CHAPTER 2: CALCULATING SUBSEQUENT INTERNAL INSPECTION INTERVALS OF A TANK BOTTOM

Activities: Read Chapter 2: CALCULATING SUBSEQUENT INTERNAL INSPECTION INTERVALS OF A TANK BOTTOM. Watch the Video "Subsequent Inspection Intervals" and analyze the questions at the end of the chapter. Have Office Excel ready for the calculations.

Internal inspection of the tank is necessary usually when you don´t have access to the underside of the bottom of a tank, so it is very important that you can know in advance the next due inspection date.

Subsequent inspection intervals of a tank (it is, the ones after the initial inspection) can be determined using the measured tank bottom corrosion rate and the minimum remaining thickness in accordance with 4.4.5. Some companies have invented equipment that they claim, can inspect the bottom of a tank without opening it, but the most effective and common method is the use of a combination of the MFL and UT techniques.

The formula in 4.4.5.1 goes this way:

$$\text{Eq. 8.} \quad MRT = \left(Minimum\ of\ RT_{bc}\ or\ RT_{ip}\right) - O_R(S_tP_R + UP_R)$$

THIS EQUATION APPLIES TO BOTTOM PLATES, SKETCH PLATES IN THE CRITICAL ZONE, AND ANNULAR PLATES

But you are looking for an answer in years, so you will have to reorder the equation the following way

$$\text{Eq. 9.} \quad O_R = \frac{\left(Minimum\ of\ RT_{bc}\ or\ RT_{ip}\right) - MRT}{(S_tP_R + UP_R)}$$

This is the explanation for all those variables.

VARIABLE	DEFINITION
O_R	Is the in-service interval of operation in years
MRT	Is the minimum remaining thickness at the end of interval O_R
UP_R	Is the maximum rate of corrosion on the soil side
S_tP_R	Is the maximum rate of corrosion not repaired on the top side
RT_{bc}	Is the minimum remaining thickness from bottom side
RT_{ip}	Is the minimum remaining thickness from internal

TABLE 3. VARIABLES FOR THE FORMULA TO CALCULATE MINIMUM REMAINING THICKNESS OF BOTTOM

When the formula puts a value on any of these variables, is not an average between the measurements taken in a tank bottom, but the most critical spot value measured. Product side corrosion rate is zero while the lining is still in perfect condition ($S_tP_R = 0$) and soil side corrosion rate is 0 when the cathodic protection system is working properly ($UP_R = 0$).

If the remaining life of the bottom of the tank is less than the chosen interval (a common value in the industry is 10 years), then action should be taken. Welded-on patch plates are used repairing portions of the bottom, critical zone or annular plates. See figure 4

MINIMUM ALLOWABLE THICKNESS OF BOTTOM PLATES

The minimum thickness of bottom plates at the end of the in-service period of operation shall be 0,1in or 0,05in. Check the following table and figure 5 for better understanding.

Minimum Bottom Plate Thickness at next inspection	Tank Bottom/Foundation design
$0.10in$	Tank bottom/foundation design with no means for detection and containment of a bottom leak

0.05*in*	Tank bottom/foundation design with means to provide detection and containment of a bottom leak.
0.05*in*	Applied tank bottom reinforced lining, > 0.05in. thick, in accordance with API 652

