ARPEL Guideline
Storage tanks inspection plans

Best Practices

REGIONAL ASSOCIATION OF OIL, GAS AND BIOFUELS SECTOR COMPANIES IN LATIN AMERICA AND THE CARIBBEAN

ARPEL Guideline
Storage tanks inspection plans

July 2012

ARPEL Guideline MP02-2012
July 2012

This document was devised within the context of the Mechanical Integrity and Risks Analysis Project, of the ARPEL Refining Committee. The ARPEL Refining Committee was in charge of the content and review of this document:

Mauro de Camilli - ANCAP
Daniel Cebey - ANCAP
Rosario Martino- ANCAP
Nikolai Guchín – ANCAP
Jaime López – ECOPETROL
Jairo Buitrago – ECOPETROL
Daniel Ramirez Livingston -ENAP
Oscar Gonzalez Contreras -ENAP
Daniel Santamarina - ExxonMobil
Victor Casalotti - IAPG
Ernani Filgueiras – IBP
Andrea Reid- PCJ (Vice-chairmanship)
Othón Valverde Yáñez - PEMEX
Rodrigo Abramof – PETROBRAS (Vice-chairmanship)
Frederico Kremer – PETROBRAS
Angela Martins – PETROBRAS
Sergio Fontes – PETROBRAS
Geraldo Marcio Diniz Santos - PETROBRAS
Marco Calvopiña – EPPETROECUADOR
Nelson Chulde - EPPETROECUADOR
Gerardo León Castillo - PETROPERU
Alfredo Coronel Escobar – PETROPERU
Margaret Ocando – PETROTRIN
Sergio Cavallín – PLUSPETROL
Julian Meiller – PLUSPETROL
Henry Arias Jiménez - RECOPE
Oscar Acuña Céspedes – RECOPE
Carlos Jiménez López – REPSOL (Chairmanship)
Arsedio Carbajal González - REPSOL
Carlos Hughes – STAATSOLIE
Aubrey Nai Chung Tong – STAATSOLIE
David Jalma – WPC
Roberto Cuadros – YPFB (Vice-chairmanship)
Guillermo Achá Morales - YPFB

The ARPEL **Mechanical Integrity Project Team** was responsible for drawing up this document.

ANCAP: Silvia Infanzón; **ECOPETROL:** Luis Eduardo Zabala; **ENAP:** Gustavo Jiménez; **ExxonMobil:** Daniel Santamarina; **IBP**: Luiz Moschini; **PCJ**: Brian Case; **ARPEL:** Irene Alfaro.

In addition, we are most greatful to the following professionals for their invaluable contribution:

Álvaro Montes de Oca, Juan Carlos Hernández, Rodolfo Ibarrondo (ANCAP); Francisco Elicer (ENAP); Hervandil Morosini Sant'Anna (PETROBRAS).

Content

Tables

Figures

1. Objective of the guideline

To show the guidelines to implement a storage tank inspection plan, taking API 653 standard as frame of reference, as well as the best practices developed within ARPEL´s scope.

2. Scope of the guideline

It applies to above-ground tanks, hydrocarbon storage tanks, located in distribution plants, refineries, petrochemical companies, distribution terminals and oil production facilities. In general, these storage tanks are manufactured according to API standards: 650 Welded Steel Tanks for Oil Storage, 620, etc. It covers the tank's floor, shell, and roof, up to the flange against its shell. It does not apply to its auxiliary input and output systems.

3. Related documents

API 650, 353, 580, 650, 579, 575, 581, 620, ASTM D 86, D 610, D 659, D 661 and D 714, API RP 651, NACE RP 01-93, ISO 9712.

4. Background

The development of this guideline is part of the activities in charge of the Mechanical Integrity and Risk Analysis Project of the ARPEL Refining Committee. This project was created with the aim of improving the management in the oil and gas industry in the mechanical integrity and risk analysis areas, as they represent critical elements of the environmental, health and safety management system in downstream.

5. Glossary

ABENDI

Brazilian Association for Non-destructive Testing and Inspection.

ACFM

The ACFM technique, Alternating Current Field Measurement, is a pretty highly used technique to detect fatigue and sub-surface cracks. It may be particularly used in the detection of cracks in the bottom of tanks.

Alteration

Any modification in a tank which changes its shape or size.

Anchorage

System by which a tank is fixed to its base or foundation.

Rings

Concentric cylinders that make up the tank's layer.

