STANDARD FOR REPAIR
OF SHOP FABRICATED
ABOVEGROUND TANKS
FOR STORAGE OF
COMBUSTIBLE AND FLAMMABLE LIQUIDS

SP031

BALLOT COMMENTS
APRIL 2008
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PREFACE

The Steel Tank Institute (STI), formed in 1916, is a not-for-profit organization whose purpose is to secure co-operative action in advancing by all lawful means the common purposes of its members and to promote activities designed to enable the industry to conduct itself with the greatest economy and efficiency. It is further the purpose of STI to cooperate with other industries, organizations and government bodies in the development of reliable standards which advance industry manufacturing techniques to solve market-related problems.

This Standard was developed by the Steel Tank Institute AST Repair Standard Committee consisting of the following members and alternates:

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1.0 SCOPE

1.1 This standard covers the repair and modification of an atmospheric-type shop-fabricated carbon or stainless steel tank. It applies to tanks storing stable, flammable and combustible liquids at atmospheric pressure with a specific gravity not greater than 1.0.

1.2 This standard covers repair and/or modification of a tank built to a nationally recognized standard for aboveground storage tanks. It may be used for the repair and modification of other tanks at the discretion of the tank owner noting owner's responsibilities below. The current edition of the construction standard, to which the tank was built, will be consulted for minimum construction requirements not otherwise covered in this standard.

1.3 The scope is limited to the top and bottom of the tank, the tank supports, inner and outer shells, nozzles to the face of the first flange, the first threaded joint, or the first welded end connections. Other accessories, such as stairways, catwalks or items that are attached to the tank, are not included.

1.4 This standard does not cover repairs to riveted or bolted tanks. It also does not cover the repair or modification of an underground tank to be used aboveground. This standard does not cover insulation repair.

1.5 The owner is responsible for complying with the provisions of this standard, in addition to compliance with fire codes, local ordinances, and other applicable rules and regulations. The owner may want to retain assistance from specialists to aid in regulatory compliance, safe operations and installations in accordance with recognized industry standards. The owner shall verify that persons working on tanks understand and address the hazards associated with the contents as well as procedures associated with those tanks.

1.6 The repair or modification of a tank may affect the Listing status of the tank. This standard does not address the Listing status of a tank. Contact the original Listing organization for more information.

1.7 This Standard is intended for use by organizations and/or individuals who are knowledgeable and experienced in aboveground tank fabrication, repair, modification and inspection.

1.8 All repairs and modifications shall be in accordance with good engineering practice.

2.0 DEFINITIONS

ATMOSPHERIC STORAGE TANK – a tank or container designed to operate at pressures from atmospheric pressure through a gauge pressure of one psig measured at the top of the tank. The tank may be sitting on the ground, or set on supports, such as saddles, skids or legs, etc. or may be installed in a vault.

CONTINUOUS RELEASE DETECTION METHOD (CRDM) – a means of detecting a release of liquid through inherent design. It is passive because it does not require sensors or power to operate. Liquid releases are visually detected by facility operators. The system shall be designed in accordance with good engineering practice. Several acceptable and commonly used CRDM systems are as follows:

1. Release prevention barrier (RPB) described in definition of release prevention barrier.
2. Secondary containment tank including double-wall tank or double-bottom tank
3. Elevated tank with release prevention barrier described in definitions of elevated tank and release prevention barrier.

CORNER JOINT – a joint where intersecting plates are attached perpendicularly to each other, such as at the base of a vertical tank where the shell is welded to the tank bottom.

DOUBLE-WALL TANK – a tank with a primary tank contained within a secondary tank forming an interstitial (annular) space. An interstitial (annular) space between the two tanks is formed that is capable of being tested and monitored for leakage into the interstice.
ELEVATED TANK – a tank which is not in contact with the ground and which is raised above the surface of the ground or bottom of a vault using tanks supports. Elevating the tank allows for a visual external inspection of the bottom of the tank. Examples of elevated tanks are tanks constructed on grillage or grating, or tanks on supports.

FULL FILLET WELD – A fillet weld whose size is equal to the thickness of the thinner member joined.

INTERSTICE – in a double-wall tank, the space between the primary tank and secondary tank. In a double-bottom tank, the space or void between the two bottoms. This space may be open or closed to the atmosphere and may be monitored or tested by vacuum or leak detection equipment or by visual inspection.

KNUCKLE - the bottom of vertical tanks and the heads of horizontal tanks often use a circular piece of steel with a formed flange. The curved portion of the steel is commonly called the knuckle.

LOCKOUT/TAGOUT – a procedure for affixing disabling devices, and tagging them as such, to energy isolating equipment and for otherwise disabling machines or equipment to prevent unexpected energization, startup, or release of stored energy. Its intent is to prevent injury to employees, and to comply with the following OSHA (Occupational Safety & Health Administration) regulations or their equivalent:

- 29 CFR part 1910.147, The Control of Hazardous Energy (Lockout/Tagout)

MANWAY – an opening designed to allow inspection or entry into a tank.

MAXIMUM NORMAL LIQUID LEVEL – the maximum level of the liquid in the tank encountered during normal operations.

NONDESTRUCTIVE EXAMINATION (NDE) – the development and application of technical methods to examine materials and/or components in ways that do not impair future usefulness and serviceability in order to detect, locate, measure, interpret, and evaluate flaws.

