Consulta
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Assunto: Tanques API-650

Sou projetista de tubulações e seu blog tem sido muito útil para mim, mas tenho uma dúvida e gostaria de pedir sua ajuda.
De acordo com a norma API-650 5.6.3.2 td=(4.9*D*(H-0,3)*G)/Sd+CA, quando devo usar na fórmula para obtenção da espessura das chapas do costado a eficiência de solda (E) - (0,7 - 0,85 - 1,0)

Resposta

- **Introdução**

A primeira edição do API 650 *Welded Tanks for Oil Storage* foi publicada em 1961, mas seu predecessor, API 12C *Specification for Welded Oil Storage Tanks*, estava em uso desde 1936, quando a soldagem começou a substituir a rebitagem, que era o método de construção de tanques da época.

O API 650 *Welded Tanks for Oil Storage* atual está na 12ª Edição *e* aborda o projeto e construção de tanques novos; para o acompanhamento operacional de tanques existentes há o API 653 *Tank Inspection, Repair, Alteration, and Reconstruction,* hoje na 5ª Edição.

- **Cálculo do costado até a 6ª Edição do API 650**

No passado, para o projeto do tanque, conforme o API 650, a eficiência da junta soldada do costado era considerada no cálculo da espessura.

Até o API 650 6ªEdição, inclusive, havia a consideração de eficiência E da junta soldada na equação de cálculo da espessura das chapas do costado, conforme apresentado a seguir.

$$t = \frac{2.6D\ (H-1)G}{SE} + C$$

Em Unidades Inglesas (US Customary units)

Onde:
t = espessura mínima calculada;
H = altura desde um pé acima da borda inferior de cada chapa até a cantoneira de topo do costado;
G = densidade do líquido;
D = diâmetro do tanque;
E = fator de eficiência da junta longitudinal tanque básico E = 0,85;
S = tensão de projeto;
C = tolerância à corrosão.

- **Cálculo do costado conforme API 650 atual**

Porém, desde a 7º edição, os tanques são projetados e construídos com um padrão único de eficiência das soldas do costado de 100%, isto é, não se considera o parâmetro E de eficiência da junta de solda, seja pelo método do One Foot ou o de Ponto Variável.

A equação para cálculo de espessura do costado de tanque projetado pelo API 650 método One Foot é como a seguir e não há a variável E de eficiência de solda.

5.6.3 Calculation of Thickness by the 1-Foot Method

5.6.3.1 The 1-foot method calculates the thicknesses required at design points 0.3 m (1 ft) above the bottom of each shell course. Appendix A permits only this design method. This method shall not be used for tanks larger than 61 m (200 ft) in diameter.

5.6.3.2 The required minimum thickness of shell plates shall be the greater of the values computed by the following formulas:

In SI units:

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

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

where

t_d = design shell thickness, in mm,

t_t = hydrostatic test shell thickness, in mm,

D = nominal tank diameter, in m (see 5.6.1.1, Note 1),

H = design liquid level, in m,

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

CA = corrosion allowance, in mm, as specified by the Purchaser (see 5.3.2),

S_d = allowable stress for the design condition, in MPa (see 5.6.2.1),

S_t = allowable stress for the hydrostatic test condition, in MPa (see 5.6.2.2).

Nota: O método de One Foot é aplicável a tanques com diâmetro igual ou menor que 61 metros (200 ft).

- **Cálculo do costado conforme API 650 Anexo A**

A exceção é o projeto conforme o API-650 Anexo A, em que a equação utilizada para calcular a espessura de costado, para um novo tanque, contém o parâmetro E de eficiência da junta de solda.
O parágrafo 5.6.2.3 do API 650 admite este projeto alternativo, que deve ser especificado pelo Comprador, o API-650 Annex A-Optional Design Basis for Small Tanks, com uma tensão admissível fixa de 145 MPa (21.000 Ibf/in²) e um fator de eficiência de solda E de 0,85 ou 0,70, mas esse projeto só pode ser usado para tanques com espessura do costado menor ou igual a 13 mm (1l2 pol.).

