# CHAPTER 1: CORROSION RATES AND INITIAL INSPECTION INTERVAL

Activities: Read Chapter 1: CORROSION RATES AND INITIAL INSPECTION INTERVAL. Watch the Video "Introduction to API 653" and analyze the questions at the end of the chapter

## WHAT IS THE API 653 STANDARD?

API 653 is the standard for Tank Inspection, Repair, Alteration, and Reconstruction. It is a standard developed and published by the American Petroleum Institute (API)

It covers the inspection, repair, alteration, and reconstruction of steel aboveground storage tanks used in the petroleum and chemical industries, built to API 650 and API 12C. It provides minimum requirements for maintaining the integrity of those tanks after they have been placed in service.

The scope is limited to the tank foundation, bottom, shell, structure, roof, attached appurtenances, and nozzles to the face of the first flange, first threaded joint, or first welding end.

## WHAT IS THE BIGGEST THREAT FOR ABOVEGROUND STORAGE TANKS?

The most important threat to metallic equipment is corrosion.

Corrosion is the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment.

Any action in the universe is a result of a potential. Corrosion is no different.

Little differences in potential across the surface of steel make electrons start going from the anode to the cathode though the metallic path, creating small corrosion cells that can result in metal loss.

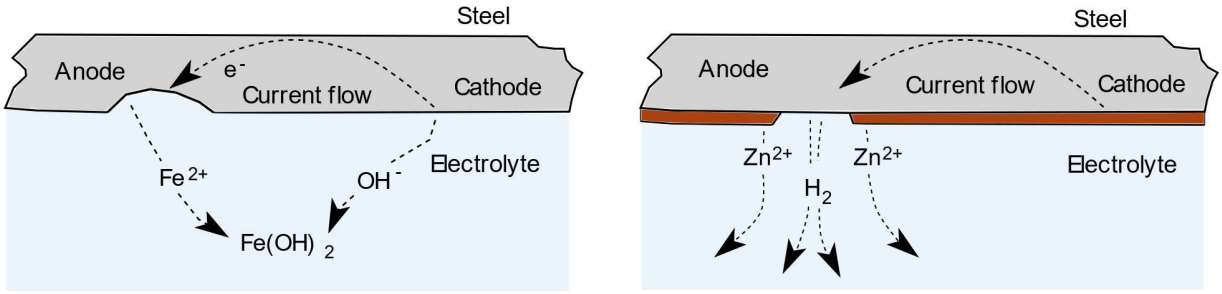



Figure 1. Initial. *Right*: Schematic picture of a steel corrosion cell: Metal ions go into solution at the local anode and are reduced at the local cathode, to form corrosion products. *Left*: Schematic picture illustrating the role of zinc in steel corrosion protection: Zinc offers cathodic protection to steel, even upon a layer breakthrough.

## DEFINITION OF FAILURE

The main objective of construction and repair standards is to keep the integrity of the assets and avoid failure, understanding the Word "failure" as lack of containment.

There are several maintenance standards that deal with loss of containment, like API 570 for pressure vessels, API 510 for pipes and STI001 for horizontal tanks.

API 653 is one of them. It reduces the risk of losing the containment of liquids and releasing them to the environment.

## SCHEDULING EQUATIONS

Among your duties as an inspector of static equipment, there is the need to calculate inspection intervals, metal loss (including corrosion averaging), corrosion rates and remaining service life. For an aboveground storage tank, you can calculate inspection intervals based on the Remaining Life of the containment of the tank (Shell and bottom). Remaining Life is determined using the Corrosion Rate of the tank. There are two aspects to consider when inspecting a tank: (a) the rate at which deterioration is proceeding and (b) the allowable limit of deterioration.

Let´s look at all the following definitions

**Metal Loss** due to general corrosion is defined as the difference between the thicknesses measured in the same spot before and after.

$$\text{Eq. 1.} \quad Metal\ Loss = t_{previous} - t_{last}$$

Metal loss is measured in distance units, being mm the most common

**Corrosion rate CR** is metal loss divided by the time between measurements

$$\text{Eq. 2.} \quad Corrosion\ Rate = \frac{Metal\ Loss}{Time\ period} = \frac{t_{previous} - t_{last}}{Time\ period}$$

Corrosion rate units are distance/time, being inches per year or mm per year the more common.