TABLE 4. (TABLE 4.4 OF API 653)—BOTTOM PLATE MINIMUM THICKNESS

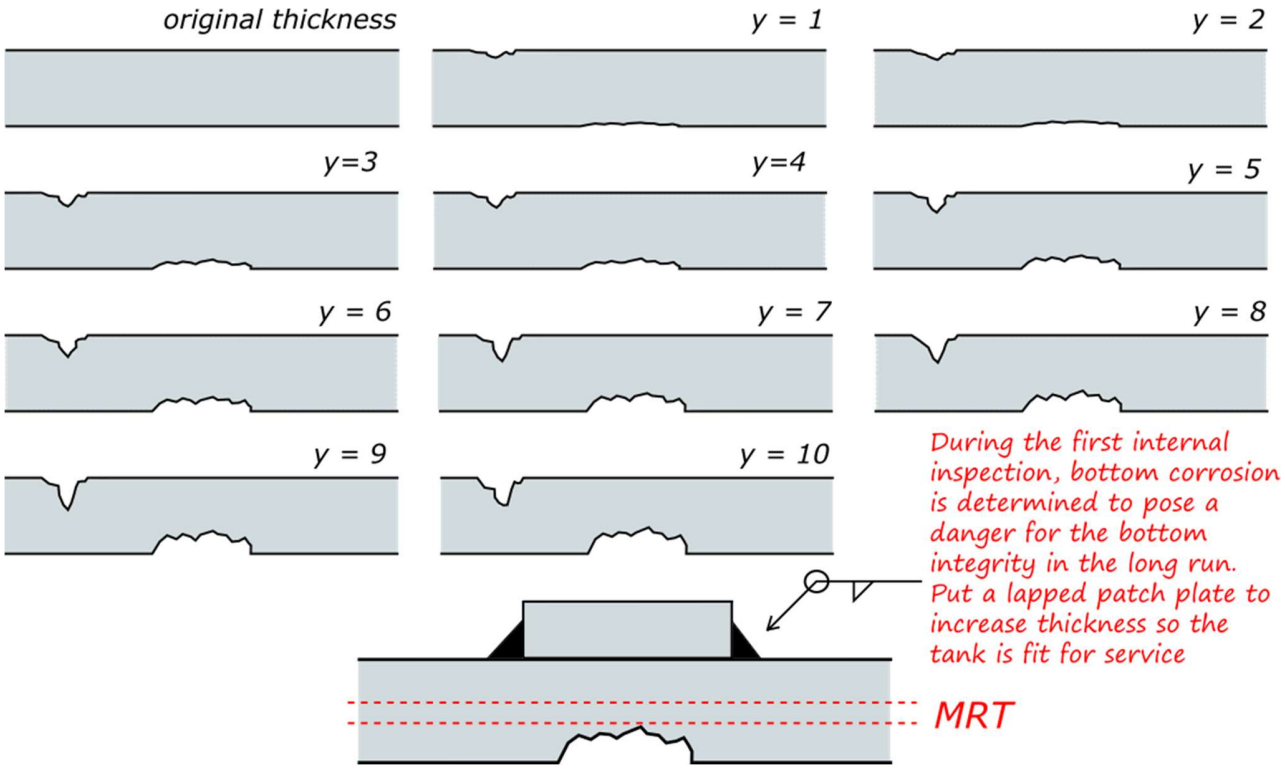

FIGURE 4 BOTTOM CORROSION AND TREATMENT ASSESSMENT

EXAMPLE

We have a tank that contains water; its original bottom thickness is 1/4", and the bottom was already repaired in some points by adding lapped patch plates. There is one point in the bottom, though, that is 5mm thick. Corrosion rate for the top side of the bottom is 0.5mm per year, and the corrosion rate for the underside of the bottom is 0. There are no corroded areas in the soil side. The owner/operator asks if the tank can resist 10 more years in service, since it has no means for detection and containment of a bottom leak.

SOLUTION:

$MRT = 2.54mm$

$UP_R = 0$

$RT_{bc} = 6.35 - 0 = 6.35mm$

$RT_{ip} = 6.35 - 5 = 1.35mm$

Minimum between RT_{bc} and $RT_{ip} = 5mm$

$S_tP_R = 0.5mm/year$

$$O_R = \frac{(5mm) - 2.5mm}{(0.5mm/year - 0)} = 5\ years$$

The tank is NOT safe to operate until next internal inspection. Repair the corroded areas to increase inspection interval.

EXAMPLE

An AST is being inspected. The original bottom thickness was 10 mm. Maximum depth of corrosion pits from inside of tank on the tank bottom = 4 mm. Maximum corrosion from bottom side = 5 mm. Rate of corrosion on topside of bottom = 50 microns / year. Rate of corrosion on bottom side = 150 microns / year. The tank does have a leak detection system on the bottom. Calculate when the next inspection interval should be due.

SOLUTION:

$RT_{bc} = 10 - 5 = 5mm$

$RT_{ip} = 10 - 4 = 6mm$

$MRT = 0.05" = 1.25mm$

MRT = Minimum between RT_{bc} and RT_{ip} -$O_R(S_tP_R + UP_R)$

$1.25mm = 5mm - O_R\ (0.05mm/y + 0.15mm/y)$

$O_R * 0.2mm/y = 3.75mm$

$O_R = 3.0 / 0.25 = 18.75years$

The next inspection interval is 18.75 years or earlier.

MINIMUM ALLOWABLE THICKNESS OF THE CRITICAL ZONE OF SKETCH PLATES

The minimum bottom plate thickness in the critical zone of the tank bottom shall be the smaller of:

- 1/2 the original bottom plate thickness (not including the original corrosion allowance) or
- 50 % of t_{min} of the lower shell course calculated per 4.3.3.1 but not less than 0.1 in.

Check figure 5 for better understanding.

