Title: **Anchorage Update and Strap Details**

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Contact:

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Purpose: Improve tank anchorage design and add anchor strap details/guidance

Source: B. Mistry E-Mail of October 10, 2011 and SGD meeting 11/13/2012 in Los Angeles, CA during discussion of Agenda Item 650-753.

Revision: 0

Impact: The business impact of this item is generally neutral with some cost savings potential in quantity of anchors installed on very small diameter tanks and quality improvement on anchor straps.

Background/Rationale: Rules for corroded anchors need clarification. Rules for anchor straps should be included. For SGD to consider:

(1) Why does restriction on hooked anchors in E.6.2.1.2 only apply to Appendix-E tanks?
(2) Anchor straps are more suitable for high anchor loads as the load is transferred in shear. Anchor straps minimize local bending stress in shell. Figure EC-11 shows some details but no design guideline. AWWA D-100, 3.8.5.2, has some Anchor Strap design provisions.
(3) Consolidate existing and add design guidelines for anchor straps in section 5.12.
(4) The minimum number of anchors for seismic condition only affects tanks 19' diameter and below. All other tanks are satisfied with 10' spacing. 6 minimum anchors place an undue burden on smaller tanks with potential to interfere with nozzle orientations, etc. Very small tanks, such as 6 or 8 feet diameter tanks require anchors every 3' to 4' around the tank circumference. This is overkill and 3 to 4 anchors total are more than sufficient for very small tanks, for all loading conditions. Propose to drop min. anchor quantity to 4 for seismic, to match all other loading cases. 10' max. spacing requirement to remain in effect.
(5) Many questions arise as to where to measure the 10' anchor spacing: bolt circle, tank circumference, or chord length. Clarify it is measured along tank circumference. Clarify it is center to center spacing, not a distance measured between edges of anchor chairs, since chairs may be wide. This also helps with interpretation for placement of anchor straps.
(6) Insert new Figures 5-28 and 5-29 for anchor straps, and 5-30 for chairs.
(7) Allow for using bolting materials up to 50,000 psi yield in lieu of limiting to 36,000 psi only as applies for A-36 steel.

Proposal: REV-0 changes in red. Existing text in black. Deletions in ~~blue strikethrough~~. Only affected excerpts and partial paragraphs from API-650 are shown.

5.12 TANK ANCHORAGE

5.12.2 N = number of equally spaced anchors. If not equally spaced then t_b shall be increased to account for unequal spacing. (a minimum of 4 anchors are required~~; a min. of 6 anchors are required if seismic load case governs~~)

5.12.3 The anchor center-to-center spacing measured along the tank circumference at shell OD ~~between anchors~~ shall not exceed 3 m (10 ft.).

5.12.4 Allowable stresses for anchor bolts shall be in accordance with Tables 5-21a and 5-21b for each load case. The allowable stress shall apply to the net ~~(~~root~~)~~ area or area based on nominal corroded shank diameter of the anchor bolt, whichever is less. In the case of hold down straps, the allowable stress shall apply to the corroded area of the anchor strap. F_y shall be taken at maximum design temperature for insulated anchors and at ambient temperature for exposed anchors.

5.12.6 Attachment of the anchor bolts to the shell shall be through stiffened chair-type assemblies or anchor rings of sufficient size and height. An acceptable procedure for anchor chair design is given in AISI Steel Plate Engineering Data, Volume 2, Part 5 "Anchor Bolt Chairs". See Figure 5-30 for typical chair detail. When acceptable to the Purchaser, hold down straps may be used. See Figure 5-28 and 5-29 for typical hold down strap configurations.

Table 5-21a – Uplift Loads (SI)
F_y is the minimum yield strength of the anchor bolt or ~~250~~ 345 MPa, whichever is less, in MPa;

Table 5-21b – Uplift Loads (USC)
F_y is the minimum yield strength of the anchor bolt or ~~36,000~~ 50,000 psi, whichever is less, in psi;

5.12.11 Any anchor bolts shall be uniformly tightened to a snug fit (nuts hand tight in contact with anchor chair top plate plus maximum of $^1/_8$ turn with wrench), and any anchor straps shall be welded while the tank is filled with test water but before any pressure is applied on top of the water. Measures such as peening the threads, ~~or~~ adding locking nuts, or tack welding nuts to chairs shall be taken to prevent the nuts from backing off the threads.