Anode

Metal surface from which current emerges to go through a solution, in which the metal corrosion or dissolution is carried out.

Sacrificial anodes

Metal with a normal oxidation potential higher than the one of the metallic structure to be protected, so that it is consumed with protective current. It is used in cathodic protection systems in which the metal that acts as anode is sacrificed (disintegrated) in favor of the one acting as cathode. In this type of system, the anode material is consumed depending on the protection current demand of the structure to be protected, the electrolyte's resistivity and the material used as anode, during its discharge process.

Settlement

Gravity natural accommodation of the tank to its base or foundation.

ASNT

American Society for Non-destructive Testing.

Point of entry

Flanged hole situated in the first ring of the tank. Used by people to go into the tank.

Piping

Set of components used to transmit, distribute, mix, separate, discharge, measure, control or purge. Pipes also include the support elements, but do not include the support structures, such as building posts, tilts and/or foundations. It is a pipe that transports fluids.

Cathode

The cathode is the metal surface in which the current leaves the solution and returns to the metal, there is no metal dissolution in the cathode.

Certification

It is a document which guarantees the qualification. In general, it is a certificate issued which is a proof that states that all the requirements established in a certification system are met.

Condensate

Hydrocarbon liquid separated from natural gas which is condensed due to changes in temperature and pressure and remains liquid in standard conditions.

Operative conditions

Contained fluid, temperature, liquid level, filling and emptying speed, and other conditions given during the service. In general, this concept is used related to the design conditions, which limits should not be surpassed in operation.

Impressed current

Cathodic protection system that introduces direct current by means of a transformer in the circuit which consists of the structure to be protected and the anode bed. The current dispersion is carried out with the help of inert anodes which characteristics and application depend on the electrolyte (scrap metal, ferro-silicon, titanium oxides, lead – silver, graphite, etc.). The positive terminal of the source should always be connected to the anode bed, so as to force the protection current discharge for the structure.

Corrosion

Electrochemical process by which the refined metals tend to form thermodynamically stable compounds (oxides, hydroxides, etc.) due to the interaction with the environment.

Grading

Done to prove that the personnel that is going to be certified has the education level, the experience, the formal training and the skills to carry out a certain job. The proof is carried out through examinations.

Mass loss coupon

Metallic test tube (corrosion coupon) of known weight that is exposed to the corrosive environment to be analyzed and the weight loss for a specific period is monitored, after having previously eliminated the corrosion products through adequate methods.

Degradation

It is the reduction of the ability of a component to achieve its purpose. This can be caused by different deterioration mechanisms (examples: slimming or loss of thickness, cracking, fissures, etc.). Damage or degradation can be used instead of deterioration.

Pipeline

Transportation system through pipelines which includes components such as valves, flanges, cathodic protection, communication and/or data transmission lines, safety or relief devices by which liquid hydrocarbons and gases are transported; generally placed under the surface (buried) in dry, wet soil or under water streams. In some areas they are placed in elevated structures to get over land depressions.

Electrolyte

Chemical substance, or a combination of them, liquid or solid, which contains ions that migrate under the action of an electric field.

NDT

Non-destructive Testing. Test performed on an object to verify its quality or status without causing any damage or making it useless.

Chalking

Superficial degradation of the paint in a uniform and progressive way due to the exposure to the sun's ultraviolet rays.

Shell

The shell of an above-ground storage tank is the vertical component containing the fluid inside the tank. Moreover, it supports the roof and other connections of the tank like the stairs, nozzles, and pipes.

Failure scenario

It is the physical expression of the damage (for example: slimming of wall, rusting, cracking, rupture).

Risk assessment or estimation

Process used to measure the level of risk on life, health, the environment or properties and includes a frequency analysis or failure probability for each threat, consequence analysis and its integration. In the risk assessment or evaluation, judgments and values are part of the decision process, explicitly or implicitly, including considerations on the importance or seriousness of the estimated risks, the social, physical, environmental and economic consequences linked with the purpose of identifying alternatives for their mitigation or reliable management.

Evaluation of the service ability

It is a methodology by which the defects within a structure are evaluated so as to determine the adaptation of the defective structure for the continuous service with no imminent failure.

Evaluation of similar services

It is the process through which corrosion speed and inspection intervals are set for a candidate tank with corrosion speeds and the history of a control tank in order to set the next inspection date.

Failure

Undesirable fault or imperfection in a material. It is also defined as failure when an equipment does not offer the service for which it was devised or built anymore.