EXAMPLE

Calculate the minimum thickness of the bottom and the critical zone of a tank bottom at the end of the in-service operation period. Use the following data:

$D = 35ft$

$H = 30ft$

Original bottom thickness = $0.354in$

Tank has no lining or means for detection and containment of a bottom leak

Material: ASTM A36

Specific gravity of the product = 1 (water)

E = 1

SOLUTION

Minimum thickness of the bottom for containment reasons: 0.1*inches*

Minimum thickness of the critical zone for strength reasons:

the smaller of:

- ½*0.354" = 0.177*inches*
- 50 % of t_{min} of the lower shell course per 4.3.3.1 but not less than 0.1*in*.

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

$$t_{min} = \frac{2.6(30-1)35*1}{24{,}900*1} = .105inches$$

Then, the minimum allowable thickness in the critical zone would be 50% of 0.105*inches* = 0.0525*inches*. However, it cannot be less than 0,1in.

Then the minimum allowable thickness = 0,1in.

MINIMUM ALLOWABLE THICKNESS OF ANNULAR PLATES

Annular plates also have a critical zone. However, the method to find the minimum thickness of an annular plate is different. For tanks in service with a product specific gravity less than 1.0, considerations, the thickness of the annular plates shall be not less than the thicknesses given in Table 4.5, plus any specified corrosion allowance.

Check figure 6 for better understanding.

Plate thickness* of First Shell Course (in)	Stress in First shell course (lbf/in2)			
	24,300	27,000	29,700	32,400
t<=0.75	0.17	0.20	0.23	0.30
.75<t<=1.00	0.17	0.22	0.31	0.38
1.00<t<=1.25	0.17	0.26	0.38	0.48
1.25<t<=1.50	0.22	0.34	0.47	0.59
t>1.50	0.27	0.40	0.53	0.68
* As constructed				

TABLE 5. (TABLE 4.5 OF API 653)—ANNULAR PLATE MINIMUM THICKNESS FOR TANKS WITH PRODUCT WITH SG<1

Stresses are calculated from $[2.34D(H-1)]/t$

Where t = nominal thickness of first shell course ("as constructed").

For tanks in service with a product specific gravity 1.0 or greater, go to API 650, Table 5.1*

EXAMPLE:

Calculate the minimum allowable thickness of the bottom and the annular plate of a tank bottom at the end of the in-service operation period. Use the following data:

$H = 52ft$

$D = 131ft$

Specific gravity of product: 0.9

Nominal thickness of first shell course = $0.61in$

SOLUTION:

- Minimum thickness of bottom plates: $0.05inches$

- Minimum thickness on annular plates

$$S = 2.34D(H-1)/t$$

$$S = 2.34 * \frac{131(52-1)}{0.61} = 25{,}268psi$$

From table 4.4, the minimum thickness of the annular plate is 0.2*inches*

POINTS TO REMEMBER

During the first internal inspection, bottom thicknesses must be measured in order to calculate rates of corrosion in the product side and in the soil side. With these corrosion rates, choose the minimum thickness from table 4.4 (bottom), or section 4.4.5.4 (sketch plates in critical zone), or table 4.5 + CA (annular plates) and then compare against the MRT calculated from the equation.

Or

You can conduct an RBI assessment that can be used to establish the interval for subsequent inspection intervals for tank bottoms

Or

You could conduct a stress analysis to assess the annular plates or the critical zone of sketch plates

If the result indicates that the tank will have a shorter than needed service life, make repairs, recoat if necessary and close the tank.