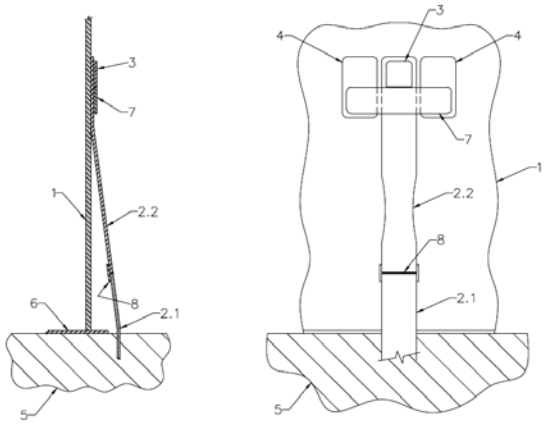
5.12.14 Anchor strap design guidance:

5.12.14.1 When anchor straps are utilized, the anchorage into the foundation should be mechanical, and not rely on bond strength alone. Since there are no direct technical testing methods for validation as exist for anchor bolts, the ability of the detail selected to yield the anchor strap should be demonstrated preferably by test or by calculation at a minimum. Anchor strap embedment shall terminate in an anchor plate welded to the bottom of the strap. The minimum thickness of the anchor plate shall match the thickness of the embedded anchor strap. The minimum width and length of the anchor plate shall match the embedded anchor strap width. Additionally, shear studs may be added to the embedded anchor strap to help develop the anchorage design load.

5.12.14.2 The design and detailing of the strap should account for corrosion of the strap near the foundation, while not providing too much steel area that reduces the desirable ductile stretching of the strap under overload. One solution is to contour the strap to produce reduced area over a portion of the strap length. See Figures 5-28 and 5-29. A second solution is to specify stainless steel for the hold down strap portion cast in the foundation pour as shown in item 2.1 of Figure 5-28.

15.12.14.3 The connection to the shell is also often poorly detailed and stresses the attachment weld in the weak direction. Attaching the strap with a single horizontal fillet weld is not recommended. Attaching the strap to a thicker reinforcing plate may be necessary to avoid over-stressing the shell. One method of detailing a strap is shown is Figure 5-29.

15.12.14.4 The design slope of the anchor strap from vertical shall not exceed 5 degrees.

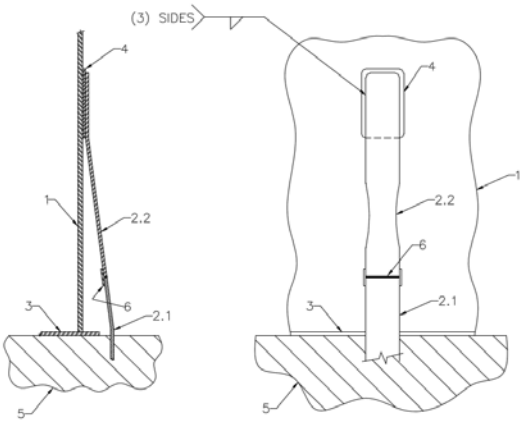


KEY

1) TANK SHELL
2.1) SS HOLD DOWN STRAP
2.2) CS HOLD DOWN STRAP
3) STOPPER PLATE
4) SHELL RE-PADS
5) BASE FOUNDATION
6) TANK FLOOR
7) CROSS PLATE
8) BUTT WELD JOINT (W/ BACKING BAR)

FIGURE 5-28 TYPICAL HOLD DOWN STRAP CONFIGURATION (FOR CARBON STEEL TANK)

NOTE: PART 2.2 TENSILE AND YIELD PROPERTIES OF THE STRAP MATERIAL TO BE EQUAL TO OR LESS THAN THOSE OF THE SHELL PLATE MATERIAL



