Agenda Item 620-1024

Title: Expand Table R-6 for Shell Thicknesses up to 2.5 inches

Date: November 13, 2023

Revision: 0

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Purpose: The expansion of Table R-6, thickness requirements for the annular bottom plate, is to work along with agenda item 620-2060, which is clarifying requirements for first course thicknesses up to 2.5". The current table stops with a first course thickness of 1.5".

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 low temperature tanks will be facilitated.

Rationale: An evaluation methodology was first determined that matches the existing Table R-6 values well. A fatigue check considering 1,300 fill cycles and limiting the surface stress of the annular plate at the inside corner weld to a design fatigue stress of 75,000 psi was performed for each data point on the existing Table R-6. This original approach appears to have been taken from the fatigue curves that are currently located in Table I-9.1 from ASME BPVC Section III Appendix I. Therefore, this same association is used for extrapolating the Table R-6 to maintain a consistent basis. The tank dimensions in the evaluation of each point on the table were back calculated considering a bearing pressure of 6000 psf with 0.610 product specific gravity but limited the liquid height over diameter ratio to 1.2. The required annular plate thickness from each analysis was rounded up to the nearest 1/32.

An interesting sidenote is that while Table R-6 addresses shell design stresses up to 26000 psi, the greatest strength listed in Table 5-1 is 24000 psi for A537 Class 2.

With the evaluation basis matching the existing table well, the expansion of Table R-6 was generated. As a means of validating the table, two example shell designs were analyzed in ANSYS and evaluated the acceptable number of cycles using two approaches from ASME Section VIII Div 2. The two approaches are Smooth Bar Fatigue per 5.5.3 with Section 3-F.1; and Welded Joint Fatigue per 5.5.5 with Section 3-F.2.

1. The first design considers the upper bound of the existing table with a 1.5 inch thick first shell ring with design stress of 24 ksi, annular plate thickness

of 3/8", and shell-to-annular fillet welds equal to 3/8". The minimum number of cycles for the smooth bar and welded joint approaches are 3247 and 1432, respectively.
2. The second design considers the upper bound of the extrapolated table with a 2.5" thick first shell with design stress of 24 ksi, annular plate thickness of 19/32" and a combined groove and fillet weld width of 19/32" in accordance with API 620 5.9.5.3. The minimum number of cycles for the smooth bar and welded joint approaches are 3276 and 1445, respectively.

More details of the methodology and analysis can be found in the included report.

A separate agenda item will be required for generating a metric version of the table because the formula in Table R-6 Note b will require a metric equivalent, a decision needs to be made on what decimal the results should be rounded up to, and the metric equivalent first shell courses and design stresses need to be selected. Also, a USC decimal instead of fractional table could be considered.

Proposed Changes in Annex R:

Table R-6—Thickness Requirements[a] for the Annular Bottom Plate (in.)

Nominal Thickness of First Shell Course (in.)	**Design Stress[b] in First Shell Course (lbf/in.^{2})**			
	≤ 20,000	22,000	24,000	26,000
≤ 0.75	¼	¼	¼	¼
> 0.75 to 1.00	¼	¼	¼	5/16
> 1.00 to 1.25	¼	¼	5/16	3/8
> 1.25 to 1.50	¼	9/32	3/8	7/16
> 1.50 to 1.75	¼	5/16	7/16	17/32
> 1.75 to 2.00	¼	3/8	15/32	19/32
> 2.00 to 2.25	9/32	13/32	17/32	11/16
> 2.25 to 2.50	5/16	7/16	19/32	3/4

a The thicknesses and width (see R.3.4.1) are based on the foundation providing a uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate. The minimum thickness for annular bottom plates were derived based on a fatigue cycle life of 1300 cycles with a rigid foundation.

b The stress shall be calculated using the formula (2.6D)(HG)/t, where D = nominal diameter of the tank, in ft; H = maximum filling height of the tank for design, in ft; G = design specific gravity; and t = design thickness of the first shell course, excluding corrosion allowance, in inches.