OWNER – the legal entity having control and responsibility for the operation of the existing tank and storage facilities.

PAINT FAILURE – significant peeling, cracking, spalling, blistering, pitting and chipping etc. of the paint or coating on a tank resulting in the exposure of the metal surface and corrosion of the tank shell.

PRIMARY TANK – the tank in direct contact with the liquid stored.

RELEASE PREVENTION BARRIER (RPB) – a liquid containment barrier that is sufficiently impervious to the liquid being stored and is installed under the tank. Its purpose is to divert leaks toward the perimeter of the tank where they can be easily detected as well as to prevent liquid from contaminating the environment. RPBs are composed of materials compatible with the liquid stored in the tank and meet engineering standards. Examples are steel (such as in steel double-bottom tanks), concrete, elastomeric liners, or other suitable materials provided the above criteria are met.

REINFORCING PLATE - A plate installed around a connection to replace the material removed from the opening in the shell.

SECONDARY TANK – the outer tank of a double-wall tank.

SHOP-FABRICATED TANK – a welded carbon or stainless steel tank fabricated in a manufacturing facility typically with a volume less than or equal to 75,000 U.S. gallons (283,906 liters).
SINGLE-WALL TANK – a tank with only one shell.

SPILL CONTROL – a means of preventing a release of liquid to the environment. Methods include the following:
- Remote impounding
- Secondary containment dike/berm
- Secondary containment tank
- Secondary containment system

TANK SUPPORTS – structures designed to elevate a tank above the ground. These include saddles, skids, beams, legs, and similar structures.

3.0 SAFETY CONSIDERATIONS

3.1 The hazards associated with the cleaning, entry, inspection, testing, maintenance or other aspects of tanks are significant. Safety considerations and controls should be established prior to undertaking physical activities associated with tanks.

3.2 This standard does not address all applicable health and safety risks and precautions with respect to particular materials, conditions or procedures. Information concerning safety and health risks and precautions should be obtained from the applicable standards, regulations, suppliers of materials and material safety data sheets.

3.3 The following activities may be regulated. The inspection, repair and modification of a tank shall include consideration to the relevant requirements and best management practices:
- Breaking Lines, Isolating, and Release of Equipment
- General Work Permit
- Hot Work
- Lockout/Tagout
- Gas Testing
- Contractor Safety
- Respiratory Protection
- Tank Cleaning, Repair, and Dismantling
- Confined Space Entry

3.4 Plans to enter a tank require development or use of appropriate safety procedures, precautions and requirements. The owner, contractors and all persons associated with the tank inspection, repair or modification, cleaning or entry, shall review these prior to the start of work.

3.4.1 Before the repair or modification begins, check for the accumulation of harmful vapors around and in the tank. Refer to the following documents for additional information:
- NFPA 326, Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning or Repair
- API RP 2015, Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks
- API RP 2016, Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks

3.4.2 Each tank entry requires an Emergency Action Plan. The owner and contractor must develop the Plan together. This Plan describes the actions required for personal safety from fire and other emergencies. This plan includes the following requirements as well as others:
- SCBA (Self Contained Breathing Apparatus) and lifelines on site, as well as rescuers trained in their use.
- Establishment of and review of emergency escape routes and procedures with authorized entrants.
- Establishment of an assembly area and procedures to account for all authorized entrants after emergency evacuation is complete.
- Establishment of rescue and first-aid duties for those authorized entrants assigned to
3.4.3 After plans, procedures and administrative controls are in place and before entering the tank, isolate the tank by locking out and tagging all energy sources associated with the tank. Line isolation shall be at the closest flange practical to the equipment or space. Lockout/Tagout establishes a procedure for affixing lockout or tagout devices to energy-isolating equipment and for otherwise disabling machines or equipment to prevent unexpected energization, startup, or release of stored energy. Its intent is to prevent injury to employees, and to comply with the following OSHA regulations or their equivalent:
- 29 CFR part 1910.147, The Control of Hazardous Energy (Lockout/Tagout)
- 29 CFR part 1910.331 to 1910.333, Electrical Lockout/Tagout
- 29 CFR part 1910.146, Permit-required Confined Spaces

3.4.4 The atmosphere inside the space shall be tested and confirmed safe before authorized entrants may enter. The atmosphere shall be tested at the start of each work shift every day and whenever work conditions may have changed. Continuous atmospheric monitoring is recommended. At a minimum, test the space for the following:
- Oxygen content
- Carbon Monoxide (CO)
- Hydrogen Sulfide (H₂S)
- Lower Explosive Limit (LEL)

3.4.5 Inspect the roof and support structures for soundness. Inspect stairs, ladders and platforms to determine that they can safely support equipment and people before accessing them. Corrosion may attack the deck plate at the edge of a fixed roof and at the rafters in the center of the roof first. Therefore, in addition to entry hazards, there are those associated with the access to tank roofs. For tank roofs where one side is not visible, it may be necessary to check the plate thickness with ultrasonic instrument or hammer test it to verify its adequacy. If there is a doubt, place planks on the roof that span structural members and walk on the planks instead of directly on the roof. These same hazards may also apply to other tank walking surfaces, such as the surfaces of floating roofs. Guidance for this is covered in API RP 2016, Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks.