HAZOP

HAZard and OPerability. The operating functional analysis is a technique for identifying operative risks based on the premise that hazards, accidents or operating problems occur as a consequence of a deviation of the process variables from the normal parameters of an operation in a specific system and in a certain stage. Therefore, even if it is applied in the design stage, or in the operation stage, the procedure is to evaluate, in all the lines and in all the systems, the consequences of possible deviations in all the process units, whether if it is continous or not. The technique is to systematically analyze the causes and the consequences of some deviations of the process variables, expressed through “guiding words”.

RBI

Abbreviation for Risk Based Inspection. It is a methodology through which, from the risk evaluation of a static equipment (pipe, tank, vessel, furnace, boiler, others), threats and failure modes that those equipment can have are established to define the methods and techniques, with the frequencies and importance required for them to be evident. Monitoring and inspection programs of the threats and the consequences, and their mitigation actions can be defined from the RBI exercise.

ICP

Individual Certification Programs.

External inspection

It is a visual inspection carried out by an authorized inspector to evaluate all the possible aspects of the tank without interrupting operations or withdrawing the tank from operation.

Inspector

Competent person, with the necessary knowledge and ability to carry out the mechanical integrity inspection of an equipment and prepare the respective report. When the equipment to be inspected is a tank; different types of inspectors can be distinguished: non-destructive testing ones, welding ones, quality control inspectors, etc.

Internal inspection

It is a complete inspection by an authorized inspector of all the tank’s accessible internal surfaces.

ISO

International Organization for Standardization.

Product side

Tank surface that is in contact with the liquid product stored.

Soil side

Tank lower surface that is in contact with the land.

LFET

Descriptive abbreviation for Low Frequency Electromagnetic Technique. The LFET inspection is a quick and efficient way to detect a loss of thickness.

Compound material

Material made up of two components to obtain a combination of properties that is not feasible to be obtained in the original materials. These compounds can be selected to obtain unusual combinations as for stiffness, strength, weight, performance under high temperatures, resistance to corrosion, hardness or conductivity.

Degradation mechanisms

It is a process that leads to micro and/or macro changes in a material; which could be dangerous for the material conditions or its mechanical properties. Damages are usually incremental, cumulative, and, in some cases, irretrievable. The most frequent damage mechanisms include: corrosion, stress corrosion cracking, erosion, fatigue, fracture, etc.

Non-destructive Testing Method (NDT)

Discipline that applies a physical principle in non-destructive testing (for example, ultrasonic testing).

MFL

Descriptive abbreviation for: Magnetic Flux Leakage. The magnetic flux leakage inspection is a quick and efficient way to detect a loss of thickness.

Tank floor

Tank lower part, located horizontally, which separates the fluid contained from the ground.

Pitt (or pitting)

Local metal loss, as a cavity or hole, which diameter or deepness is lower than the thickness of the sheet.

Probability of failure

Probability of a leak or failure in the system in a certain period. It can also be defined as the level of occurrence susceptibility of damage or loss of integrity by each possible threat in the system.

Certification process

It is a process in which a person proves his/her knowledge, experience and skills to carry out a job. The verification is proved by a certificate that is obtained when someone has gone through exams and other requirements from an association or organization that monitors the application of standards for a certain type of industry.

Owner/operator

It is the legal entity that is in charge of, or is responsible for the operation and maintenance of an existing storage tank.

Cathodic protection

Technique to control the corrosion of a metal surface by turning it into the cathode of an electrochemical cell.

Hydrostatic testing

A test carried out with a liquid in which the fluid static height is used to produce test loads.

Breakover point

Point in the bottom of a tank in which the settlement begins.

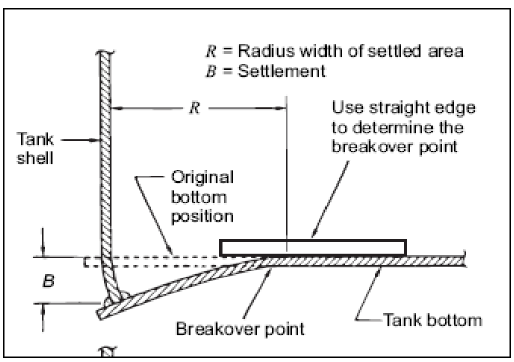

Figure 5: settlement point

Reconstruction

Any job necessary to set up a tank again that has been dismantled and moved to a new place.

