CHAPTER 11: RECONSTRUCTED TANKS

First of all, let´s see the definition of a reconstructed tank according to API 653

reconstruction

Any work necessary to reassemble a tank that has been dismantled and relocated to a new site. In short, a reconstructed tank is a tank that has been dismantled and its pieces used together to make a new tank. But this should be made carefully.

The effects of brittle fracture are devastating. *In fact, the Ashland Oil Spill attributed to brittle fracture is credited as the triggering event for the creation of the API 653 and other integrity standards*.

WHAT TO STUDY

The body of knowledge says this about reconstructed tanks:

The inspector should be able to determine the minimum thickness of the shell of a reconstructed tank. The inspector should be able to:

a) Determine "S_d", allowable stress for design condition (API-650, table 5-2, API-653, 8.4.2)

b) Determine "S_t", allowable stress for hydrostatic test condition (API-650, Table 5-2, API-653, 8.4.3)

c) Calculate "t_d", design shell thickness (API-650, 5.6.3.2, for tanks of 200feet diameter and smaller)

d) Calculate "t_t", hydrostatic test shell thickness (API-650, 5.6.3.2)

RECONSTRUCTED TANKS SHELL

The following are the numerals dealing with allowable stresses is reconstructed tanks

8.4.2 The maximum design liquid level for product shall be determined by calculating the maximum design liquid level for each shell course based on the specific gravity of the product, the actual thickness measured for each shell course, the allowable stress for the material in each course, and the design method to be used. The allowable stress for the material shall be determined using API 650, Table 5-2. For material not listed in Table 5-2, an allowable stress value of the lesser of 2/3 of the yield strength or 2/5 of the tensile strength shall be used.

8.4.3 The maximum liquid level for hydrostatic test shall be determined by using the actual thickness measured for each shell course, the allowable stress for the material in each course, and the design method to be used. The allowable stress for the material shall be determined using API 650, Table 5-2. For material not listed in Table 5-2, an allowable stress value of the lesser of 3/4 of the yield strength or 3/7 of the tensile strength shall be used.

Knowing these 2 numerals, let´s go on to the determination of allowable stresses.

DETERMINE ALLOWABLE STRESSES

First, we will see how to determine allowable stresses for reconstructed tanks. If you were going to study by yourself, it will be easy to get confused and use for reconstructed tanks the table 4.1 of API 653 in search of allowable stresses, but that is a mistake. You should use table 5-2 of API 650 instead

The following are 2 questions of the kind that would appear in the open book section of the exam.

DETERMINE ALLOWABLE STRESSES USING TABLE 5-2 OF API 650

QUESTION: For plates of A283 Gr C steel used in a reconstructed tank, determine S_d (allowable stress for the design condition).

ANSWER: You simply go to Table 5.2B of API 650 and read from the sixth column that S_d is 20,000psi.

QUESTION: For plates of A516 Gr 60 steel used in a reconstructed tank, determine S_t (allowable stress for the hydrostatic test condition)

ANSWER: Reading the seventh column, we get a value for S_t of 24,000psi.

And now let´s look at some examples of questions that can be made in the exam.

DETERMINE ALLOWABLE STRESSES USING THE FRACTION VALUES OF SECTION 8.4 OF API 653

QUESTION: For a material not listed in Table 5.2, having Y = 36,000psi and T = 62,000psi, which is the allowable stress for the design condition?

ANSWER: *The lesser* of 2/3*36,000 = 24,000psi or 2/5*62,000 = 24,800psi, then choose 24,000psi

QUESTION: For a material not listed in Table 5.2, having Y = 30,000psi and T = 55,000psi, which is the allowable stress for the hydrostatic condition?

ANSWER: *The lesser* of 3/4*30,000 = 22,500psi or 3/7*55,000 = 23,570psi, then choose 22,500psi

CALCULATION OF DESIGN AND HYDROSTATIC SHELL THICKNESS

Calculation of minimum thicknesses for design and hydrostatic conditions in reconstructed tanks follow the same rules for new tanks. Let´s see a summary.

- Joint efficiency E is 1, as in new tanks. That´s why the E variable won´t show up in the formulas. Note that this is for tanks that have been completely cut apart.
- Values for S_d and S_t are the same as in new tanks. This has to do with the fact that a new and a reconstructed tank haven´t been subjected to a hydrostatic test and hasn´t proved itself against operational conditions. Values of S_d and S_t for new and reconstructed are LOWER than for existing tanks, for the same reason.
- Compare **API 653 8.4.2 to API 650 5.6.2.1** and **API 653 8.4.3 to API 650 5.6.2.2.** The values of the fractions for S_d and S_t are the same.

- The values of S_d and S_t for a reconstructed tank are the same for all shell courses, as opposed to API 653, in which this values vary according to shell height for existing tanks. (See table 4.1 of API 653)

The formulas for thickness calculation for reconstructed tanks are found in 5.6.3 of API 650.