3.4.6 A safety analysis shall be conducted prior to a leak test. Leak testing methods may be hazardous. For example, the leak test methods referenced in 8.0 require that either an inert gas be used or that the tank be thoroughly cleaned and gas free prior to testing and pressurizing a tank. Combining hydrocarbons with air provides a potentially hazardous atmosphere. Each test method may have unique hazards and these shall be considered and addressed in a pre-test safety plan. A qualified person shall review and approve the safety plan.

4.0 PERSONNEL QUALIFICATIONS

4.1 Personnel qualified to make repairs and modifications in accordance with this standard shall be one of the following:
- Company qualified welding personnel of a facility which manufacturers STI, API, UL, ULC, or SwRI tanks.
- ASME Section IX qualified welders.
- AWS D1.1 qualified welders
- Additional certifications as may be required by individual states or other governing bodies.
5.0 MATERIALS AND WELDING

5.1 MATERIALS

5.1.1 Repair plate material shall be of the same material specification (or equivalent from corrosion-resistance, strength and weldability standpoints) as the material to which it is welded. For carbon steel tanks for which the original material specification is unknown or obsolete, the repair material shall be equivalent to ASTM A36 material as a minimum.

5.1.2 The user of this standard shall be aware that new steel used in repairs or modifications has the potential to corrode more quickly than the existing steel.

5.2 WELDING

5.2.1 Welding procedure specifications shall be qualified in accordance with the original construction standard, if known, or Section IX of the ASME Code, AWS D1.1, or D1.6.

5.2.2 Welding procedures and materials shall be selected to minimize hydrogen embrittlement which may result in cracking. Hydrogen embrittlement can be minimized by the use of low hydrogen electrodes or equivalent methods.

5.2.3 Weld procedures to minimize distortion and residual stresses shall be used.

6.0 MODIFICATIONS

6.1 GENERAL

6.1.1 Certain modifications to existing tanks require specialized engineering assistance, including but not limited to the following:

- Shell height modification
- Addition of anchor chairs
- Change of service
- Pipe penetrations larger than 12 inches below maximum liquid level
- Pipe connections with external loads

6.1.2 If the tank has bracing in the area to be modified, then the modified section must also be braced to match the original design.

6.1.3 Reinforcing plates shall be formed to the contour of the tank.

6.1.4 All aboveground tanks shall have provisions for normal and emergency venting. Modifications to a tank shall not eliminate or reduce the sizes of the vents below that required by the applicable code.

6.2 PIPE CONNECTIONS

6.2.1 All piping and fittings shall be a minimum of schedule 40.

6.2.2 Piping flanges shall be ANSI Class 150, raised face.

6.2.3 Verify that the type of connection (threaded, welded or flanged) is appropriate per local building codes. For example, some local codes do not allow threaded connections greater than 2 inches.

6.2.4 Connections for venting shall be flush with the underside of the roof.

6.2.5 As a minimum, continuous welding from the exterior of the tank is required.

6.2.6 Reinforcing plate requirements:

6.2.6.1 Reinforcing plates are not required for penetrations that are completely above the maximum normal liquid level.

6.2.6.2 Shell connections of 2 inches diameter and less do not require reinforcing plates.

6.2.6.3 Reinforcing plates are required for connections of piping for 2-1/2 inches to 12 inches in diameter if any portion of the penetration is below the maximum normal liquid level.

6.2.6.4 The reinforcing plate shall be at a minimum the same thickness as the shell. The outside diameter of the reinforcing plate shall be twice the diameter of the opening. The diameter of the reinforcing plate may be proportionally reduced with an increase in thickness, but the minimum cross sectional area of reinforcing plates shall be the product of the vertical diameter of the hole cut in the shell and the nominal plate thickness. The reinforcing plate shall be at least 3 inches in width.

6.2.6.5 There shall be a minimum distance of 3 inches from the toe of a new weld to the toe of an
existing weld and the minimum overlap of an existing weld shall be 3 inches.

6.2.6.6 Reinforcing plates shall have one ¼ inch threaded test hole for testing of the reinforcing plate.

6.3 MANWAYS

6.3.1 Refer to Figure 6.3a and 6.3b, as well as Table 6.3a and 6.3b for recommended constructions. There shall be a minimum distance of 3 inches from the toe of a new weld to the toe of an existing weld.

6.3.2 Reinforcing plate requirements:
6.3.2.1 Reinforcing plates are required for manways if any portion of the penetration is below maximum normal liquid level.
6.3.2.2 The diameter of the reinforcing plate may be proportionally reduced with an increase in thickness, but the minimum cross sectional area of reinforcing plates shall be the product of the vertical diameter of the hole cut in the shell and the nominal plate thickness.
6.3.2.3 The reinforcing plate shall be at least 3 inches in width.
6.3.2.4 The minimum thickness of the reinforcing plate shall be the thickness of the existing shell plate or ¼ inch, whichever is greater. Refer to Table 6.3b. Reinforcing plates shall have one ¼ inch threaded test hole for testing of the reinforcing plate.

6.3.3 A manway-cover joint shall be provided with a ring or face gasket of material determined to be acceptable for use with the product contained in the tank and shall have a thickness of not less than 1/8 inch (3.2 mm).

