Agenda Item: 650-1128

Title: API 650 ASCE 7 Wind Update 2

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Purpose: Remaining work to update API 650 to be consistent with ASCE 7 wind methodologies and properties.

Source: Justin Kline

Revision: 1

Complete re-write, changes in red.

Impact: Neutral

Rationale:

Proposal: 5.9.5.3 The required section modulus of the top wind girder shall be determined by the following equation:

In SI units:

$$Z = \frac{6H_2D^2}{0.5F_y}\left(\frac{P_{wd}}{1.72}\right)$$

where

Z is the required minimum section modulus, in cm^3;

D is the nominal tank diameter (for tanks in excess of 61 m diameter, the diameter shall be considered to be 61 m when determining the section modulus), in meters (m);

H_2 is the height of the tank shell, in meters, including any freeboard provided above the maximum filling height as a guide for a floating roof;

F_y is the least minimum yield strength of shell and stiffening ring material at maximum operating temperature in MPA or 210 MPA, whichever is less;

P_{wd} is design wind pressure including inward drag = P_{wv} + 0.24 in kPa;

P_{wv} is design wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (kPa), or

P_{wv} is design wind pressure = $1.48(V/\cancel{190}250)^2$ in kPa where design wind speed (V) is used.

V is the design wind speed (3-sec gust), in km/h [see 5.2.1.k)].

In USC units:

$$Z = \frac{1.5}{0.5F_y}H_2D^2\left(\frac{P_{wd}}{36}\right)$$

where

Z is the required minimum section modulus, in inches^3;

D is the nominal diameter of the tank (for tanks in excess of 200 ft diameter, the diameter shall be considered to be 200 ft when determining the section modulus), in feet (ft);

H_2 is the height of the tank shell, in feet, including any freeboard provided above the maximum filling height as a guide for a floating roof;

V is the design wind speed (3-sec gust), in mph [5.2.1k];

Fy is the least minimum yield strength of the shell and stiffening ring at maximum operating temperature or 30,000, in psi, whichever is less;

P_{wd} is design wind pressure including inward drag = P_{wv} + 5 in (lb/ft^2);

P_{wv} is wind pressure at 33 ft above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (lb/ft^2); or

P_{wv} is wind pressure = $31\ (V/\cancel{120}155)^2$ in (lbf/ft2) where design wind speed (V) is used.

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5.9.5.4 For tanks larger than 61 m (200 ft) in diameter, an additional check for the minimum required moment of inertia for the top wind girder shall be performed.

The required minimum moment of inertia of the stiffening ring shall be determined by the following equations:

In SI units:

$$I = [(3583 \times H_2)/E] \times D^3 \times (P_{wd}/1.72)$$

where

I is the required minimum moment of inertia (cm^4);

D is the nominal diameter of the tank, in meters (m);

H_2 is the height of the tank shell (m), including any freeboard above the maximum filling height as a guide for a floating roof;

E is the modulus of elasticity (MPa) at maximum design temperature;

P_{wd} is the design wind pressure including inward drag = P_{wv} + 0.24 in (kPa);

P_{wv} is the wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (kPa), or

P_{wv} is wind pressure = $1.48(V/\cancel{190}250)^2$ in kPa where design wind speed (V) is used;

V is the design wind speed (3-sec gust) (km/h) (see 5.2.1[k]).

In USC units:

$$I = \frac{108H_2}{E}D^3\left(\frac{P_{wd}}{36}\right)$$

where

I is the required minimum moment of inertia (in.^{4});

D is the nominal diameter of the tank, in feet (ft);

H_2 is the height of the tank shell (ft), including any freeboard above the maximum filling height as a guide for a floating roof;

E is the modulus of elasticity (psi) at maximum design temperature;

P_{wd} is the design wind pressure including inward drag = P_{wv} + 5 in (lb/ft^2);

P_{wv} is the wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (psi), or

P_{wv} is wind pressure = 31(V/~~120~~155)^2 in (lbf/ft^2) where design wind speed (V) is used

V is the design wind speed (3-sec gust) (mph) [see 5.2.1(k)].