**Remaining life** is the time before the minimum allowable thickness is reached, at the calculated corrosion rate.

$$\text{Eq. 3.} \quad Remaining\ life = \frac{t_{actual} - t_{minimum}}{Corrosion\ Rate}$$

Values for Remaining life are commonly given in years. Corrosion rate here can be short-term (the most recent measured) or long-term.

Short term Corrosion

$$\text{Eq. 4.} \quad Short\ term\ Corrosion\ Rate\ (CR_{ST}) = \frac{Metal\ Loss}{Short\ time\ period}$$

Long term Corrosion

$$\text{Eq. 5.} \quad Long\ term\ Corrosion\ Rate\ (CR_{LT}) = \frac{Metal\ Loss}{Long\ time\ period}$$

Suitable use of short-term versus long-term corrosion rates is determined by the inspector. Short-term corrosion rates are typically determined by the two most recent thickness readings whereas long-term rates use the most recent reading and one taken earlier in the life of the equipment. These different rates help identify corrosion mechanisms hat act over the short-term from

those acting over the long-term. Comparing the values of short term vs long term corrosion, you can find tendencies or discover damage mechanisms.

**Corrosion allowance** describes an extra measurement added to the thickness of the wall calculated for safe operation. Units for corrosion allowance are distance units. It is the metal expected to be lost over the life of the equipment. Basically, it is chosen by the designer

Eq. 6. $Corrosion\ Allowance\ (CA) = \ Design\ Corrosion\ Rate\ per\ year\ x\ Number\ of\ years\ of\ life$

**Remaining Corrosion Allowance (RCA)** is the thickness remaining of the original Corrosion Allowance

Eq. 7. $Remaining\ Corrosion\ Allowance\ (RCA) = Design\ Corrosion\ Allowance - Metal\ Loss$

**Inspection interval** is the time between the last inspection and the next one

Eq. 8. $Next\ Inspection\ Date\ = \ Last\ Inspection\ Date\ + \ Inspection\ Interval$

All inspection intervals in are given in years.

**AND…. WE ARE GOING TO THE MEAT RIGHT NOW**

The maximum allowable next inspection interval is given by codes and standards. For API 653, use the following summary.

***External inspection by an authorized inspector***: must be conducted at least every 5 years or RCA/4CR years, whichever is less

***External Ultrasonic Measurements (they can be made by a technician, but the authorized inspector needs to verify)***: if the corrosion rate is not known, the interval between inspections is 5 years, but if the corrosion rate is known, measurements shall be taken the lesser of RCA/2CR, or 15 years

***Internal inspection by an authorized inspector***: The interval from initial service date until the first internal inspection shall not exceed 10 years unless it has one or more of the leak prevention, detection, corrosion mitigation or containment safeguards listed in Table 6.1 of API 653.

| Tank safeguard | Add to initial interval |
|---|---|
| i. Fiberglass-reinforced lining of the product-side of the tank bottom | 5 yrs |
| ii. Installation of an internal thin-film coating | 2 yrs |
| iii. Cathodic protection of the soil-side of the tank bottom | 5 yrs |
| iv. Release prevention barrier | 10 yrs |
| v. Bottom corrosion allowance greater than 0.150in | Actual corrosion allowance - 150 mils) / 15 mpy |
| v. Stainless steel bottom according to API 650 and Appendices | 10 years |

TABLE 1. TABLE 6-1 OF API 653. TANK SAFEGUARDS

Subsequent inspection intervals can be determined using the measured tank bottom corrosion rate and the minimum remaining thickness in accordance with 4.4.5 of API 653. An RBI assessment or stress analysis can be used to establish the inspection interval from initial service, and also subsequent inspection intervals. (Check figure 1 for Initial inspection interval)

## HOW TO ASSESS OTHER PARTS OF A TANK

For many parts of atmospheric storage tanks, neither the required thickness nor the methods for calculating the thickness are given in the tank standards. Such parts include pontoons, swing lines, floating-roof drain systems, nozzles, valves, and secondary structural members. In these cases, a minimum thickness should be stablished that would set the retirement thickness to ensure replacement prior to the occurrence of leaks.

For example, an owner on tank farms uses the following table for the replacement of necks in pipe nozzles. When the thickness reaches the values in the table, an alert is created for the replacement.

