CHAPTER 4: JOINT EFFICIENCIES

Activities: Read Chapter 4: JOINT EFFICIENCIES. After that, watch the Video "JOINT EFFICIENCIES" and analyze the questions at the end of the chapter.

What is joint efficiency?

Joint efficiency is a concept found in several API and ASME codes. It is a numerical value, which represents a percentage, expressed as the ratio of the strength of a riveted, welded, or brazed joint to the strength of the base material. It is also a way to introduce safety factors in welding of shells for containment, and can be expressed as follows:

$$\text{Eq. 22. } Joint\ efficiency = \frac{Strength\ of\ weld}{Strength\ of\ base\ material}$$

In other standards, values for Joint Efficiency in welds are assumed according to 2 traits

1. Type of welded joint
2. Extent of NDE required for the welded joint

In the API 650 basic standard, joint efficiency for shell welds is currently 1 for complete penetration butt welds. In the API 653 standard, joint efficiency for welded joint varies with the as-built standard, while joint efficiency for rivet joints varies with geometry.

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Please take a look at the following table based on API 653

Standard	Edition and year	Type of joint	Joint Efficiency e	Applicability or limits
API 650	**Seventh and later**	Butt	1.00	Basic Standard
	(1980 to present)	Butt	0.85	Appendix A Optional Design Basis for Small Tanks spot RT
		Butt	0.70	Appendix A Optional Design Basis for Small Tanks no RT
	First to sixth	Butt	0.85	Basic Standard
	(1961 to 1978)	Butt	1.00	Appendices D and G
API 12C	14th and 15th	Butt	0.85	
	(1957 to 1958)			
	Ord to 13th	Lap*	0.75	3/8in max, t
	(1940 to 1956)	Butt*	0.85	
	First and second	Lap*	0.70	7/16in, max.t
Unknown		Lap*	0.70	7/16in max.t
		Lap*	0.50-k/5	1/4in max.t
		Butt	0.70	
		Lap*	0.35	

TABLE 6. TABLE 4.2 OF API 653 - JOINT EFFICIENCIES FOR WELDED JOINTS

Joint efficiency varies with weld type. Various weld types and joint efficiencies for them can be found in Table UW-12 "*Maximum allowable joint efficiencies for arc and gas welded joints*" of ASME VIII, Div 1, Sec B. for pressure vessels. A butt welded joint will have a greater value of *E* than a fillet welded joint.

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Type of Joint	Number of Rivet Joints	Joint Efficiency E
Lap	1	0.45
Lap	2	0.60
Lap	3	0.70
Lap	4	0.75
Butt*	2**	0.75
Butt	3**	0.85
Butt	4**	0.90
Butt	5**	0.91
Butt	6**	0.92
All butt joints listed have butt straps both inside and outside		
Number of rows on each side of joint center line		

TABLE 7. TABLE 4.3—JOINT EFFICIENCIES FOR RIVETED JOINTS

Of course, regarding welded aboveground storage tanks, we will speak only about butt welded joints. According to API 650 5.1.5, vertical and horizontal shell joints shall be butt joints with complete penetration and complete fusion.

Since the seventh edition of API 650, all tanks are constructed with a default 1 joint efficiency, meaning that shells are the thinner they can be (See table 4.2). This only was reached, obviously, with improvements in base material (which improves the yield strength value), weld consumables and welding processes. Besides, only complete penetration butt welds are permitted in new tanks, simplifying the issue.

What has to do joint efficiency with tank inspections?

1. When determining the minimum acceptable thickness for an entire shell course, for any other portions of a shell course, according to the following equations

Eq. 12. $t_{min} = \frac{2.6(H-1)DG}{SE}$

$$\text{Eq. 13.} \quad t_{min} = \frac{2.6HDG}{SE}$$

2. When determining the maximum level of water to be used during hydrostatic test of a tank (for example, if you need to change tank service to a higher specific gravity liquid), according to the following equations

$$\text{Eq. 23.} \quad H_t = \frac{S_t E t_{min}}{2{,}6D} + 1$$

$$\text{Eq. 24.} \quad H_t = \frac{S_t E t_{min}}{2{,}6D}$$

t_{min} is the minimum acceptable thickness, in inches for each course as calculated from the above equation;

however, t_{min}shall not be less than 0.1 in. for any tank course;

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

H is the height from the bottom of the shell course under consideration to the maximum liquid level when evaluating an entire shell course, in feet (ft.); or

is the height from the bottom of the length L (see 4.3.2.1) from the lowest point of the bottom of L of the locally thinned area to the maximum liquid level, in feet (ft.); or

is the height from the lowest point within any location of interest to the maximum liquid level, in feet (ft.);

G is the highest specific gravity of the contents;

S is the maximum allowable stress in pound force per square inch (lbf/in.2); use the smaller of 0.80 Y or 0.429 T

for bottom and second course; use the smaller of 0.88 Y or 0.472 T for all other courses. Allowable shell

stresses are shown Table 4.1 of API 653 (**See table 8 of this document**) for materials listed in the current and previous editions of API 12C and API

650; When compared to table 5.2 of API 650, the values for allowable stress in API 653, for the same material, are generally higher.