### TABLE 6.3a

**MANWAY DIMENSIONS**

<table>
<thead>
<tr>
<th>Nominal size of manway, inches</th>
<th>Nominal diameter of cover plate, inches</th>
<th>Nominal diameter of bolt circle, inches</th>
<th>Minimum number of bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20-1/2</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>18</td>
<td>22-1/2</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>20</td>
<td>24-1/2</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>26-1/2</td>
<td>25</td>
<td>22</td>
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<td>24</td>
<td>28-1/2</td>
<td>27</td>
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<td>30</td>
<td>35-1/2</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td>36</td>
<td>41-1/2</td>
<td>39</td>
<td>52</td>
</tr>
</tbody>
</table>
TABLE 6.3b
MANWAY COVER PLATE AND BOLTING FLANGE DIMENSIONS
(Manway Is Below Liquid Level)

<table>
<thead>
<tr>
<th>Maximum tank height, feet</th>
<th>Minimum thickness of cover plate, inches</th>
<th>Minimum thickness of bolting flange after finishing, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16 inch manway</td>
<td>18 inch manway</td>
</tr>
<tr>
<td>21</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>27</td>
<td>5/16</td>
<td>5/16</td>
</tr>
<tr>
<td>32</td>
<td>5/16</td>
<td>5/16</td>
</tr>
<tr>
<td>35</td>
<td>5/16</td>
<td>3/8</td>
</tr>
<tr>
<td></td>
<td>24 inch manway</td>
<td>30 inch manway</td>
</tr>
<tr>
<td>21</td>
<td>3/8</td>
<td>7/16</td>
</tr>
<tr>
<td>27</td>
<td>7/16</td>
<td>1/2</td>
</tr>
<tr>
<td>32</td>
<td>7/16</td>
<td>9/16</td>
</tr>
<tr>
<td>35</td>
<td>1/2</td>
<td>5/8</td>
</tr>
</tbody>
</table>
FIGURE 6.3a
MANWAY DETAILS
(above liquid level)
FIGURE 6.3b
MANWAY DETAILS
(below liquid level)

Note:
The minimum cross sectional area of the
repeats shall be the product of the
vertical diameter of the hole cut in the
shell and the nominal plate thickness.

See Table 6.3b

Minimum 1/2 inch bolts
in 9/16 inch holes

Continuous full
fillet weld (typ.)
6.4 **INSTALLATION OF A SECOND BOTTOM**

6.4.1 This section establishes the requirements for the installation of a second bottom in an existing tank for the purpose of providing secondary containment of the tank bottom. Unlike a bottom replacement, when a new bottom is installed, the original bottom is to be left in place.

6.4.2 The thickness of the new bottom plate shall comply with the requirements of the current edition of the applicable standard of construction. If no known reference exists, the bottom plate shall be a minimum of 0.250 inch nominal thickness.

6.4.3 All welds shall be continuous welds.

6.4.4 **Installation of a new tank bottom below the existing bottom**

6.4.4.1 Lifting of the tank will be required with this method. Disconnection of piping, cathodic protection anodes, and grounding mechanisms is required.

6.4.4.2 The old tank bottom shall be clean. Remove soil, bedding material and disbonded coatings adhered to the underside of the tank bottom.

6.4.4.3 The new bottom plate shall extend outside the shell a minimum of 1.5 inches or as required by the applicable standard of construction.

6.4.4.4 A tank with a knuckle requires the use of a flat bar wrapped around tank and welded to both the new bottom and the tank. This flat bar shall be sufficient in width so that weld to the tank is at least 3 inches above the old tank bottom to shell joint.

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**FIGURE 6.4.4.4**

**FLAT BAR FOR TANK WITH KNUCKLE**
6.4.4.5 If tank has a corner joint, no flat bar is needed. The new bottom shall be welded directly to the existing one.

6.4.4.6 A minimum 1/4-inch fitting must be provided for interstitial monitoring of the space between the old and new bottom. Refer to Section 8 for testing.

6.4.4.7 Tank bottoms shall be uniformly supported. Voids in the supporting material shall be filled with sand, crushed limestone, grout, pea gravel or concrete. The top 3 inches of the entire supporting material shall be of homogeneous material.

6.4.4.8 Additional non-mandatory recommendations are included in Appendix A.

6.5 PENETRATION REMOVAL AND PATCHING

6.5.1 To remove the existing penetration, the tank shell shall be cut at least 1 inch away from the penetration weld. The cut-out can be round or oval, and all corners must have a minimum of 2 inch radius.

6.5.2 The cut to remove a penetration shall be a minimum of one inch from an existing weld. The cut can cross over an existing weld seam, but must extend beyond the seam by a minimum of 3 inches. This dimension may be larger depending on the type of repair procedure required to cover the removal. The cut should not follow along an existing weld seam.

6.5.3 If the existing penetration had a reinforcing pad, the entire reinforcing plate shall also be removed. The reinforcing plate can be removed by grinding or cutting the external full fillet weld from the tank surface.

6.5.4 The cut to remove a penetration shall be at least 3 inches away from the edge of a rolled knuckle in the tank head or bottom. Under no circumstances shall the removed section include any part of the rolled knuckle in a head or bottom of a tank.

6.5.5 Covering the opening created by removal of the shell, bottom or roof section shall be performed following the procedures in Section 7.0 of this standard for installation of patch plates or insert plates.