FORMULAS FOR THE CALCULATION OF MINIMUM THICKNESS FOR RECONSTRUCTED TANK SHELLS

The minimum thickness of the shell of a reconstructed tank, is given by the following formulas found in

In International System (SI) units

$$t_d = \frac{4.9D(H - 0.3)G}{S_d} + CA$$

$$t_t = \frac{4.9D(H - 0.3)G}{S_t}$$

In United States Customary System (USC) units

$$t_d = \frac{2.6D(H - 1)G}{S_d} + CA$$

$$t_t = \frac{2.6D(H - 1)G}{S_t}$$

t_d is the shell design thickness (*mm* and *inches*)

t_t is the hydrostatic test shell thickness (*mm* and *inches*)

D is the nominal tank diameter (m and ft)

H is the design liquid level (m and ft)

= is the height from the bottom of the course under consideration to the top of the shell including the top angle, if any; to the bottom of any overflow that limits the tank filling height; or to any other level specified by the Purchaser, restricted by an internal floating roof, or controlled to allow for seismic wave action.

G is the design specific gravity of the liquid to be stored, as specified by the Purchaser

CA is the corrosion allowance (mm and $inches$)

S_d is the allowable stress for the design condition (mpa and psi)

S_t is the allowable stress for the hydrostatic test condition (mpa and psi)

EXAMPLE

Let´s consider the following example

A tank built with A283 Gr C is completely de-seamed and the reconstructed. Product stored is Texas Crude Oil at 60°F (G= 0,918), CA is 1/8", and the diameter of the tank is 28,6m. Design liquid level is 9,5m. Plates to be used are 6ft high. Which are the minimum thicknesses for the first shell course for the design and the hydrostatic test condition?

SOLUTION

t_d=?

t_t=?

D = 28.6m

H = 9.5m

G = 0.918

CA = 0.125"

S_d = 137Mpa

S_t = 154Mpa

E = 1 because the tank is completely de-seamed

Using the formula to calculate the minimum thickness for the design condition, we have:

$$t_d = \frac{4.9 * 28.6(9.5 - 0.3)}{137} + 0.125 * 25.4 = 11.814mm$$

And for the hydrostatic test condition:

$$t_t = \frac{4.9 * 28.6(9.5 - 0.3) * 0.918}{154} = 7.685mm$$

EXAMPLE:

A tank built in 1970 is dismantled and later reconstructed using A283 Gr C steel plates for the shell. Product stored is vehicle gasoline at 60°F (G = 0,739), CA is 3mm, and the diameter of the tank is 15,6m. Design liquid level is 12,5m. Plates to be used are 6ft high. Which are the minimum thicknesses for each shell course for the design and the hydrostatic test condition if the tank wasn´t completely de-seamed?

SOLUTION:

t_d=?

t_t=?

D = 15.6m

H = 12.5m

G = 0.739

CA = 0"

S_d = 137Mpa

S_t = 154Mpa

E = 0,85 according to Table 4.2 of API 653, given that the tank wasn´t completely de-seamed. This is a hint at the fact that these formulas hide the E variable, because it is 1 for de-seamed tanks as by default in new tanks.

Using the formula to calculate the minimum thickness for the design condition, we have:

$$t_d = \frac{4.9 * 15.6 * (12.5 - 0.3)}{137 * 0.85} + 0 = 5.92mm$$

And for the hydrostatic test condition:

$$t_t = \frac{4.9 * 15.6 * (12.5 - 0.3) * 0.739}{154 * 0.85} = 5.26mm$$

You can see the E variable in the lower portion of the equation.

EXAMPLE:

Example 3. A tank of unknown material was completely de-seamed and reconstructed with the following measures: D = 58m, E = 27ft. Product is water and corrosion allowance is 0,1". Samples of the tank shell material are taken and yield strength is found to be 32000psi, while tensile strength is found to be 56000psi. Which is the minimum thickness for design and hydrostatic conditions? Use USC unit of systems.

SOLUTION:

t_d=?

t_t=?

D = 58m = 190ft

H = 27ft

G = 1

CA = 0.1"

E = 1

For the calculation of S_d, have in mind what API 653 8.4.2 says

For material not listed in Table 5-2, an allowable stress value of the lesser of 2/3 yield strength or 2/5 tensile strength shall be used.

Then

S_d is the lesser of 2/3*32,000 = 21,333psi or 2/5*56,000 = 22,400psi

For tanks of unknown material, have in mind what API 653 8.4.3 says regarding S_t

For material not listed in Table 5-2, an allowable stress value of the lesser of 3/4 yield strength or 3/7 tensile strength shall be used.

Then

S_t is the lesser of 3/4*32,000 = 24,000psi or 3/7*56,000 = 24,000*psi*

With these data, we can solve for the design condition:

$$t_d = \frac{2.6 * 190 * (27 - 1)}{22,333} + 0.1 = 0.675in$$

And for the hydrostatic test condition:

$$t_t = \frac{2.6 * 190 * (27 - 1) * 1}{24{,}000} = 0.525in$$

POINTS TO REMEMBER

Most API 653 exams contain questions that require you to pick out *S* values from Table 4.1 of API 653 or table 5.2 of API 650. Make sure to use table 5.2 of API 650 for new and reconstructed tanks.

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