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Changes to API 650, Eleventh Edition Welded Steel Tanks for Oil Storage

By Vincent A. Carucci

Two addenda have been issued for the Eleventh Edition of API 650 since it was published in June 2007. Addendum 1 was issued November 2008, and Addendum 2 was issued November 2009. The following highlights several of the changes that were made and is not all inclusive. Refer to API 650 for complete information.

Section 1: Scope

- Table 1-1 includes the titles of new appendices that have been added to API 650:
  - Appendix EC – Commentary on Appendix E
  - Appendix SC – Stainless Steel and Carbon Steel Mixed Material Storage Tanks
  - Appendix X – Duplex Stainless Steel Tanks
  - Appendix AL – Aluminum Storage Tanks
- A new Para. 1.5 requires that consistent units be used where units are not defined in formulas. I have not checked all the formulas, but presumably there are cases where this occurs. Perhaps a future revision will define the units in each case to avoid potential errors?

Section 2: References

The following additional references have been added:

- API RP 582 – Welding Guidelines for the Chemical, Oil and Gas Industries
- API Publ 937 – Evaluation of the Design Criteria for Storage Tanks with Frangible Roofs
- API Publ 937-A – Study to Establish Relations for the Relative Strength of API 650 Cone Roof, Roof-to-Shell, and Shell-to-Bottom Joints

Section 4: Materials

- Figure 4-1 that specifies the MDMT curves for materials has been replaced by Figures 4-1a and 4-1b in SI and US Customary Units, respectively.
- New Tables 4-3a and 4-3b provide linear equations for the curves contained in Figures 4-1a and 4-1b, respectively. The addition of these tables resulted in renumbering of subsequent tables in this section.

Work Highlights

Machinery

Provided onsite machinery engineering assistance during the startup and initial operation of a petrochemical plant located in the Middle East. In addition to the normal new unit startup issues addressed, also provided support to a root cause failure analysis team investigating the failure of a valve stem on a new steam turbine system.

Process, Operations & Safety

Provided startup support for a fluid coker, consultation on coke transport bottleneck issues, and troubleshooting of modifications designed by others that did not work as expected. The client eventually decided to process lighter crudes and shut down the unit due to overall refinery economics rather than resolve issues at this time.

Provided facilitator and designer support on numerous HAZOP safety efforts at several locations for multiple clients.

- New Para. 4.4.4 permits the use of weldable-quality pipe for structural purposes with its physical properties and allowable stresses as stated.
- Separate Tables 4-5a and 4-5b are now included that specify impact test requirements for steel plates in SI and US Customary Units, respectively.

Section 5: Design

- Para. 5.2.1b now permits a 0 kPa (0 in. water) design external pressure for internal floating roof tanks with circulation vents that meet Appendix H requirements.
- New Para. 5.2.1e specifies internal floating roof design loads. Subsequent paragraphs in Para. 5.2.1 have been renumbered.
- Para. 5.2.1f permits the minimum roof live load to be determined per ASCE 7 as an alternative.
- Para. 5.2.1g provides more requirements for determining the general snow load.
- Table 5-1 that specifies annular bottom-plate thicknesses has been separated into Table 5-1a and 5-1b for SI and US Customary Units, respectively.
- Para. 5.6.1.3 has been modified to permit shell thicknesses to be determined by an elastic analysis if the allowable stress for an upper shell course is less than the allowable stress of the next lower shell course. This approach may be used as an alternate to the "historical" requirement that the lower shell course cannot be thinner than the one above it.
- Table 5-2 that specifies permissible plate materials and corresponding allowable stresses has been separated into Tables 5-2a and 5-2b for SI and US Customary Units, respectively.
- Para. 5.7.1.7 provides more details covering insert plate requirements for shell openings.
- Generally speaking, the tables that specify the dimensional requirements for openings (e.g., 5-3, 5-4, etc.) were separated into two tables each for SI and US Customary Units, respectively.
- Para. 5.8.3.4 for an opening in the cover plate of flush-type cleanout fittings specifies requirements for its location and design. It also points out that the free movement of connected piping and applied piping loads must be considered.
- Para. 5.8.4 requires that loads applied to roof manholes and supporting roof structure be considered.
- In Tables 5-20a and 5-20b, Paras. 5.9.7.1, 5.9.7.2, etc. (i.e., where top and intermediate wind girder requirements are specified), the definition for "shell thickness" was generally changed from "as-ordered" to "as-built" thickness. Of course, the "as-built" shell thicknesses represent the actual strength of the shell, and these should be at least equal to the "as-ordered" thicknesses.
- Para. 5.10.2.6 covering frangible roof joint requirements is now divided based on tank diameter – tanks 50 ft. (15 m) diameter or greater, self-anchored tanks with a diameter greater than or equal to 50 ft. (9 m) but less than 50 ft. (15 m), and alternate requirements for self-anchored tanks less than 50 ft. (15 m) diameter. These modified requirements recognize the long-known fact that the "historic" API 650 frangible joint requirements did not ensure frangible joint behaviors for tanks less than 50 ft. (15 m) in diameter. The revised requirements are based on a R&D program that was done on behalf of API.
- Para. 5.10.4.4 has been changed by now using an equation to determine the maximum permitted roof plate space between rafters for supported cone roof tanks.
- Para. 5.10.5.1 covering the required roof plate thickness for self-supporting cone roofs has been changed to also consider two different ways to consider snow loads. A similar change was made in Para. 5.10.6.1 for self-supporting dome and umbrella roofs.
- The equation in Para. 5.10.5.2 to calculate the participating area of the roof-to-shell joint of self-supporting cone roof tanks has been changed. It now explicitly accounts for the material strength. A similar change was made in Para. 5.10.6.2 for self-supporting dome and umbrella roofs.
- Tables 5-21a and 5-21b that specify the design uplift loads for anchored tanks now include a formula to account for the frangibility pressure for tanks with frangible roofs. The formulas that account for wind and seismic loads have also been changed.

