Agenda Item 620-1025

Title: Rules for Compression-Ring Regions Exceeding 2 Inches Thickness

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Revision: 0

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Purpose: Provide thickness limits for compression-ring regions and additional design requirements for thicknesses exceeding 2 inches or where excessive discontinuity stresses may occur in the sidewall of large diameter tanks.

Source: Split out from 620-2060 which was initiated by Inquiry 620-2021-F1 (rec'd 6/15/2021) asked what rules apply in 2" - 2.5" range for the shell.

Impact: Larger tanks will be facilitated and higher internal pressures may be feasible for moderately sized tanks.

Rationale: Compression bars become quite thick on large API 620 tanks. The authors find more Annex R tanks needing compression bars > 2" than tanks needing shells > 2". The largest membrane stresses in the compression-ring are compression, so toughness is of lesser importance, but the big difference between the thick compression-ring parts and the thinner roof plates and upper shell plates, suggests that more attention to discontinuity stresses is needed.

The suggested criteria of 2.0 x sqrt(R_c x (t_c-c)) comes from ASME VIIII, Division 2, Section 4.3.11 and Figure 4.3.9. The intention of the 2.0 x sqrt(R_c x (t_c-c)) formula is different than the 0.6 x sqrt(R_c x (t_c-c)) formula in API 620 Figure 5-5 used to determine the height of the sidewall participating in the compression-ring. The 0.6 x sqrt(R_c x (t_c-c)) formula covers the secondary stresses at the roof to sidewall junction. The 2.0 x sqrt(R_c x (t_c-c)) identifies a threshold where the geometry may result in significant discontinuity stresses at the transition from a thickened sidewall to the adjacent sidewall thickness. Having the sidewall transition within this threshold requires analysis only when the compression-ring sidewall is at least double the thickness of the adjacent sidewall thickness. Although a smaller factor may be reasonable, determining an acceptable factor without it being arbitrarily selected would require an extensive parametric study. The suggested provisions allow the designer to use less than 2.0 x sqrt(R_c x (t_c-c)) for the compression-ring sidewall by performing an elastic stress analysis.

Proposed Changes

5.12.5 Details of Compression-ring Regions

5.12.5.1 If the force Q is negative, indicating compression, then the horizontal projection of the effective compression-ring region shall have a width in a radial direction not less than 0.015 times the horizontal radius of the tank wall at the level of the juncture between the roof or bottom and the sidewalls; if the projected width does not meet this requirement, appropriate corrective measures shall be applied as specified in this section.

5.12.5.2 Whenever the magnitude of the circumferential force Q determined in accordance with 5.12.4 is such that the area required by Equation (27) is not provided in a compression-ring region with plates of the minimum thicknesses established by the requirements of 5.10 or when Q is compressive and the horizontal projection of the width, w_h, is less than specified in 5.12.5.1, the compression-ring region shall be reinforced by:

a) thickening the roof or bottom and sidewall plates as required to provide a compression-ring region having the necessary cross-sectional area and width as determined on the basis of the thicker plates.;[18]

b) adding an angle, a rectangular bar, or a horizontally disposed ring girder at the juncture of the roof or bottom and sidewalls plates; or

c) using a combination of these alternatives. This additional area shall be arranged so that the centroid of the cross-sectional area of the composite corner compression region lies ideally in the horizontal plane of the corner formed by the two members. In no case shall the centroid be off the plane by more than 1.5 times the average thickness of the two members intersecting at the corner.

5.12.5.3 The thickness of the components in 5.12.5.2(a) are limited to 3 in. If the thickness of one or more of these components exceeds 2 in, or if a thickness change with ratio greater than 2.0 is made in the sidewall at a location closer than $2.0\sqrt{(R_c\,(t_c-c))}$ to the roof/sidewall junction, then all of the following shall apply. t_c refers to the thickened part of the sidewall that is considered part of the compression-ring.

a) All secondary bending stresses shall be shown by an elastic stress analysis to not exceed the smaller of each component's ambient temperature specified ultimate strength or two times its yield strength for all design conditions. The analysis model shall include the roof, compression-ring and sidewall.

b) Membrane tension stress shall not exceed 1/3 of the allowable tensile stress for all design conditions.

c) Charpy impact testing of the material is required if Design Metal Temperature is less than -5°F with impact value not less than given in Table 4-3 raised by 5 additional foot-pounds.

Existing 5.12.5.3 through 5.12.5.8 will need to be renumbered.