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Some Tips for Shell Thickness Evaluations of In-Service Aboveground Atmospheric Storage Tanks – Part 2

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An earlier article introduced the basic equations used in API-653 to determine whether the shell thickness of in-service aboveground atmospheric storage tanks is acceptable for continued operation. It highlighted several items that inspectors and engineers should be aware of, and help avoid being overly conservative. This article highlights several other items.

The Originally Specified Corrosion Allowance is Gone – Are Repairs Needed?

Maybe not. As noted in the earlier article:

- The API-653 allowable stress is higher than that specified in API-650. Therefore, the shell can be thinner than what would be obtained from just subtracting the corrosion allowance from the original plate thickness and still be acceptable.
- The original plate was most likely purchased to a standard thickness, which could be a little thicker than the minimum needed based on the design calculations plus corrosion allowance.

Even if the shell has corroded below the minimum required thickness, an alternative to making repairs is to reduce the maximum permitted liquid fill height so that the remaining thickness is acceptable. This might also be an alternative to consider depending on the overall storage capacity needs of the facility.

General vs. Pitting-Type Corrosion

Tank shell corrosion may be either of a general, nominally "uniform" nature or be pitting type. API-653 contains different evaluation procedures and acceptance criteria for each corrosion type. Pitting type corrosion may be evaluated as uniform corrosion as a simplification (i.e., by using the measured shell thickness at the bottom of the deepest pit). But that approach is conservative and could result in requiring unnecessary repairs or liquid fill height restrictions.

Shell Thickness Averaging

Areas of nominally uniform corrosion do not thin to exactly the same thickness throughout the region. There is actually thickness variation. When shell thickness inspection results are initially reported, they will typically be the thinnest value that was measured in the corroded region. If the evaluation concludes that the tank shell thickness is acceptable, then there is no reason to proceed further.

Work Highlights

Project Management

- *Full time, onsite contracts/ procurement consulting support provided in the contractor's Paris office for a gas project being constructed in the Middle East. Numerous deviations between the owner's requirements and contractor/ supplier procedures were identified and corrected during the course of this activity. Same person currently on assignment in Japan on a different project in a similar capacity.*
- *Independent audits were provided of the lifting plans that were developed by mechanical contractors at several locations, both in the US and overseas. These "heavy lifts" typically involved the replacement of FCCU Reactor and/or Regenerator vessel heads and associated cyclone and plenum chamber systems. The objective of these reviews was to help ensure that these lifts would be carried out in a safe and reliable manner. In all cases, the lifts were successfully carried out without incident.*

Reliability & Maintenance

- *A fully integrated, multi-discipline, reliability assessment was completed for the FCCU and HF Alkylation units for a refinery that covered process engineering, operations, mechanical and materials/corrosion engineering. This assessment was prompted by several unplanned and costly shutdowns that occurred in the FCCU over a relatively short time, and a desire for an independent review of the HF Alky Unit. Potential vulnerabilities were identified for both units, and numerous recommendations were made which, when implemented, will improve the units' overall mechanical and operations reliability.*

However if the thickness is found to be unacceptable, API 653 permits the measured thicknesses to be "averaged" in order to arrive at an overall strength of the shell to use in the maximum allowable fill height determination. The basic concept employed here is that thicker areas in a corroded region serve to reinforce more corroded areas. An analogy is the use of excess metal available in a pipe or pressure vessel shell that is not required for other reasons to provide reinforcement of a branch connection. The average thickness must be at least equal to t_{min}, and the minimum measured thicknesses must be at least $0.6t_{min}$ (plus the required corrosion allowance for the entire next period of operation in each case). Refer to API 653 for details of this thickness averaging approach.

Change In Service

A change in tank service to one employing a higher specific gravity liquid, or a design temperature above 200°F (93°C), could affect the minimum required shell thickness and maximum allowable fill height. A higher specific gravity liquid increases the applied hydrostatic head and resulting shell stresses. Design temperatures over 200°F (93°C) result in a lower allowable shell plate stress since the material strength reduces as its temperature increases. Either of these possibilities decreases the maximum permitted fill height for given shell thicknesses, or requires thicker shell plates for a given fill height. In addition, thermal stresses must be considered at temperatures over 200°F (93°C). See API-650, Appendix M, for additional design requirements for elevated temperature storage tanks.

It should also be determined if the new service is anticipated to have a higher corrosion rate than the previous service. In this case, the required interval to the next inspection must be adjusted to account for this.

Variable Design Point vs. One-Foot Method for Required Shell Thickness Calculation

The equations used in the minimum required thickness calculations discussed in the prior article are based on the One-Foot Method of API-650 and may only be used for tank diameters less than or equal to 200 ft. (60 m). API-653 requires that the Variable Design Point Method of API-650 (VDP) be used for tanks greater than 200 ft. (60 m) in diameter, consistent with API-650 requirements, but it may be used for any tank diameter.

The VDP method is a more detailed (and time consuming) procedure, but may result in a slightly lower minimum thickness requirement, and may be used even if the tank was originally designed using the One-Foot Method. Note that if a commercially available computer program is used for evaluating a tank, using the VDP Method is no more time consuming than the One-Foot Method.

Detailed Stress Analysis

If the relatively simple calculation procedures previously discussed do not result in the tank being found acceptable for the required service, API-653 permits using the "design by analysis" approach contained in Section VIII, Division 2 of the ASME pressure vessel code. An ASME Division 2 analysis requires more detailed calculations (typically axisymmetric Finite Element Stress Analysis) and thickness inspection measurements in order to accurately model the corrosion, and categorize and evaluate the stresses. However, a tank that is found to be unacceptable by the simple procedures is often found to be acceptable using the Division 2 procedures.

One common example of where a Division 2 analysis approach often yields significantly improved results is when evaluating localized shell corrosion in the bottom-to-shell junction region of the tank. Analyses done on this basis have often found that fairly severe localized corrosion in this region that would have required repair if the simplified calculation procedures were used is acceptable without repair. After pointing this out while presenting storage tank training courses, I've often been greeted by examples where major repairs were actually done that might not have been necessary [e.g., complete replacement of the lower 25 in. (600 mm) of the bottom shell course]. In cases where such corrosion is found to be acceptable, it is common practice to coat the region with a material that is suitable for the tank's service conditions. Such a coating protects the shell surface from further corrosion.

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.