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5.9.6 Intermediate Wind Girders

In SI units:

$$H_1 = 9.47t\sqrt{\left(\frac{t}{D}\right)^3}\left(\frac{1.72}{P_{wd}}\right)$$

where

H_1 is the maximum height of unstiffened shell, in meters;

t is the nominal thickness, unless otherwise specified, of the thinnest shell course, in millimeters (see Note 1);

D is the nominal tank diameter, in meters;

P_{wd} is the design wind pressure including wind drag = P_{wv} + 0.24 in (kPa);

P_{wv} is wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (kPa), or

P_{wv} is wind pressure = 1.48(V/~~190~~250)^2 in (kPa) where design wind speed (V) is used;

V is the design wind speed (3-sec gust), in km/h [see 5.2.1k)].

In USC units:

$$H_1 = 600{,}000\ t\sqrt{\left(\frac{t}{D}\right)^3\left(\frac{36}{P_{wd}}\right)}$$

where

H_1 is the maximum height of unstiffened shell, in feet;

t is the nominal thickness, unless otherwise specified, of the thinnest shell course, in inches (see Note 1);

D is the nominal tank diameter, in feet;

P_{wd} is the design wind pressure including wind drag = P_{wv} + 5 in (lbf/ft^2);

P_{wv} is wind pressure at 33 ft above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, ~~importance factor,~~ in (lbf/ft^2), or

P_{wv} is wind pressure = $31(V/\cancel{120}155)^2$ in (lbf/ft^2) where design wind speed (V) is used;

V is the design wind speed (3-sec gust), in km/h [see 5.2.1k)].

NOTE 1 The structural stability check of wind girder stiffened shells in accordance with 5.9.5 and 5.9.6, shall be based upon nominal dimensions of the shell course and the wind girders irrespective of specified corrosion allowances whenever the "No" option is selected for "Check Buckling in Corroded Cond.?" On the Data Sheet, Line 9. Whenever the "Yes" option is selected, the check must be based on upon the nominal dimensions minus the specified corrosion allowance.

NOTE 2 This formula is intended to cover tanks with either open tops or close tops and is based on the following factors (for the background for the factors given in this note, see ASCE 7 and R. V. McGrath's "Stability of API Standard 650 Tank Shells"): [16]

Note:
See footnotes 17 and 18 on last page.

a) The velocity pressure is:

$$p = 0.00256K_zK_{zt}K_d0.6V^2\cancel{I}G = 1.48\text{ kPa }(31\text{ lbf/ft}^2)$$

K_Z equals the velocity pressure exposure coefficient = 1.04 for exposure C at a height of 40ft;

Kzt is 1.0 for all structures except those on isolated hills or escarpments;

K_d is the directionality factor = 0.95 for round tanks[17];

V equals the 3-second gust design wind speed = ~~190~~250 km/h (~~120~~155 mph) at 10 m (33 ft) above ground [see 5.2.1.k][18];

~~I equals the importance factor = 1.0 for Category II structures;~~

G equals the gust factor = 0.85 for exposure C.

5.9.6.6 The required minimum section modulus of an intermediate wind girder shall be determined by the following equation:

In SI units:

$$Z = \frac{6h_1 D^2}{0.5F_y}\left(\frac{P_{Wd}}{1.72}\right)$$

where

Z is the required minimum section modulus, in cm^3;

D is the nominal tank diameter, in meters;

h_1 is the vertical distance, in meters, between the intermediate wind girder and the top wind girder of an open-top tank;

V is the design wind speed (3-sec gust), in km/h [see 5.2.1k)].

Fy is the least minimum yield strength of the shell and intermediate wind girder at maximum operating temperature ~~or 210, in MPa, whichever is less~~.