KEY

1) TANK SHELL
2.1) SS HOLD DOWN STRAP
2.2) CS HOLD DOWN STRAP
3) TANK FLOOR
4) SHELL RE-PAD
5) BASE FOUNDATION
6) BUTT WELD JOINT (W/ BACKING BAR)

FIGURE 5-29 TYPICAL ANCHOR STRAP WELDED ATTACHMENT (FOR CARBON STEEL TANK)

NOTE: PART 2.2 TENSILE AND YIELD PROPERTIES OF THE STRAP MATERIAL TO BE EQUAL TO OR LESS THAN THOSE OF THE SHELL PLATE MATERIAL

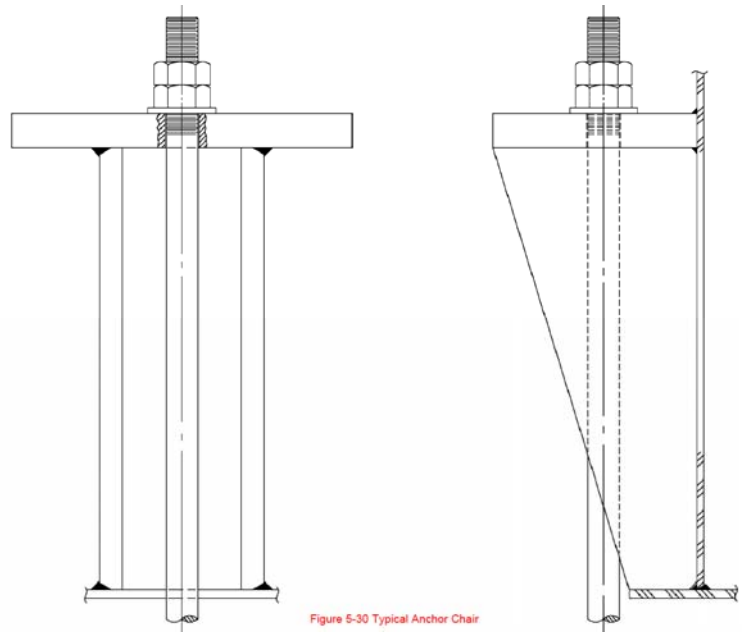


Figure 5-30 Typical Anchor Chair

EC.7.1 ~~Anchorage~~ Shell Support

<none>

~~EC.7.1.1 Self-Anchored~~

~~EC.7.1.1.1 Mechanically Anchored~~

~~Although not the preferred solution for mechanical anchors, straps are permitted. However, if straps are utilized proper details are vital to achieve the performance objective. The anchorage into the foundation should be mechanical, and not rely on bond strength alone. Since there are no direct technical testing methods for validation as exist for anchor bolts, the ability of the detail selected to yield the anchor strap should be demonstrated preferably by test or, at a minimum, by calculation.~~

~~The design and detailing of the strap should also allow for the commonly occurring corrosion of the strap near the foundation, while not providing too much steel area that reduces the desirable ductile stretching of the strap under overload. One solution is to contour the strap to produce reduced area over a portion of the strap length. See figure EC.11.~~

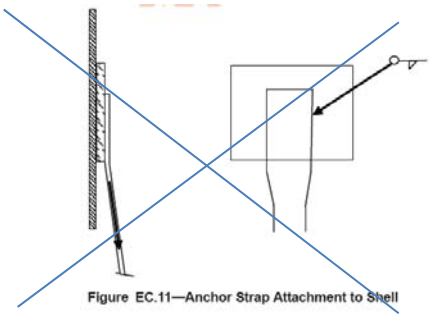


Figure EC.11—Anchor Strap Attachment to Shell

~~The connection to the shell is also often poorly detailed and stresses the attachment weld in the weak direction. Attaching the strap with a single horizontal fillet weld is not recommended. Attaching the strap to a thicker reinforcing plate may also be necessary to avoid over-stressing the shell. One method of detailing a strap is shown is Figure EC.11.~~

~~EC.7.3.1 Method for Estimating Tank Uplift~~

~~<none>~~

~~EC.7.9 Shell Support~~

~~<none>~~

~~EC.7.10 Repair, Modification, or Reconstruction~~

~~<none>~~