Title:	Seismic Overturning at the Base of Each Shell Course	**Agenda Item # 650-1045**
Date:	05/15/2024	
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Purpose:	To clarify the extent to which the calculations are to be performed for vertical seismic effects on tank shell rings above the tub ring.	
Source:	INQ-650-D77	
Revision:	3	
Impact:	Improve clarity in text by removing ambiguous text.	
Rationale:	There are currently requirements in paragraphs E.6.2.2.1 and E.6.2.2.2 to calculate the compressive stress at the base of the shell. It is then compared to the allowable value calculated in E.6.2.2.3. There is ambiguity as to whether this check is required to be performed for each shell course. The proposed verbiage in the original version of this agenda item checked for the compressive stress at the base of *each* shell course using the methods in E.6.2.2. Hypothetically, this has merit, as buckling of higher shell courses has been observed due to seismic loadings. However, after running test cases for a variety of tank sizes, it was determined that checking the compressive stress for each shell course using the methods in E.6.2.2 was ineffective for courses beyond the first (see supporting documents). Thus, text that suggests to evaluate compressive stresses in each shell course above the first using the methods in E.6.2.2 are indeed unhelpful. This revision 3 to agenda item 650-1045 proposes to eliminate ambiguous text that implies upper shell courses can be evaluated by the methods in E.6.2.2. • The guidance provided at the end of E.6.1.5 (referenced by the end of E.6.2.2.3) implies that shell compression at the bottom of each shell course must be evaluated. It will be removed. • The existing provision at the end of E.6.2.2.3 to perform a “special analysis” of the upper shell courses in lieu of increasing their thicknesses is sufficient as is. So, the reference to the end of E.6.1.5 (see previous bullet) will be removed as well.	
Proposed verbiage:	Proposed changes to API 650 Ed 13 Errata 1 are in red font. Formatting notes and commentary are in blue font.	

E.6.1.5 Overturning Moment

The seismic overturning moment at the base of the tank shell shall be the SRSS summation of the impulsive and convective components multiplied by the respective moment arms to the center of action of the forces unless otherwise specified.

Ringwall Moment, Mrw:

$$M_{rw} = \sqrt{[A_i(W_iX_i + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_c)]^2} \quad \text{(E.6.1.5-1)}$$

Slab Moment, Ms:

$$M_s = \sqrt{[A_i(W_i X_{is} + W_s X_s + W_r X_r)]^2 + [A_c(W_c X_{cs})]^2}$$ (E.6.1.5-2)

~~Unless a more rigorous determination is used, the overturning moment at the bottom of each shell ring shall be defined by linear approximation using the following.~~

~~1) If the tank is equipped with a fixed roof, the impulsive shear and overturning moment is applied at the top of the shell.~~

~~2) The impulsive shear and overturning moment for each shell course is included based on the weight and centroid of each course.~~

~~3) The overturning moment due to the liquid is approximated by a linear variation that is equal to the ringwall moment, Mrw at the base of the shell to zero at the maximum liquid level.~~

E.6.2.2.3 Allowable Longitudinal Shell-Membrane Compression Stress in Tank Shell

The maximum longitudinal shell compression stress σc must be less than the seismic allowable stress FC, which is determined by the following formulas and includes the 33% increase for ASD. These formulas for FC, consider the effect of internal pressure due to the liquid contents.

When GHD2/ t2 is ⍰⍰44 (SI units) (106 USC units),

In SI units:

$$F_C = 83\ t_s/D$$ (E.6.2.2.3-1a)

or, in USC units:

$$F_C = 10^6\ t_s/D$$ (E.6.2.2.3-1b)

In SI units:

When GHD2/ t2 is < 44:

$$F_C = 83 t_s/(2.5D) + 7.5\sqrt{(GH)} < 0.5F_{ty}$$ (E.6.2.2.3-2a)

or, in USC units:

When GHD2/t2 is less than 1 × 106:

$$F_C = 10^6\ t_s/(2.5D) + 600\sqrt{(GH)} < 0.5F_{ty}$$ (E.6.2.2.3-2b)

If the thickness of the bottom shell course calculated to resist the seismic overturning moment is greater than the thickness required for hydrostatic pressure, less corrosion allowance, then the calculated thickness of each upper shell course for hydrostatic pressure shall be increased in the same proportion, unless a special analysis is made to determine the seismic overturning moment and corresponding stresses at the bottom of each upper shell course ~~(see E.6.1.5)~~.