Pipe and nozzle minimum thickness

| Size | 0.060 | 3 | 4 | 6 | 8 | 10-24 |
|---|---|---|---|---|---|---|
| Thickness | 0.060 | 0.070 | 0.090 | 0.110 | 0.120 | 0.130 |
| For manways and nozzles over 24 inches, use 0.006 x Outside diameter | | | | | | |

TABLE 2. PIPE AND NOZZLE MINIMUM THICKNESS, TAKEN FROM API 574

Methods for determining the minimum shell thickness suitable for continued operation are given in 4.3.2, 4.3.3, and 4.3.4 of API 653 (SEE

SECTION X). Methods for determining minimum bottom thickness can be found in 4.4.5 of API 653 (SEE SECTION X).

## INITIAL OUT-OF SERVICE INTERVAL

The initial out-of-service inspection interval can be stablished this way:

The Maximum initial out-of-service inspection interval for a tank without safeguards = 10 years

This initial out-service interval isn´t written in rock. You can add a number of years dependent of the different safeguards that you can put in your tank. For example, if you add a Fiberglass Lining, you can add 5 years to the initial 10 years. Also, if you use a thick bottom with a Corrosion Allowance Higher than 0,15in, you can add a number of years

$$Number\ of\ years\ to\ add = \frac{(Actual\ corrosion\ allowance\ - 150mils)}{corrosion\ rate}$$

You can make that longer if you use a safeguard, or Release Prevention *System*, one of which can be a Release Prevention *Barrier*. You can add a number of years to the initial inspection interval by using any of these safeguards

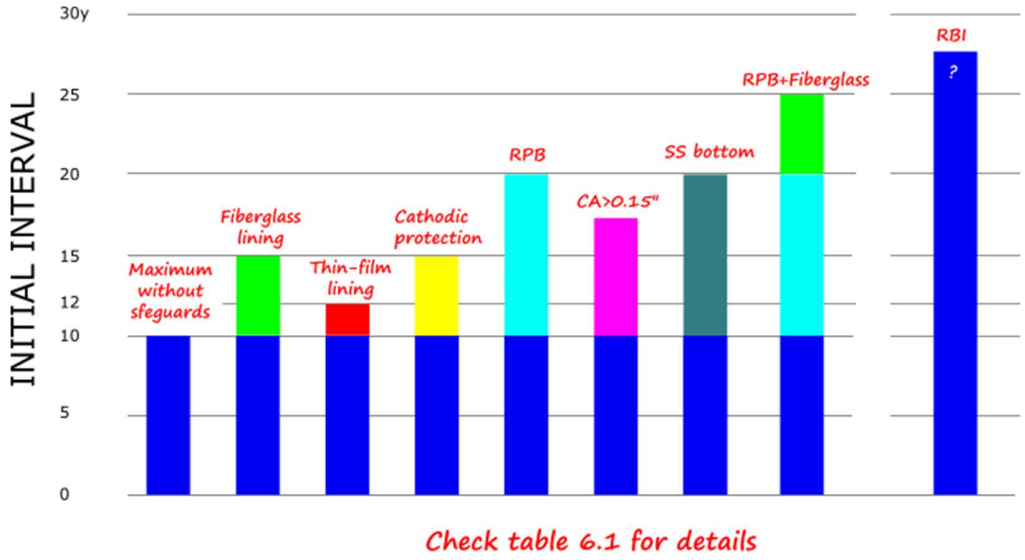
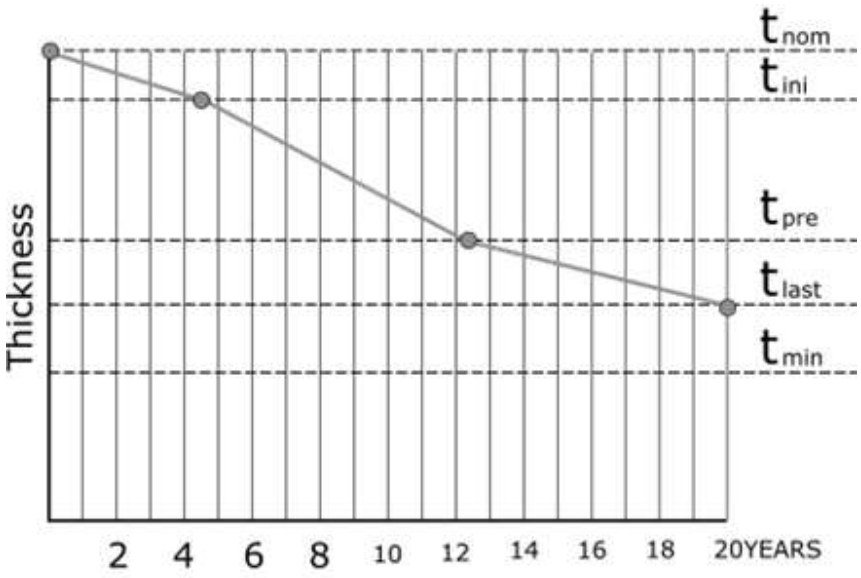