No API 650 Anexo A, conforme o parágrafo A.3.4, o factor de eficiência de solda é E= 0,85 para inspeção com o exame radiográfico requerido no parágrafo A.5.3. Por acordo entre o Comprador e o Fabricante, a radiografia local pode ser omitida e, neste caso, deve ser utilizado um coeficiente de eficiência de solda E= 0,70.

A equação para cálculo de espessura do costado de tanque projetado pelo API 650 Anexo A é conforme a seguir.

A.4.1 The nominal thicknesses of shell plates shall not be less than that computed from the stress on the vertical joints, using the following formula:

In SI units:

$$t = \frac{4.9D(H-0.3)G}{(E)(145)} + CA$$

where

t = nominal thickness, in mm (see 5.6.1.1),

D = nominal diameter of the tank, in m (see 5.6.1.1, Note 1),

H = design liquid level, in m (see 5.6.3.2),

G = specific gravity of the liquid to be stored, as specified by the Purchaser. The specific gravity shall not be less than 1.0,

E = joint efficiency, which is either 0.85 or 0.70 (see A.3.4),

CA = corrosion allowance, in mm, as specified by the Purchaser (see 5.3.2).

- **Obrigatoriedade da inspeção com o exame radiográfico da Seção 8 do API 650**

De acordo com o API 650 parágrafo 5.1.5, as juntas do costado, verticais e horizontais, devem ser juntas de topo com penetração e fusão completas.
Para estas soldas, o API 650 requer o exame radiográfico de acordo com a Seção 8 Methods of Inspecting Joints, que é consistente com uma eficiência de solda de 1,0.
Se não se cumprir com a Seção 8, é impossível usar E=1.0 no dimensionamento do costado de um tanque API 650.
A extensão da inspeção radiográfica das juntas verticais soldadas de topo é baseada em uma escala de espessuras das chapas do costado.

- Para juntas em que a chapa do costado mais fina é menor ou igual a 10 mm (3/8 pol.) de espessura: radiografia parcial;
- Para juntas em que a chapa do costado mais fina é maior que 10 mm (3/8 pol.), mas menor ou igual a 25 mm (1 pol.) de espessura: radiografia parcial e mais alguns requisitos;
- Para juntas em que as chapas do costado têm uma espessura superior a 25 mm (1 pol.): radiografia total.

Para as juntas horizontais soldadas se requer radiografia parcial complementada por uma série de requisitos adicionais.

- **Conclusão**

Ao se utilizar a equação do parágrafo API-650 5.6.3.2 do API 650, para cálculo das espessuras das chapas do costado, não se deve considerar o parâmetro E de eficiência de solda, como explicitado na própria fórmula, que não apresenta a variável E.
A contrapartida é a obrigatoriedade de inspecionar as soldas conforme os requisitos do exame radiográfico, apresentados na Seção 8 Methods of Inspecting Joints, do mesmo API 650.

Complementando
Para tanques fabricados e construídos dentro de uma fábrica, o API 650 apresenta o Anexo J:
ANNEX J-SHOP-ASSEMBLED STORAGE TANKS
Para tanques de Alumínio ou Aço Inoxidável, também há os anexos, respectivamente:
ANNEX AL-ALUMINUM STORAGE TANKS
ANNEX S-AUSTENITIC STAINLESS STEEL STORAGE TANKS.

Anexo J- Tanques de armazenamento fabricados e montados na fábrica e entregues inteiros.

Apresenta os requisitos para o projeto e fabricação de tanques verticais de armazenamento em tamanhos que permitam montagem completa na fábrica e entrega ao local de instalação em uma só peça.
Aplica-se para os tanques de diâmetro menor ou igual a 6 m (20 ft) e autorizado pelo . Comprador. .

