Example 9.1 Reinforcement of an API 650 Regular-Type Shell Opening

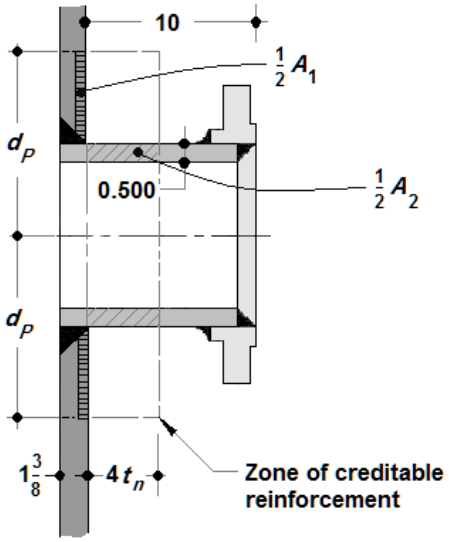
Design Task: An area of a tank wall is fabricated from a 1⅜ inch thick plate based on a calculated required minimum thickness of 1.117 inches plus the application of a specified corrosion allowance of ⅛ inch. An 11 inch diameter radially oriented opening will be cut in this area of the tank wall to receive an NPS 10 inch schedule 60 pipe nozzle whose wall thickness is ½ inch and whose overall projection is 10 inches. The pipe has yield and tensile strengths respectively of 83 percent and 85 percent of the host shell component material. The tank shell and pipe nozzle have material allowable design stresses of 28,000 lb/in^2 and 18,000 lb/in^2, respectively. Calculate the actual amount of opening reinforcement required and the creditable reinforcing material inherent in the unreinforced opening connection. Investigate an alternative to the standard 23 inch diameter extrinsic reinforcing element typically retrofitted to this size opening connection.

Given: $t = 1.500$ in ; $t_r = 1.117$ in ; $c = 0.125$ in ; $d_P = 11$ in ; $t_n = 0.500$ in ;
$L = 10$ in ; $S_{hs} = 28{,}000$ lb/in^2 ; $S_p = 18{,}000$ lb/in^2 ; $d_o = 23$ in

Strategy: Credit for reinforcing material can be taken for the excess thickness that is greater than the design thickness of the tank wall (shell). Because the indicated yield and tensile strengths of the pipe are greater than 70 percent and 80 percent of that of the host shell component, the Standard allows a portion of the nozzle neck material be applied to the required amount of reinforcement as well. Were either of these strengths to be less than these values, no nozzle neck material credit would be allowed. These two material cross-sectional credits may result in a reduced diameter reinforcing element compared to the required tabulated size for the 10 inch opening of 23 inches.

Solution:

1. The zone of creditable reinforcement for this opening is,



(NOT TO SCALE)

2. The required amount of reinforcement is,

$$A = d_P t = (11)(0.500) = 5.5 \text{ in}^2 \quad .$$

3. From the information provided it can be concluded that the tank shell design thickness t_d is 1.117 + 0.125 = 1.242 inches. Therefore the excess shell thickness available as credit for reinforcement is 1.375 – 1.242 = 0.133 inches.

4. From the illustration it can be observed that the meridional boundary above and below the opening connection is equal to,

$$d_P - \tfrac{1}{2} d_P = \tfrac{1}{2} d_P = (0.5)(11) = 5.5 \text{ in} \quad ,$$

and thus the excess cross-sectional area in the tank shell available as reinforcement becomes,

$$A_1 = (2)(\tfrac{1}{2} d_P)(0.133) = (11)(0.133) = 1.463 \text{ in}^2 \quad .$$

5. Again, from the illustration, it can be observed that amount of nozzle neck material available for reinforcement can be calculated to be,

$$A_2 = 2\left[(t_n - c)\right]\left[4t_n\right] = 8t_n(t_n - c) = (8)(0.500)(0.500 - 0.125) = 1.5 \text{ in}^2 \quad .$$

6. However, because the pipe has a lower design allowable stress than that of the host shell component, the nozzle material available for reinforcement within this zone must be reduced by a factor of,

$$\frac{18{,}000 \text{ lb/in}^2}{28{,}000 \text{ lb/in}^2} = 0.64 \quad .$$

7. Therefore A_2 becomes,

$$A_2' = 0.64 A_2 = (0.64)(1.5) = 0.960 \text{ in}^2 \quad .$$

8. The total cross-sectional area available for reinforcement will be,

$$A_T = A_1 + A_2' = 1.463 + 0.960 = 2.423 \text{ in}^2 \quad .$$

9. Consequently, the amount of extrinsic reinforcement required is,

$$A - A_T = 5.500 - 2.423 = 3.077 \text{ in}^2 \quad .$$

By Standard design rules the reinforcing element will have the same thickness (1½ inch) as the tank shell to which it will be attached. Based on this thickness a required element diameter can be determined to be,

$$d_o = d_P + \frac{3.077}{t} = 11 + \frac{3.077}{1.500} = 13.238 \text{ in} \quad [\text{make } 13\tfrac{1}{4} \text{ in}] \quad .$$

Conclusion:
The effort expended in calculating the creditable reinforcing material inherent in the unreinforced opening connection allowed the outside diameter of the extrinsic reinforcing element to be reduced from 23 inches to 13¼ inches resulting in a connection weight reduction of approximately 87 percent or 100 pounds.