Engineering Consulting & Training Services

CARMAGEN Engineering, Inc.

eNewsReport

February 2013

Shell Repairs to Aboveground Atmospheric Storage Tanks Using Lap-Welded Patch Plates

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API-653, *Tank Repair and Alteration*, intends that repairs and alterations made on an Aboveground Atmospheric Storage Tank (AST) result in general equivalence to API-650 requirements. Section 9 of API-653, contains specific requirements that are intended to meet this objective. After the AST has been in service for some time, thinning due to corrosion may require that sections of the shell be repaired in order for the tank to have adequate strength for its next period of operation. Such repairs are generally done by installing insert plates into the shell using full-thickness butt welds.

Before Addendum 1 issued in December 1996, API-653 did not permit the use of lap-welded shell patch plates under any circumstances. The primary concerns with using lap-welded patch plates relate to the quality and strength of the attachment fillet weld, the possible increased risk of initiating a brittle fracture at the fillet weld (especially in steels that do not meet current fracture toughness requirements), and the ease with which the patch plate is installed (which may lead some individuals to not take it as seriously as they should). Addendum 1 relaxed this general prohibition on the use of lap-welded patch plates provided that the owner specifies their use and they meet requirements stated in API-653. Despite this relaxation, the specified requirements for lap-welded patch plates will still limit their widespread use. As noted below, the maximum shell and patch plate thickness limit is a significant constraint.

Lapped patch repairs may be considered permanent repairs subject to an established inspection and maintenance program. The requirements specified in API-653 may be used to evaluate pre-existing lapped patch repairs, except that the various plate thickness limits need not be applied.

The following highlights several of the requirements for using lap-welded patch plates. This is not an all-inclusive list; so, refer to API-653 for additional details.

- All repair material must meet the requirements of the applicable construction standard and API-653.
- Lap patches cannot be used on any shell course whose original construction thickness is greater than 1/2 in. (12.5 mm), and cannot be used to replace doorsheets or shell plates. The 1/2 in. (12.5 mm) thickness limit relates to potential brittle fracture concerns. There has never been a documented case of a brittle fracture in plates less than 1/2 in. (12.5 mm) thick. Therefore, limiting patch plate thickness to 1/2 in. (12.5 mm) minimizes the brittle fracture risk.

Upcoming Training Course held in our NJ offices

- Course 607, *Design and Maintenance of Aboveground Atmospheric Storage Tanks*, April 9 - 11, 2013

See our website for details

Work Highlights

Mechanical Engineering

- *Mechanical engineering design audits were made of piping systems, pressure vessels, heat exchangers, and packaged equipment being supplied for onshore and offshore facilities for "upstream" projects. Considerable effort was made to help ensure that the contractors were using appropriate procedures to correct potential acoustically induced piping vibration issues that were identified.*

Process, Operations & Safety

- *Provided patent review and technical consultation regarding fuels hydroprocessing.*
- *Providing long-term facilities/ equipment layout optimization support services for various locations.*
- *Performing ongoing process planning support for domestic refinery and miscellaneous related consultation.*

This maximum thickness limit effectively limits the use of lap patches to small diameter tanks, or the upper courses of large diameter tanks, where the shell plate thickness is not over 1/2 in. (12.5 mm).

- The lap patch must be at least 3/16 in. (4.8 mm) thick, but no thicker than the smaller of 1/2 in. (12.5 mm) or the thickness of the plate to which it is being welded. Therefore, if the design calculations conclude that a lap patch plate must be over 1/2 in. (12.5 mm) thick, a butt-welded insert patch must be used instead.
- The shape of the lap patch may be circular, oblong, square, or rectangular. All corners must be rounded to a 2 in. (50 mm) minimum radius (except at the bottom-to-shell joint). This reduces local stress concentrations and facilitates welding.
- Minimum spacing limits between the lap patch welds and shell seams are specified. The size and placement of the lap patch might require adjustment to respect these limits.
- A lap patch may extend to and intersect with the external bottom-to-shell joint at a 90° angle. Acceptable attachment details are specified in API-653.
- Shell openings and their reinforcement shall not be positioned within a lapped patch shell repair. The main concern here is the additional loads that could be imposed on the lap patch fillet welds.
- The area on the shell where the lap patch welds are to be made must first be ultrasonically examined for plate defects and remaining thickness. The plate size must be changed (probably increased) as needed to weld to sound shell plate material.
- Lap patches shall not be lapped on lap-welded shell seams, riveted shell seams, other lap patch repairs, distorted areas, or unrepaired cracks or defects.
- Minimum and maximum lap patch size limits are specified (see API-653 for details). The patch plate must be formed to the shell curvature in all cases.

The following Table highlights additional requirements that must be met when lapped patch repairs are used for particular situations.

Repair Situation	Additional Requirements
Closure of holes caused by removal of: • Existing shell openings • Thinned areas of shell	• Continuous fillet welds in outer perimeter of plate and inner perimeter of hole. • 2 in. (50 mm) minimum hole diameter. • 2 in. (50 mm) minimum corner radius of shell hole. • Complete removal of original nozzle neck and any associated reinforcement plate. • Repair plate thickness calculated based on $E \leq 0.7$, where E is the weld joint efficiency of the double fillet weld. Note that using this weld joint efficiency may result in the lap patch being thicker than the shell plate. If this results in a thickness greater than 1/2 in. (12.5 mm), a lap patch cannot be used. • Repair plate thickness $\leq$ nominal thickness of shell plate adjacent to repair. • Full-thickness fillet welds. • 4 in. (100 mm) minimum repair plate dimension.

Repair Situation	Additional Requirements
Reinforce thinned areas of shell without removal	• Repair plate thickness calculated using E ≤ 0.35. Here again, using this weld joint efficiency may result in the lap patch being thicker than the shell plate. If this results in a thickness greater than 1/2 in. (12.5 mm), a lap patch cannot be used. • Full-thickness fillet weld. • Repair plate thickness cannot exceed: - Shell plate thickness by more than one-third, but by no more than 1/8 in. (3 mm) - 1/2 in. (12.5 mm) • Strength of remaining shell under repair plate cannot be considered effective in carrying calculated service or hydrotest loads.
Repair small leaks or minimize potential for leaks at isolated or widely scattered pits	• Existing shell thickness meets minimum thickness requirements. • Repair plate thickness calculated using E ≤ 0.35 (same comments as above regarding resulting patch plate thickness). • Full-thickness fillet weld. • Repair plate thickness cannot exceed: - Shell plate thickness by more than one-third. - 1/2 in. (12.5 mm) • Minimum repair plate thickness ≥ 3/16 in. (4.8 mm) • Cannot be used if: - Crevice corrosion or concentration cell corrosion is a concern if fillet weld is exposed to stored liquid. - Presence of stored liquid between shell and repair plate will prevent tank gas freeing for hot work. • Thickness of shell plate under repair plate must be evaluated for acceptability during future inspections.

As is evident from the above summary, many of the lap-welded patch plate requirements can easily be met. However, others [e.g., the maximum 1/2 in. (12.5 mm) thickness limit] effectively precludes their use for tank shell repairs.

About the Author

Vincent Carucci, President of Carmagen Engineering, Inc., also provides mechanical engineering expertise in the areas of pressure vessels, heat exchangers, piping systems, and storage tanks to the process and power industries, insurance companies, and attorneys. If you would like more information, please contact Vince at vcarucci@carmagen.com.