c) General Corrosion
For a corroded area of considerable size, the thickness along the most critical plane of such area may be averaged over a length not exceeding 20 in. (500 mm). The thickness at the thinnest point shall not be less than 50% of the required wall thickness, and the average shall not be less than 75% of the required wall thickness. When general corrosion is identified that exceeds the limits set forth in this paragraph, the pressure vessel shall be removed from service until it is repaired by a qualified organization or permanently removed from service.
- c) For a corroded area of considerable size, the thickness along the most critical plane of such area may be averaged over a length not exceeding 10 in (254 mm). The thickness at the thinnest point shall not be less than 75% of the required wall thickness. When general corrosion is identified that exceeds the limits set forth in this paragraph, the pressure vessel shall be removed from service until it is repaired by a qualified organization, a fitness for service is performed, or the vessel is permanently retired from service.
- d) Vessels in services where liquid ammonia is used as a reactant or is being preheated/vaporized should be inspected for localized corrosion in the reaction or vaporizing zones.