7.0 REPAIRS

7.1 SHELL REPAIRS

7.1.1 General - The purpose of this section is to describe shell repair procedures that may be required as a result of an SP001 inspection. Repairs to the shell shall be made with weld deposition, with lap-welded patch plates, or with butt-welded insert plates as described below. The appropriate method(s) of repair shall be determined from an evaluation of the nature and extent of damage requiring the repair. The placement of patches on top of a previous repair is not permitted. The repair provisions contained herein are limited to shell plates not exceeding 1/2-inch in thickness. Details are included below for vertical and horizontal cylindrical tanks. The following requirements also apply to rectangular tanks except contouring of plates is not required.

7.1.2 Weld deposition - Weld deposition may be used to repair damage or defects that adversely affect the structural or leak integrity of the tanks as follows:

7.1.2.1 Cracks, lack of fusion, and rejectable slag and porosity that need weld repair shall be removed completely by gouging and/or grinding and the resulting cavity properly prepared and welded. Use the nondestructive examination methods described in Section 8 to determine extent of the defect.

7.1.2.2 Existing weld undercut in excess of 1/32-inch shall be repaired by additional weld metal, as appropriate.

7.1.2.3 Welded joints that have preferential loss of metal (as compared to adjacent shell plates) due to corrosion shall be repaired by welding, if deemed necessary by the inspector.

7.1.2.4 Pits shall be repaired, if deemed necessary by the inspector, by weld deposition or by the use of lap-welded patch plates or insert plates.
7.1.2.5 Broken welds on attachments to the shell shall be repaired, if necessary, as described in 7.1.2.1. Dents need not be repaired, providing they do not include cracking or severe gouging. Cracking or gouging shall be repaired, if necessary, as described in 7.1.2.1.
7.1.2.6 Continuous welding on the accessible side of the repair is required.
7.1.2.7 For repairs to penetrations through the shell and where the patch plate is accessible on both sides of the repair, welding on the second side is required. The hole shall be at least 2 inches in diameter. Holes smaller than 2 inches diameter shall be enlarged in order to repair with a patch plate. The patch plates shall be continuously welded, that is, to the shell around the patch plate perimeter and around the inner perimeter of the hole.
7.1.2.8 All welds shall be deposited with a minimum of two passes for plates 3/16 inches or greater. The minimum shell thickness to which the patch plate is welded is 0.10 inches.

7.1.3 Lap Patches - Lapped patch shell repairs are an acceptable form of repair for butt-welded and lap-welded tank shells, providing the following conditions are satisfied:
7.1.3.1 The patch plate shall match the as-built thickness of the existing shell plate to be repaired.
7.1.3.2 The minimum dimension of a patch plate shall be 6 inches. For maximum dimensions, refer to Figure 7.1.3.2.

FIGURE 7.1.3.2
MAXIMUM PATCH PLATE DIMENSIONS
7.1.3.3 Patch plate shape:
7.1.3.3.1 Patch plates shall be accurately formed to the contour of the tank shell in a manner that is non-injurious to the physical properties of the patch plate and that results in a smooth and uniform appearance.
7.1.3.3.2 Patch plates may be circular, oval, or rectangular with corners rounded to a minimum radius of 2 inches. Patch plates shall extend one inch minimum beyond the tank defect. Square-cornered patch plates shall not be used.
7.1.3.3.3 Patch plates may extend to and intersect with the shell-to-bottom joint if the vertical sides intersect the bottom at a 90-degree angle of a vertical tank. Similarly, for a horizontal tank, patch plates may extend to and intersect with the shell-to-head joint if the horizontal sides intersect the head at a 90-degree angle. Such plates, when used, shall not have rounded corners at the intersecting weld but shall have them at all other corners. Refer to Figure 7.1.3.3.
7.1.3.3.4 Patch plates installed near the bottom of tanks which are fabricated with a knuckle type bottom shall be a minimum of 3 inches from the knuckle. Refer to Figure 7.1.3.3a.

FIGURE 7.1.3.3
PATCH PLATE SHAPES
7.1.3.4 Patch plates over existing weld joints
7.1.3.4.1 Shell plate butt weld joints that are to be covered with a patch plate shall be ground flush and smooth with the surface of the plate.
7.1.3.4.2 Existing lap-welded shell joints shall not be covered with lap-welded patch plates. Patch plates shall not be welded over other lap-welded patch repair plates.
7.1.3.4.3 Repair of lap-welded shell joints shall be with a combination of a lap welded plate and an insert plate. Refer to Figure 7.1.3.4.3. Lapped plate attachment welds shall be full fillet welds. Butt welds shall be in accordance with paragraph 7.1.4 concerning insert plate installation.
7.1.3.5 Shell openings and nozzles shall not be positioned in a lap-welded patch plate.
7.1.3.6 New patch plate weld joints shall not be closer than 3 inches to an existing weld joint.
7.1.4 Insert plates - Insert plates shall be used when the damaged or deteriorated area of the shell is larger than can be repaired with the largest lap-welded patch plate permitted by 7.1.3 and may be used as an alternative to lap-welded patch plates.

7.1.4.1 The insert plate shall match the as-built thickness of the existing shell plate to be repaired. The maximum dimension of the insert plate may be as large as is permitted by constructability considerations. The minimum dimension of an insert plate shall be 6 inches.