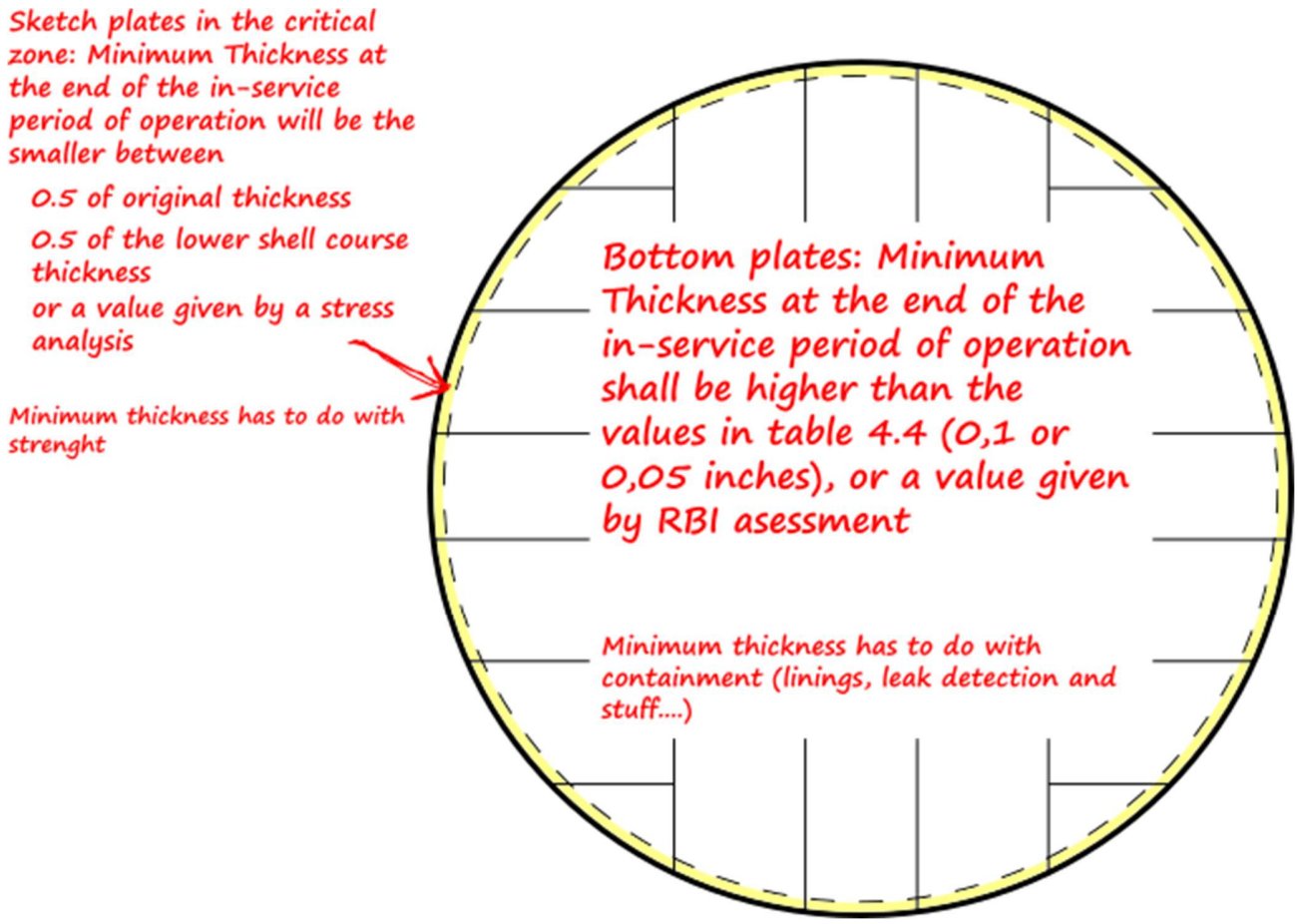

FIGURE 5 MINIMUM THICKNESS OF A BOTTOM OF A TANK WITHOUT ANNULAR PLATES

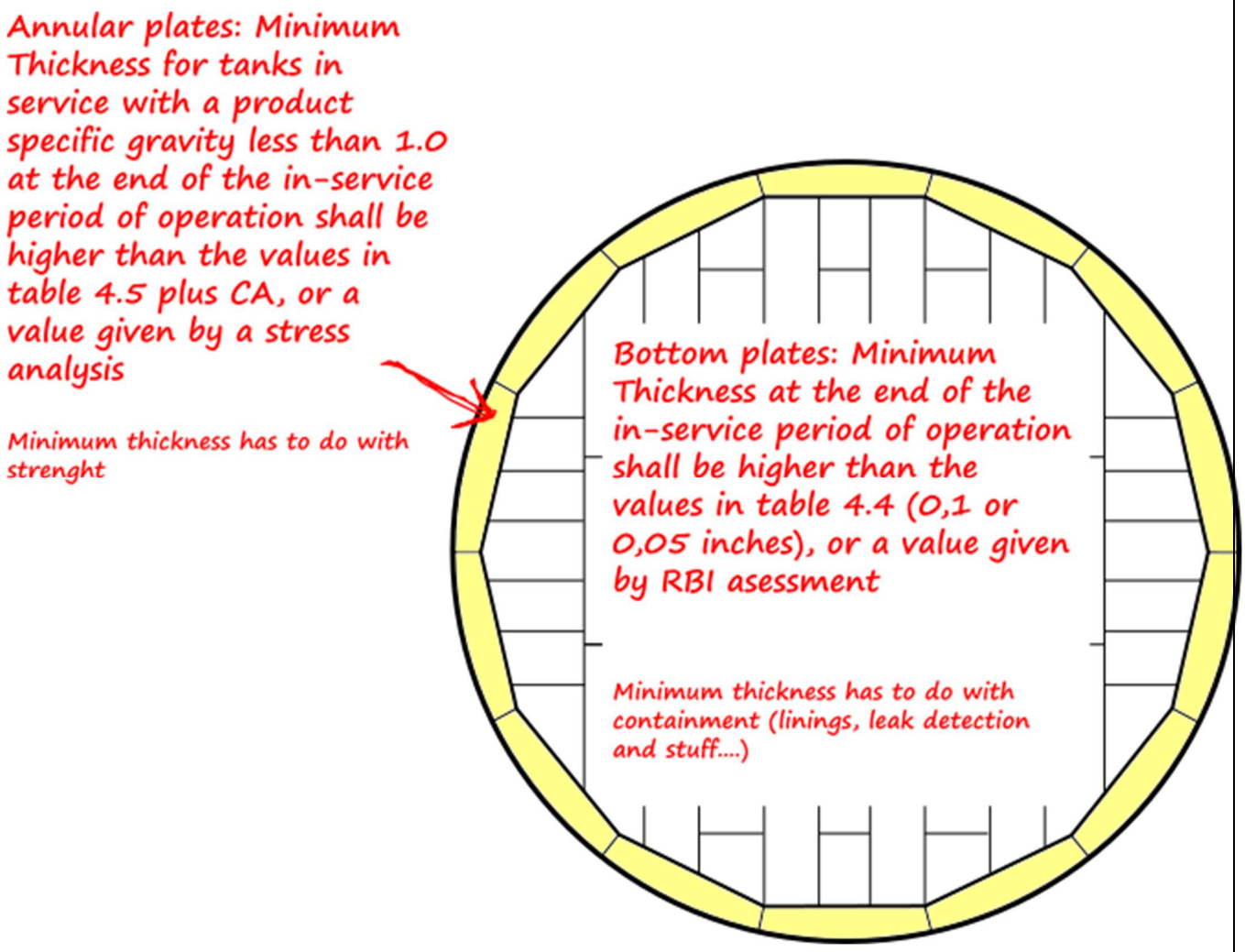

FIGURE 6 MINIMUM THICKNESS OF A BOTTOM OF A TANK WITH ANNULAR PLATES

IF YOU DON´T KNOW THE RATES OF CORROSION

Maybe you are inspecting a tank that has no information from the construction or from previous inspections and there is no possibility of a similar service assessment. If that´s the case, you won´t be able to calculate the remaining thickness at the end of your interval O_R. In this case, assess the risk of continued service (RBI) and take the action you think is the best.

QUESTIONS FOR CHAPTER 2: CALCULATING SUBSEQUENT INTERNAL INSPECTION INTERVALS OF A TANK BOTTOM

1. What is the minimum allowable thickness of bottom plates in a tank bottom with tank bottom/foundation design with no means for detection and containment of a bottom leak?
2. What is the minimum allowable thickness of bottom plates in a tank bottom without tank bottom/foundation design with means to provide detection and containment of a bottom or a with reinforced lining, > 0.05in. thick, in accordance with API 652?
3. What is the minimum allowable thickness of a sketch plate that had an original thickness of 1/4inch?
4. Using your excel spreadsheet, calculate the minimum allowable thickness of a sketch plate of a tank containing water using the following data