Section 10: Marking

Specific markings are now identified to be used depending on where thermal stress relief has been done.

Appendix AL: Aluminum Storage Tanks

A new Appendix AL has been added covering material, design, fabrication, erection and testing requirements for tanks constructed of aluminum and aluminum alloys.

Appendix B: Recommendations for Tank Foundations

A Para. B.6 has been added that identifies foundation considerations for tanks operating at elevated temperatures [> 200°F (93°C)].

Appendix E: Seismic Design of Storage Tanks

Several of the formulas contained in this Appendix have been changed. Among them are those contained in Paras. E.4.5.1, E.4.6.1, E.4.6.2, E.6.1.4, E.6.2.1.1, and E.7.2.

Appendix EC: Commentary on Appendix E

This new appendix provides background information on the development of the requirements contained in Appendix E. It also includes several example problems that illustrate the application of the requirements.

Appendix F: Design of Tanks for Small Internal Pressures

- The formulas in Para. F.4.1 have been changed to explicitly account for the lowest minimum specified yield strength (modified for design temperature) of the materials in the roof-to-shell junction. Prior editions of API 650 implicitly included an assumption of the material strength. The nominal roof thickness used in the calculation can also now be adjusted if needed to account for stiffeners welded to the roof plate.
- Figure F-2 that specifies permissible details of compression rings has been modified regarding the length of the top angle that may be considered as contributing to the reinforcement area. It now also considers the yield strength of the material.
- The formulas in Para. F.5.1 have been changed to explicitly account for the material strength, comparable to what was done in Para. F.4.1.
- Para. F.7.2 requires that full penetration butt welds shall be used to connect sections of the compression ring. It also states that the compression ring material may be selected from Section 4 of API 650 but does not need to meet toughness criteria.
- Para. F.7.3 provides more explicit and additional requirements for the design and welding of roofs and the design, reinforcement, and welding of roof manholes and nozzles.

Appendix G: Structurally Supported Aluminum Dome Roofs

- Table G-1, Bolts and Fasteners, has been split into G-1a and G-1b for SI and US Customary Units, respectively.
- The formula in Para. G.4.1.3 to calculate the allowable general buckling pressure was changed to explicitly account for the Modulus of Elasticity of the dome frame members.
- Para. G.4.1.4. Formula for the required net tension ring area was changed to account for the maximum pressure calculated per Para. R.1.(e) for gravity loads.
- Para. G.4.2 covering design loads was completely revised.

Appendix H: Internal Floating Roofs

- Para. H.4.2.2.2 has been changed regarding required load combinations for the design of floating roof supports.
- New Para. H.4.2.2.3 provides allowable load requirements for roof support cables.
- New Paras. H.4.6.10 through H.4.6.13 provide additional requirements for fixed roof supports for the operating roof position and cable supports.
- Para. H.5.2.1 covering pressure-relieving vent requirements has been divided into sub-paragraphs with several requirements changed or added.

Appendix K: Sample Applications of Variable Design Point Method

There is now a second example that provides complete calculations for both the design and hydrotest calculations.

Appendix P: Allowable External Loads on Tank Shell Openings

Para. P.3 that provided an alternative procedure for evaluating external loads considering WRC Bulletin 297 was completely deleted.

Appendix S: Austenitic Stainless Steel Storage Tanks

- Tables S-1a and S-1b include additional materials.
- Para. S.3.1.1 now specifies the minimum shell-to-bottom plate size as a function of nominal shell plate thickness.
- New Para. S.3.1.3 specifies requirements for butt-welded annular bottom plates.
- Para. S.3.4 specifies several additional requirements for roof design and roof manholes.
- Tables S-2a and S-2b contains the allowable stresses for the additional materials that were added to Tables S-1a and S-1b.
- Para. S.4.11 covering welding has more sub-paragraphs with additional welding requirements.

Appendix SC: Stainless and Carbon Steel Mixed Materials Storage Tanks

This new appendix covers materials, design, fabrication, erection, and testing requirements for tanks constructed with stainless steel and carbon steel.

Appendix V: Design of Storage Tanks for External Pressure

- Para. V.3.1. The formula to calculate the maximum wind pressure, W, has been changed but the result has not. The new equation merely directly incorporates the wind gust and wind height factors which had been specified as constant values in the prior formula.
- Para. V.7.3.3 and V.7.3.4. The formulas used to determine the length of roof and shell considered to be within the tension/compression ring region of self-supporting dome or umbrella roofs have been changed.
- Paras. V.8.1, V.8.1.2, V.8.1.3. The procedure and formulas used to determine the allowable external pressure for an unstiffened shell have been changed.
- Paras. V.8.2.1.2, V.8.2.1.4. The formulas used to determine the maximum permitted spacing and required number of intermediate shell stiffeners have been changed.

Appendix X: Duplex Stainless Steel Storage Tanks

A new appendix has been added to cover materials, design, fabrication, erection, and testing requirements for tanks constructed of duplex stainless steels.

Appendix Y: API Monogram

A new appendix provides information on use of the API Monogram.

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.

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