FIGURE 2. INITIAL INSPECTION INTERVALS IN TANKS (NOT STAINLESS-STEEL TANKS)

However, there is a limit to the initial inspection interval. Tanks with an RPB have a maximum inspection interval of 30 years, while tanks without an RPB have a maximum inspection interval of 20 years

If you want to avoid using intervals, you can conduct an RBI assessment to establish the initial inspection interval

Now let´s go to subsequent inspection intervals, in the next chapter.




$t_{nom}$ = Nominal thickness
$t_{ini}$ = Initial thickness
$t_{pre}$ = Previous Thickness
$t_{last}$ = Last Thickness
$t_{min}$ = Minimum Thickness

FIGURE 3. METAL THICKNESS SUBSCRIPTS.

## EXERCISES

After reading this chapter and watching the video "INTRODUCTION TO API 653", answers the following questions. Write the answers in the provided space. For the subscripts, refer to Figure 3.

1. Q: What is the metal loss of a metal with a $t_{ini}$ of 10.6mm and a tlast of 7.4mm?

A:

2. Q: Following are UT readings of the shell of a tank taken with a difference of 5 years in the same spot.

| Thickness | Value |
|---|---|
| $t_{1995}$ | 9.7mm |
| $t_{2000}$ | 8.3mm |

Find the corrosion rate.

A:

2. Q: If the minimum allowable thickness $t_{min}$ for tank in a given point is 5.8mm (likely the shell), and right now the thickness $t_{last}$ is 7.9mm, and the corrosion rate is 0.34mm/y, then what is the remaining life?

A:

3. Q: If the minimum allowable thickness $t_{min}$ for *tank shell* in a given point is 5.8mm, right now the thickness
$t_{min}$ is 7.9mm, and the corrosion rate is 0.34mm/y, then when should be scheduled the next UT measurement?

A:

4. Q: The following table is a record of average thicknesses of a tank shell in the same course over the years. Calculate the short-term corrosion rate $CR_{ST}$ and the overall long-term corrosion rate $CR_{LT}$

| YEAR | THICKNESS(mm) |
|---|---|
| 2009 | 9.82 |
| 2010 | 9.71 |
| 2011 | 9.45 |
| 2012 | 9.36 |
| 2013 | 9.21 |
| 2014 | 8.99 |
| 2015 | 8.87 |

A:

5.In the former exercise… would you use long-term or short-term corrosion as a basis for calculations? Explain

A:

$t_{min}$

## QUESTIONS FOR CHAPTER 1: CORROSION RATES AND INITIAL INSPECTION INTERVAL

1. What is the maximum initial out-of-service inspection interval of a new tank that has no tank safeguards?

2. How do you calculate the addition in years to the interval when the Corrosion Allowance of the bottom of the tank is greater than 0,15in?

3. Which standard has a table for the minimum allowable thickness $t_{min}$ of pressure equipment piping components?

4. After watching the video, which was the damage mode present during the Ashland Oil spill in 1988?

5. Which was the damage mechanism present during the Ashland Oil spill in 1988?

6. Which was the failure mode present during the Ashland Oil spill in 1988?

7. External inspection of a tank must be conducted at least every ___ years or RCA/4CR years, whichever is less.

8. If the corrosion rate of the shell is not known, the interval between UT measurements of the shell is 5 years. True OR false?

9. If the corrosion rate of the shell is known, UT measurements of the shell shall be taken the lesser of RCA/2CR, or 15 years. True OR false?

10. Which inspection changes when the corrosion rate is unknown? External inspection or UT measurements?

11. What is the meaning of the word failure?

12. If you add an RPB to a tank bottom, how many years can you add to the initial 10-year inspection interval of a tank?

13. A Release Prevention System is the same as a Release Prevention Barrier? Explain

14. What is the maximum initial interval for a tank without RPB?

15. What´s the definition of failure?

16. Who verifies the results of the NDT made during the inspection?