7.1.4.2 Insert plates shall be accurately formed to the contour of the tank shell in a manner that is noninjurious to the physical properties of the insert plate and that results in a smooth and uniform appearance. Insert plates may be circular, oval, or rectangular with corners rounded to a minimum radius of 2 inches. Square-cornered insert plates shall not be used.

7.1.4.3 Insert plates may extend to and intersect with the shell-to-bottom joint if the vertical sides intersect the bottom at a 90-degree angle. Similarly, for horizontal tanks, insert plates may extend to and intersect with the shell-to-head joint if the horizontal sides intersect the head at a 90-degree angle. Such plates, when used, shall not have rounded corners at the bottom but shall have them at the top. Refer to Figure 7.1.4.3
7.1.4.4 To reduce the potential for distortion of an existing tank due to welding a replacement plate into an existing tank shell, fit-up, heat input, and welding sequence must be considered. Insert plate welding shall have full penetration. If the tank has bracing in the repair area, then the insert plate shall also be braced to match the original design.

7.1.4.4.1 For the repair of a vertical tank at the shell-to-bottom joint, the shell-to-bottom joint shall be cut back a minimum of 12 inches beyond the insert plate to allow fitting and welding of the vertical joints before welding the horizontal joints. Refer to Figure 7.1.4.3, Detail A. For tanks fabricated with a knuckle in the tank bottom, the insert plate must stop above the knuckle.

7.1.4.4.2 Similarly, for the repair of a horizontal tank at the shell-to-head joint, cut back a minimum of 12 inches beyond the insert plate to allow fitting and welding of the circumferential joints. Refer to Figure 7.1.4.3, Detail A.

7.1.4.4.3 For tanks fabricated with a knuckle on the tank head, the insert plate must stop before the knuckle. Refer to Figure 7.1.4.4.3.

FIGURE 7.1.4.4.3
INSERT PLATE INSTALLED NEAR TANK BOTTOM
7.1.4.5 Weld spacing considerations for insert plates
7.1.4.5.1 Vertical cylindrical tanks - New insert plate weld joints shall not be closer than 6 inches to an existing vertical weld joint. New insert plate weld joints shall not be closer than 3 inches to an existing horizontal weld joint. Refer to Figure 7.1.4.5.
7.1.4.5.2 Horizontal cylindrical - New insert plate weld joints shall not be closer than 6 inches to an existing vertical weld joint and an existing horizontal joint. New insert plate weld joints shall not be closer than 3 inches to an existing circumferential (girth) joint. Refer to Figure 7.1.4.5.
7.1.4.5.3 Rectangular tanks - New insert plate weld joints shall not be closer than 3 inches to an existing weld joint.

**FIGURE 7.1.4.5**
**INSERT PLATE ALLOWABLE WELD SPACING**
7.2 REPAIRING A BOTTOM SECTION OF VERTICAL AND RECTANGULAR TANKS

7.2.1 General Requirements

7.2.1.1 The use of patch plates for repairing a section of tank bottoms is allowed. Refer to Figure 7.2.2. The placement of patches on top of a previous repair is not permitted.

7.2.1.2 The thickness of a patch plate shall be the greater of ¼ inch or the original thickness of the existing bottom.

7.2.1.3 The patch plate may be circular, oval or rectangular with corners rounded to a minimum radius of 2 inches.

7.2.1.4 The minimum dimension in any direction of a patch plate is 6 inches.

7.2.1.5 New patch plate weld joints shall not be closer than 3 inches to an existing weld joint.

7.2.1.6 A patch plate shall extend beyond a defect by a minimum of one inch.

7.2.1.7 The bottom plate thickness under the patch plate weld must be at least 0.100 inches thick before welding.

7.2.1.8 Refer to Figure 7.2.2 for acceptable patch plate sizes and dimensions.

7.2.2 Repairs to the bottom of tanks with a knuckle joint (Refer to Figures 7.2.2 and Figure 7.2.2a)

7.2.2.1 When a patch plate is needed near the bottom-to-shell knuckle, it must meet these requirements:
   a. The patch shall be no closer than 3 inches from the knuckle.
   b. Two sides of the patch plate shall be approximately 90 degrees to the curvature.
   c. The welds within 3 inches of the curvature shall be two-pass minimum.

7.2.2.2 Repair of corroded plates in the knuckle curvature or within 3 inches of the knuckle is limited to pit welding or deposition welding provided that the sum of the pit dimensions in any direction are less than 2 inches in any 8-inch length. Weld-on patch plates are not permitted in the knuckle. See Figure 7.2.2.4 for clarity.

7.2.3 Repairs to the bottom of tanks with a corner joint (see Figures 7.2.2 and 7.2.2b)

7.2.3.1 When a patch plate is needed within 3 inches of the internal, corner joint weld, it must meet these requirements:
   a. The patch plate shall be tombstone shaped.
   b. The sides of the tombstone shall intersect the shell-bottom joint at approximately 90 degrees.
   c. The welds within 3 inches of the corner joint shall be two-pass minimum.
   d. Overlapping patches are not permitted.

7.2.3.2 Repair of corroded plates using weld deposition within 3 inches of the corner joint weld is limited to pit dimensions where the sum of the pit dimensions in any direction are less than 2 inches in any 8-inch length. See Figure 7.2.2.4 for clarity.