NOTE for reconstructed tanks, S shall be in accordance with the current applicable standard;

Y is the specified minimum yield strength of the plate; use 30,000 lbf/in.2 if not known;

T is the smaller of the specified minimum tensile strength of the plate or 80,000 lbf/in.2; use 55,000 lbf/in.2 if not known;

E is the original joint efficiency for the tank. Use Table 4.2 if original E is unknown. E = 1.0 when evaluating the retirement thickness in a corroded plate, when away from welds or joints by at least the greater of 1 in. or twice the plate thickness.

H_t is the height from the bottom of the shell course under consideration to the hydrostatic test height when evaluating an entire shell course in feet; or is the height from the bottom of the length, L, (see 4.3.2.1) for the most severely thinned area in each shell course to the hydrostatic test height in feet; or

is the height from the lowest point within any other location of interest to the hydrostatic test height in feet;

S_t is the maximum allowable hydrostatic test stress in pound force per square inch (lbf/in.2); use the smaller of 0.88 Y or 0.472 T for bottom and second courses; use the smaller of 0.9 Y or 0.519 T for all other courses.

When you know the standard by which a tank was built, and solve any of the equations above, you can see if it is fit for continued service. Have in mind that joint efficiency evaluation makes sense only when the corrosion is in close proximity to the joints. The value of E is 1 for any spot 1inch or more apart from the weld in welded joints or 6inches to the outermost rivet away from the centerline in a riveted joint.

In the exam, one or two questions about joint efficiency will show up. That´s why you need this subject fully understood.

			Allowable Product Stress *S* (lbf/in2)		Allowable Hydrostatic test stress S_T (lbf/in2)	
Material	Minimum Specified Yield Strength *S* (lbf/in2)	Minimum Specified Tensile Strength *T* (lbf/in2)	Lower two courses	Upper Courses	Lower two courses	Upper Courses
A-283 GrC	30000	55000	23600	26000	26000	27000
A-36	36000	58000	24900	27400	27400	31000
A-283 GrC	30000	55000	23600	26000	26000	27000

TABLE 8. EXCERPT FROM TABLE 4.1 OF API 653 - MAXIMUM ALLOWABLE SHELL STRESSES (NOT FOR USE WITH RECONSTRUCTED TANKS)

EXAMPLE

Q: A riveted tank built in 1984 is being inspected. Calculate the joint efficiency for a butt joint with a total of 4 rows of rivets. What is the joint efficiency?

A:

EXERCISE:

A tank has 4 courses. Year of construction is unknown, yet it has no more than 30 years old, but has been unused. Shell height is 21.87 and diameter is 12.22ft (Maximum liquid level is unknown). Please inform if the tank can be put in service right away for oil, if the measured thicknesses of the courses are as follows: 1st course = 0.181in, 2 course = 0.181in, 3rd course = 0.168in, 4th course = 0.167in.

SOLUTION:

D = 12.22 ft.

H = 21.87 ft.

G = 1.0. (because we consider hydrostatic test height, before we put the tank in service.)

S = Given that the steel is of unknown quality, S is 23,600psi for the 2 lower courses, and 26,000 psi for the upper courses. API 653 Table 4-1.

E = 0.70 (The minimum of table 4-2, because year of construction is unknown)

$$t_{min} = \frac{2.6(H-1)DG}{SE}$$

We arrange the data in a table and we find that the tank is fit for service in all its courses.

COURSE	Heigth (ft)	Liquid level (ft)	Allowable stress (psi)	Diameter (ft)	Specific gravity	Joint efficiency	Average thickness (in)	Minimum thickness (in)
1	5.99	21.87	23,600	12.22	1.00	0.70	0.181	0.040
2	5.77	15.88	23,600	12.22	1.00	0.70	0.181	0.029
3	4.94	10.11	26,000	12.22	1.00	0.70	0.168	0.016
4	5.17	5.17	26,000	12.22	1.00	0.70	0.167	0.007

POINTS TO REMEMBER

Joint efficiency is.....

....Taken from table 4-2 if the point is less than 1inch or 2 times the thickness away from the weld in welded seams.

....Taken from table 4-3 if the point is less than 6inches away from the centerline of the riveted joint.

.... 1 for de-seamed reconstructed tanks. It is the lowest allowed in table 4-2 if the seams are left in place.

In normal conditions, when you open a tank, you will ALWAYS want to improve the internal conditions, given the high expenses associated with opening a tank. So, as an Inspector you just don´t say things like “you can put it in service”. You would say something more like “Please repair this and then put the tank back to service”

QUESTIONS FOR CHAPTER 4: JOINT EFFICIENCIES

1. What is the current default Joint efficiency for a new tank built to API 650?
2. What is the Joint efficiency for a tank already in service and built to API 12C?
3. When you don´t know when a tank was built, what you should have in mind to be more conservative in the calculation of the minimum allowable thickness?
4. If we have a defect far away from a weld seam, should we insert Joint Efficiency E in the calculations or not?
5. Where do we find values for Maximum Allowable Shell Stresses of tanks in service?
6. Where do we find values for Maximum Allowable Shell Stresses of new tanks?
7. Are values from Table 4.1 of API 653 for reconstructed tanks?
8. If someone deseams old joints from an existing tank and uses those shell sections in a new tank, what is the Joint efficiency of those joints?