Pwd is design wind pressure including inward drag = Pwv + 0.24 in kPa;

Pwv is wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, importance factor, in (kPa); or

Pwv is design pressure = $1.48(V/\cancel{190}250)^2$ in kPa where design wind speed (V) is used.

In USC units:

where

Z is the required minimum section modulus, in inches^3;

D is the nominal tank diameter, in feet;

h_1 is the vertical distance, in feet, between the intermediate wind girder and the top wind girder of an open-top tank;

V is the design wind speed (3-sec gust), in mph [see 5.2.1k)].

Fy is the least minimum yield strength of the shell and intermediate wind girder at maximum operating temperature ~~or 30,000 in psi. whichever is less~~.

Pwd is design wind pressure including inward drag = Pwv + 5 in (lbf/ft^2);

Pwv is wind pressure at 33 ft above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, importance factor, in (lbf/ft^2); or

Pwv is design pressure = 31(V/~~120~~155)^2 in (lbf/ft^2) where design wind speed (V) is used.

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AL.5.5.1 Wind Girders

Wind girders shall be designed per 5.9.5.3 and 5.9.6 using the properties of aluminum.

~~The section modulus of wind girders shall equal or exceed:~~

$$\cancel{Z = \frac{pH_wD^3}{12Ec}}$$

~~where~~

~~p equals(1.48 kPa) (V/[190 km/hr])2;~~

~~p equals (31 lb/ft2) (V/[120 mph])2;~~

~~V is the 3-sec gust design wind speed (see 5.2.1[k]);~~

~~Hw is for top wind girders on tanks with no intermediate girder, the tank height; for tanks with intermediate wind girders, the vertical distance between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank;~~

~~c is the lesser of the distances from the neutral axis to the extreme fibers of the wind girder.~~

V.3 Nomenclature and Definitions

V.3.1 Nomenclature

P_{WV} is equal to the design wind pressure on the shell (P_{WS}) from 5.2.1(k).

~~In SI units:~~

~~P_{WV} is the maximum wind pressure = $1.48\left(\frac{V}{190}\right)^2$ in (kPa) where design wind speed (V) is used.~~

~~In USC units:~~

~~P_{WV} is the maximum wind pressure = $31\left(\frac{V}{120}\right)^2$ in (lb/ft^2) where design wind speed (V) Is used.~~

~~where~~

~~V is the specified design wind velocity (3-sec gust), in kph (mph);~~

V.10 Example Calculations

The following example calculations illustrate, in US Customary units, the use of this Annex.

V.10.1 Data

Design wind velocity (3-sec gust) = 155 mph (Maximum wind pressure, P_{WV} = 31 lb/ft^2)

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V.10.2 External Pressure Calculations

4) Calculate the minimum shell thickness required for the combined loading from design external pressure and wind:

From V.8.1.3, the required minimum shell thickness is calculated as follows:

$$t_{smin} \geq \frac{1.23(PSIH_{TS}P_{s})^{0.4} D^{0.6}}{(E)^{0.4}}$$

where

Ps is the greater of 1) the specified design external pressure excluding wind or 2) ~~W~~Pwv + $F_{pe}P_e$, where P_{WV} is the specified design wind pressure, lb/ft^2;

Ps = P_e or (~~W~~Pwv + $F_{pe}P_e$) = 86.4 lb/ft^2 or [31 + 0.4(86.4)] = 86.4 lb/ft^2.

Footnotes:

17. Although ASCE 7 has changed the directionality factor from 0.95 to 1.0, the 0.95 value is retained here so that that the 31 psf value is consistent regardless of changes per edition of ASCE 7 or API 650. While 0.95 is less conservative than 1.0, other factors ensure that the reference wind pressure 31 psf is still a reasonable selection for the design wind speed.
18. The 0.6 factor is applied to ensure that the reference wind speed pressure resulting from changes in ASCE 7 from allowable stress design to strength design does not result in a change in the 31 psf reference wind pressure.