7.2.3.3 If more extensive repairs are required within 3 inches of the corner joint weld than is described in 7.2.3.1 or 7.2.3.2, then a new bottom shall be installed.
NOTES:
1. Dimensions are given from toe of fillet welds or to centerline of butt-weld.
2. Dimensions apply to existing, new and new-to-existing welds.
3. These rules apply to lap-welded and butt-welded bottoms.
4. Welded patches are not permitted in formed knuckle region.
5. When the edge of a patch plate is approximately parallel to a bottom seam, the edge shall be a minimum of 3 inches from the bottom weld seam.
6. Edge of "tombstone" plate must be 3 inches min. from edge of tank bottom weld. Therefore, if the plate is placed closer than 3 inches from weld, the plate must cross over the weld as shown by the dotted line.

FIGURE 7.2.2
BOTTOM PATCH PLATE DIMENSIONS
Figure 7.2.2a
ACCEPTABLE BOTTOM PATCH PLATE DESIGNS (KNUCKLE TYPE BOTTOM)

Figure 7.2.2b
ACCEPTABLE BOTTOM PATCH PLATE DESIGNS (CORNER JOINT BOTTOM)
Figure 7.2.2.4
ACCEPTABLE REPAIR OF PITTING IN KNUCKLE
7.2.4 REQUIREMENTS FOR REMOVAL AND REPLACEMENT OF ENTIRE TANK BOTTOM OF A VERTICAL OR RECTANGULAR TANK

7.2.4.1 The old bottom shall be removed in its entirety. Lifting of the tank will be required. Disconnection of piping, cathodic protection anodes, and grounding mechanisms is required.

7.2.4.2 Bottom removal shall be accomplished by a uniform cut in the shell, made parallel to the tank bottom. The cut shall be a minimum of ½ inch above the toe of the existing shell-to-bottom weld. The cut edges shall be ground to remove all slag and burrs from the remaining shell.

7.2.4.3 The thickness of the new bottom plate shall comply with the requirements of the current edition of the applicable standard of construction. If no known reference exists, the bottom plate shall be a minimum of 0.250 inch nominal thickness.

7.2.4.4 Refer to Figure 7.2.4 for acceptable shell to bottom joints.

7.2.4.5 Tank bottoms shall be uniformly supported. Voids in the supporting material shall be filled with sand, crushed limestone, grout, pea gravel or concrete. The top 3 inches of the entire supporting material should be of homogeneous material.

7.2.4.6 Existing shell penetrations shall be raised if the new bottom interferes with the penetration. Refer to Section 6 concerning penetration removal and patching.

7.2.4.7 For tanks with floating roofs, the roof legs must be adjusted after the new tank bottom is installed so that the roof is:
   • Level when the tank is empty or in low roof position,
   • Does not collide with a fixed roof when the tank is full.

7.2.4.8 On tanks equipped with floating roofs or column supports, new bearing plates and new striker plates shall be installed.

7.2.4.9 Additional non-mandatory recommendations are included in Appendix A.
FIGURE 7.2.4
NEW BOTTOM WELD JOINTS
7.3 REPAIRS AND MODIFICATIONS TO TANK ROOFS

7.3.1 Refer to paragraph 7.1 for instructions concerning roof repairs and modifications because these are similar to shell repairs. However, considerations concerning weld spacing, maximum patch or insert plate size are not mandatory. Welding is only required on the accessible side of the repair.

7.3.2 Make sure that roofs do not collect water after repairs and modifications are complete.

7.3.3 All tanks require normal venting and emergency venting.

7.3.4 Modifications to roofs of tanks with weak roof-to-shell joints or frangible roofs shall be evaluated by an engineer or manufacturer.

7.4 REPAIRS TO TANK SUPPORTS

7.4.1 Tank supports must conform to the standard to which the tank was built. If that is not possible, then use the current edition of an applicable standard such as UL 142.

7.4.2 Consideration should be given to seismic requirements and other building code requirements.

7.4.3 If tank supports show evidence of corrosion or deformation that affects their structural integrity, the damaged portion must be replaced or repaired to make them structurally sound.

7.4.4 Be careful not to damage the tank shell when making repairs to the supports. Should damage occur, refer to paragraph 7.1 to make the necessary repairs.

7.4.5 If support repair or modification included welding to the tank shell, test the tank in accordance with paragraph 8.0.

8.0 TESTING AND INSPECTION REQUIREMENTS FOR REPAIRS AND MODIFICATIONS

8.1 An inspection by a qualified person shall be conducted to confirm the repaired or modified area is fit to be returned to service. All inspection results, repairs, modifications, and recommendations shall be documented.

8.2 A visual examination of all repairs and modifications is required. A visual examination shall be combined with another testing procedure. Inspect all repairs or modifications.

8.3 DESCRIPTION OF TESTING METHODS AND REQUIREMENTS - Refer to Table 8.3 for appropriate use of these methods.

8.3.1 D & T- Drill and Tap - A ¼ inch NPT coupling over a predrilled hole or a 1/4 inch tapped hole can be added to the patch and air test the patch. The air test pressure must be not less than 3 psig, and no more than 5 psig. The pressure is to be held for at least one hour. Immediately apply a leak test solution (soap solution) to the welds.