API 650 1.1.17 Annex J provides requirements covering the complete shop assembly of tanks that do not exceed 6 m (20 ft) in diameter.
ANNEx J-SHOP-ASSEMBLED STORAGE TANKS
J.1 Scope
J .1.1 This appendix provides requirements for the design and fabrication of vertical storage tanks in sizes that permit complete shop assembly and delivery to the installation site in one piece. Storage tanks designed according to this appendix shall not exceed 6 m (20 ft) in diameter.
• J.1.2 The application of this appendix to the design and fabrication of shop-assembled storage tanks shall be mutually agreed upon by the Purchaser and the Manufacturer.

J.3.3 SHELLS
Shell plates shall be designed in accordance with the formula given in A.4.1, but the nominal thickness of shell plates shall not be less than the following:
a. For tanks with a diameter less than or equal to 3.2 m (10.5 ft) - 4.8 mm (3/16 in.). I
b. For tanks with a diameter greater than 3.2 m (10.5 ft) - 6 mm (0.236 in.).

A.4.1 The nominal thicknesses of shell plates shall not be less than that computed from the stress on the vertical joints, using the following formula:

In SI units:

$$t = \frac{4.9D(H-0.3)G}{(E)(145)} + CA$$

where

t = nominal thickness, in mm (see 5.6.1.1),

D = nominal diameter of the tank, in m (see 5.6.1.1, Note 1),

H = design liquid level, in m (see 5.6.3.2),

G = specific gravity of the liquid to be stored, as specified by the Purchaser. The specific gravity shall not be less than 1.0,

E = joint efficiency, which is either 0.85 or 0.70 (see A.3.4),

CA = corrosion allowance, in mm, as specified by the Purchaser (see 5.3.2).

J.5 Inspection of Shell Joints
J .5.1 The methods of inspecting shell joints described in Section 8 apply to shop-assembled tanks, but spot radiography may be omitted when a joint efficiency of 0.70 is used (see A.3.4).
J .5.2 When radiographic examination is required (joint efficiency = 0.85), the spot radiographs of vertical joints shall conform to 8.1.2.2, Item a only, excluding the 10 mm *(3/8* in.) shell thickness limitation in Item a and excluding the additional random spot radiograph required by Item a. The spot radiographs of horizontal joints shall conform to 8.1.2.3.

APPENDIX AL-ALUMINUM STORAGE TANKS
AL.1 Scope
AL.1.1 CONSTRUCTION
This appendix provides material, design, fabrication, erection, and testing requirements for vertical, cylindrical, aboveground, closed- and open top, welded aluminum storage tanks constructed of the alloys specified in AL.4.

APPENDIX S-AUSTENITIC STAINLESS STEEL STORAGE TANKS

S.1 Scope

S.1.1 This appendix covers materials, design, fabrication, erection, and testing requirements for vertical, cylindrical, aboveground, closed- and open-top, welded, austenitic stainless steel storage tanks constructed of material grades 201-1, 201LN, 304, 304L, 316, 316L, 317, and 317L. This appendix does not cover stainless steel clad plate or strip-lined construction.

Anexo

API 650 SECTION 8-METHODS OF INSPECTING JOINTS

8.1.1 Application

Radiographic inspection is required for shell butt-welds (see 8.1.2.2, 8.1.2.3, and 8.1.2.4), annular-plate butt-welds (see 8.1.2.9), and flush-type connections with butt -welds (see 5.7.8.11).

Radiographic inspection is not required for the following: roof-plate welds, bottom-plate welds, welds joining the top angle to either the roof or shell, welds joining the shell plate to the bottom plate, welds in nozzle and manway necks made from plate, or appurtenance welds to the tank.

8.1.2 Number and Location of Radiographs

8.1.2.1 Except when omitted under the provisions of A.3.4, radiographs shall be taken as specified in 8.1.2 through 8.1.9.

8.1.2.2 The following requirements apply to vertical joints:

a. For butt-welded joints in which the thinner shell plate is less than or equal to 10 mm (3/8 in.) thick, one spot radiograph shall be taken in the first 3 m (10 ft) of completed vertical joint of each type and thickness welded by each welder or welding operator.

The spot radiographs taken in the vertical joints of the lowest course may be used to meet the requirements of Note 3 in Figure 8-1 for individual joints.