   D = 36 ft

   G = 1

   H = 40 ft

   E = 1

   S = 23600psi

5. The speed in which the corrosion is occurring in the bottom

   The minimum thickness for safe operation

6. The last 3 inches of a tank bottom next to the shell are what we know as the _____ _____
7. What is the acronym for Minimum Remaining Thickness and the end of a service period?
8. How can we avoid internal inspection? There are 2 or 3 ways.

   a) _____
   b) _____

c) _____

9. During an inspection, the inspector has the following data.

   D = 100ft

   H = 43ft

   t of the first shell course = 0.25in

   There is no info on RPBs.

Initial construction thickness. Year : 1999.

POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6
Bottom Plate	Bottom Plate	Bottom Plate	Bottom Plate	Bottom Plate	Annular plate
6.35mm	6.35mm	6.35mm	6.35mm	6.35mm	8.5mm

10-year inspection report thicknesses. Year : 2009. Bottom plates

POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6
6mm	5.18mm	6.35mm	5.8mm	6.2mm	8mm

Current inspection thicknesses. Year : 2019. Bottom plates

POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6
5mm	4.2mm	4.5mm	5.5mm	6mm	5.13mm

   Which points need a patch? What is the most critical point? What is the minimum thickness of the bottom? What is the minimum thickness of annular plates?