8.3.2 DPT - Liquid Penetrant Examination (dye penetrant test) Dye penetrant testing per ASME Section V Article 6.

8.3.3 G - helium tracer gas - Tank tightness may be determined by placing an inert gas, most commonly helium, on the inside of a manufactured tank, sealing the tank and attempting to detect the gas from the opposite side (outside). The inert gas is placed under a predetermined pressure and sensitive detection equipment is used to probe the outside of the tank at likely weak points such as along seams and welds.

8.3.4 H - Hydrostatic - Hydrostatically test the tank for tightness. Consult tank manufacturer installation instructions and the Steel Tank Institute Recommended Practice R912-00, “Installation Instructions for Shop Fabricated Stationary Aboveground Storage Tanks for Flammable, Combustible Liquids.”

8.3.5 P - Pneumatic pressure test - Pressure test the tank for tightness with an appropriate gas. Consult tank manufacturer installation instructions and the Steel Tank Institute Recommended Practice R912-00, “Installation Instructions for Shop Fabricated Stationary Aboveground Storage Tanks for Flammable, Combustible Liquids.” An air pressure test shall not be used in tanks that contain flammable or combustible liquid or vapors. An inert
gas pressure test may be appropriate for pressure testing these tanks.

8.3.6 PT - highly penetrating oil examination (diesel oil test) - penetrates through to opposite side of weld by capillary action. Generously apply oil to the repaired side of the tank and then check the opposite side of the steel for evidence of oil.

8.3.7 VB - Vacuum Box or applied Vacuum - Using a vacuum box and obtaining a pressure differential of at least 5 to 7 inches Hg (approx. 3 psig). Test each joint of the repair or modification in its entirety.

8.3.8 VC - Vacuum - Vacuum test the tank for tightness. Consult tank manufacturer installation instructions and the Steel Tank Institute Recommended Practice R912-00, “Installation Instructions for Shop Fabricated Stationary Aboveground Storage Tanks for Flammable, Combustible Liquids.”

8.4 SIGNIFICANT REPAIR

8.4.1 A tank repair shall be deemed a “significant repair” when one or more of the following occurs:

• A complete replacement of a tank bottom or installation of a double bottom in a tank.

• A patch plate or insert plate is installed with a total area greater than 12 square feet.

• New openings or penetrations greater than 12 inches diameter that are installed below the maximum normal liquid level.

8.4.2 A tank that has undergone a significant repair shall undergo a pressure test or vacuum test of the entire tank for tightness. Local codes and regulations may supercede or supplement this requirement. Consult the tank manufacture installation instructions and the Steel Tank Institute Recommended Practice R912-00, “Installation Instructions for Shop Fabricated Stationary Aboveground Storage Tanks for Flammable, Combustible Liquids.” An air pressure test shall not be used in tanks that contain flammable or combustible liquid or vapors. An inert gas pressure test may be appropriate for pressure testing these tanks.
<table>
<thead>
<tr>
<th>Type or description of repair</th>
<th>Required Test methods</th>
<th>Notes</th>
</tr>
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<tr>
<td>Bottom weld patch</td>
<td>VB</td>
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<tr>
<td>Shell to bottom weld</td>
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<tr>
<td>Replacement annular ring</td>
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<td>Without hole in bottom</td>
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<td>Shell spot weld</td>
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<td>No PT if paint covers weld, or inside and not accessible</td>
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<tr>
<td>Shell patch</td>
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<tr>
<td>Shell penetration</td>
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<td>Horizontal tank head penetration</td>
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<tr>
<td>Horizontal tank shell to head joint</td>
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<tr>
<td>Roof patch</td>
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<td>No PT if paint covers weld, or inside and not accessible</td>
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<td>Roof penetration</td>
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<td>Full double bottom system</td>
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<td>Reinforcing plate</td>
<td>D &amp; T, or DPT</td>
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<td>Addition of sump - visible</td>
<td>DPT, P, H, D</td>
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<td>Addition of sump - not visible</td>
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<tr>
<td>Double-wall interstitial</td>
<td>P, VC, or G</td>
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<tr>
<td>Support replacement</td>
<td>DPT or D</td>
<td></td>
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D & T - Drill and Tap
DPT - Dye Penetrant Testing
G - Tracer Gas
H - Hydrostatic
P - Pneumatic Pressure Test
PT - Highly Penetrating Oil Test
VB - Vacuum Box
VC - Vacuum Test
APPENDIX A
RECOMMENDED PROCEDURES
(NON-MANDATORY)

1.0 BOTTOM REPLACEMENT RECOMMENDATIONS

1.1 Before the bottom replacement is installed consideration should be given to building up the foundation to a minimum of 4 inches above the surrounding grade so rain water will drain away from the tank for its remaining life. Alternately, the earth around the tank should be graded downward on a slope of 2 inches in 10 feet for the lesser of 20 feet away from the tank or to the containment shell if applicable.

1.2 When planning a bottom replacement, consideration shall be given to installing a Continuous Release Detection Method.

1.3 When the tank bottom is in contact with soil, consideration should be given to installing cathodic protection.

1.4 When planning a bottom replacement, consideration shall be given to installing an internal lining on the bottom and 18 inches up the shell to mitigate corrosion on the product side of the new tank bottom. Internal linings may be either reinforced thick-film, or thin-film linings. NACE and SSPC have nationally-recognized industry specifications for application of internal linings.