Thereafter, without regard to the number of welders or welding operators, one additional spot radiograph shall be taken in each additional 30 m (100 ft) (approximately) and any remaining major fraction of vertical joint of the same type and thickness.

At least 25% of the selected spots shall be at junctions of vertical and horizontal joints, with a minimum of two such intersections per tank.

In addition to the foregoing requirements, one random spot radiograph shall be taken in each vertical joint in the lowest course (see the top panel of Figure 8-1).

b. For butt-welded joints in which the thinner shell plate is greater than 10 mm (3/s in.) but less than or equal to 25 mm (1 in.) in thickness, spot radiographs shall be taken according to Item a. In addition, all junctions of vertical and horizontal joints in plates in this thickness range shall be radiographed; each film shall clearly show not less than 75 mm (3 in.) of vertical weld and 50 mm (2 in.) of weld length on each side of the vertical intersection.

In the lowest course, two spot radiographs shall be taken in each vertical joint: one of the radiographs shall be as close to the bottom as is practicable, and the other shall be taken at random (see the center panel of Figure 8-1).

c. Vertical joints in which the shell plates are greater than 25 mm (1 in.) thick shall be fully radiographed.

All junctions of vertical and horizontal joints in this thickness range shall be radiographed; each film shall clearly show not less than 75 mm (3 in.) of vertical weld and 50 mm (2 in.) of weld length on each side of the vertical intersection (see the bottom panel of Figure 8-1).

d. The butt-weld around the periphery of an insert plate that extends less than the adjacent shell course height and that contains shell openings (i.e. nozzle, manway, flush-type cleanout, flush type shell-connection) and their reinforcing elements shall be completely radiographed.

e. The butt-weld around the periphery of an insert plate which extends to match the adjacent shell course height shall have the vertical and the horizontal butt joints and the intersections of vertical and horizontal weld joints radiographed using the same rules that apply to the weld joints in adjacent shell plates in the same shell course.

8.1.2.3 One spot radiograph shall be taken in the first 3 m (10 ft) of completed horizontal butt joint of the same type and thickness (based on the thickness of the thinner plate at the joint) without regard to the number of welders or welding operators.
Thereafter, one radiograph shall be taken in each additional 60 m (200 ft) (approximately) and any remaining major fraction of horizontal joint of the same type and thickness. These radiographs are in addition to the radiographs of junctions of vertical joints required by Item c of 8.1.2.2 (see Figure 8-1).

8.1.2.4 The number of spot radiographs required herein shall be applicable on a per tank basis, irrespective of the number of tanks being erected concurrently or continuously at any location.

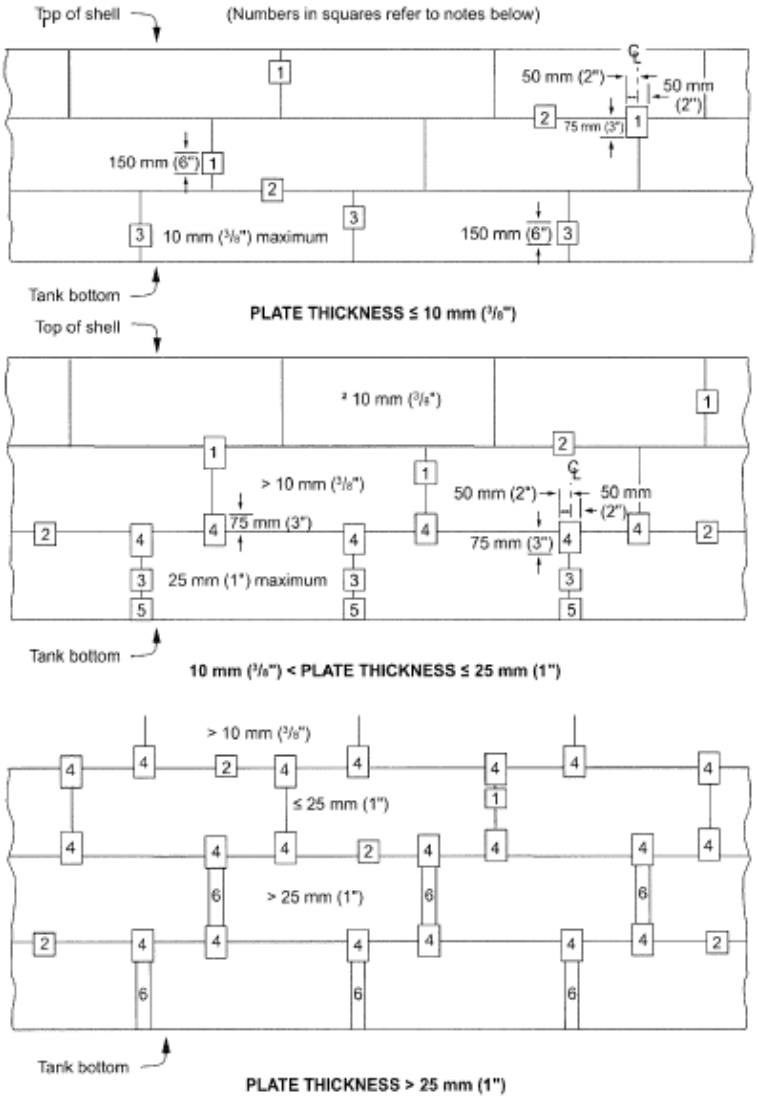
8.1.2.5 It is recognized that in many cases the same welder or welding operator does not weld both sides of a butt joint.
If two welders or welding operators weld opposite sides of a butt joint it is permissible to inspect their work with one spot radiograph.
If the radiograph is rejected, additional spot radiographs shall be taken to determine whether one or both of the welders or welding operators are at fault.

8.1.2.6 An equal number of spot radiographs shall be taken from the work of each welder or welding operator in proportion to the length of joints welded.

8.1.2.7 As welding progresses, radiographs shall be taken as soon as it is practicable. The locations where spot radiographs are to be taken may be determined by the Purchaser's inspector.

8.1.2.8 Each radiograph shall clearly show a minimum of 150 mm (6 in.) of weld length. The film shall be centered on the weld and shall be of sufficient width to permit adequate space for the location of identification marks and an image quality indicator (IQI) penetrameter.

8.1.2.9 When bottom annular plates are required by 5.5.1, or by M.4.1, the radial joints shall be radiographed as follows:
(a) For double-welded butt joints, one spot radiograph shall be taken on 10% of the radial joints; (b) For Single-welded butt joints with permanent or removable back-up bar, one spot radiograph shall be taken on 50% of the radial joints. Extra care must be exercised in the interpretation of radiographs of single-welded joints that have a permanent back-up bar. In some cases, additional exposures taken at an angle may determine whether questionable indications are acceptable. The minimum radiographic length of each radial joint shall be 150 mm (6 in.). Locations of radiographs shall preferably be at the outer edge of the joint where the shell plate and annular plate join.



Notes:
1. Vertical spot radiograph in accordance with 8.1.2.2, Item a: one in the first 3 m (10ft) and one in each 30 m (100 ft)thereafter, 25% of which shall be at intersections.
2. Horizontal spot radiograph in accordance with 8.1.2.3: one in the first 3 m (10ft) and one in each 60 m (200 ft) thereafter.
3. Vertical spot radiograph in each vertical seam in the lowest course (see 8.1.2.2, Item b). Spot radiographs that satisfy the requirements of Note 1 for the lowest course may be used to satisfy this requirement.
4. Spot radiographs of all intersections over 10 mm (3/8 in.) (see 8.1.2.2, Item b).
5. Spot radiograph of bottom of each vertical seam in lowest shell course over 10 mm (3/8 in.) (see 8.1.2.2, Item b).
6. Complete radiograph of each vertical seam over 25 mm (1 in.). The complete radiograph may include the spot radiographs of the intersections if the film has a minimum width of 100 mm (4 in.) (see 8.1.2.2, Item c).

Figure 8-1-Radiographic Requirements for Tank Shells