Repairing

Job necessary to keep or restore a tank in good conditions for a safe operation. Examples:

a) removal and replacement of material (as the roof, shell, or bottom material, including the welding metal) to keep the integrity of the tank;

b) leveling and/or lifting of the shell, the bottom or the roof of a tank;

c) inclusion or replacement of support plates (or some of them) for the penetrations of existing shells; and

d) repairing defects, cracking or erosions, with grinding or lowering and then welding.

Soil resistivity

Degree of difficulty of electrons displacement through the ground. It is the specific electrical resistance of a surface and it is expressed in Ohm-cm.

Risk

According to API RD 581, it is the combination of the failure probability and the failures consequence. This product is arithmetical when the risk assessment methodology is quantitative and can be a matrix combination when the risk assessment is qualitative.

Sprinklers

Fire extinguishing device. Generally, they activate when they detect the effects of a fire, as for example a fire-related increase in temperature, or the smoke caused by combustion.

Auxiliary systems

Additional systems, equipment or components to the main parts that are necessary for the reliable and safe operation of the tank such as: fire protection system, dikes, etc.

Corrosion rate

Loss of estimated metal for a structure that is exposed to a corrosive environment for a certain period (mm/year).

External floating roof

It is the highest roof of a tank and it is made up of a double roof, single roof, or pontoon, which depends on and is compatible with the liquid contained and is equipped with a closure seal or seals.

Internal floating roof

A roof in a fixed roof tank that depends on or is floating in the oil liquid contained and is equipped with a closure seal or seals to close the space between the tank shell and the tank roof.

NDT technique

Specific way of using a NDT method (for example, immersion ultrasonic testing).

Residual or remaining life

It is the space of time left until the end of the useful life of a component or facility, which ends when there is no more capacity left to render the service under the acceptable technical, safety and financial standards.

6. Reasons to establish a tank inspection plan

The reasons to have a plan like this are:

- to reduce the probability of failures and liberation of products stored;
- to unify inspection standards;
- to know the degradation status compared with the original manufacturing conditions;
- to estimate its remaining useful life;
- to define inspection frequencies;
- to establish better conservation and protection conditions against degradation mechanisms;
- to keep a clear and useful record of the tank, with concise and concrete, easily accessible information;
- to establish maintenance plans to optimize costs and reduce maintenance times to preserve the integrity of the tank during its life cycle;
- to keep the availability and reliability of the tank; and
- to facilitate the fulfillment of obligatory national legal requirements and act according to international reference standards.

7. Causes to revise a tank inspection plan

The tank inspection plan should be revised faced with the following circumstances:

- change of service;
- change of operative conditions;
- change of inspection or building rules;
- near the end of the useful life;
- change in regulations;
- after repairing or major changes;
- presence of new or aggravated deterioration mechanisms; or
- after extreme events (earthquakes, fires, tsunamis, etc.).

8. Development of a tank inspection plan

Failures in tanks can cause safety, environmental, as well as financial problems, and besides, risk the supply infrastructure. A good inspection plan should combine engineering techniques with knowledge of the history of the tank.

The main objectives achieved in the storage tank inspection are:

- to detect and identify damages and deterioration mechanisms;
- to determine the intensity of damages and deterioration mechanisms;
- to determine the remaining life of the tank components; and
- to determine possible repairing and changes.

Developing an inspection plan allows to reduce the probability of failure for a given component (not its consequence), which will reduce the risk to acceptable levels.

The magnitude of the reduction of the probability of failure is, in general, directly proportional to the inspection effort carried out. The effectiveness of the inspection and the failure detection probability are directly proportional to the quantity and quality of the resources used in the inspection.

Two types of inspection plans can be identified: in service and out of service. In each case, the corresponding safety measures should be taken, including the measures to access limited areas in the case of an out of service inspection.

Before every inspection, and when an inspection plan is developed, the following should be taken into account:

- analysis of the history of the equipment, at least the last three inspection reports, in order to verify design changes, deterioration or defects that have appeared, and critically analyze the inspection methods used;
- verify if the inspection recommendations and possible repairings were carried out and if there are any pending;
- consult operative records and verify the things that come up that may interfere with the remaining life of the tank, such as: pressure rise, temperatures above the design, unexpected polluting fluids, vibrations, leaks and losses, as well as unexpected efforts;
- reasearch the action of process fluids and their pollutants to the materials involved, taking operative conditions into account (when the equipment operates with several fluids and undefined conditions, for example breathing tank, it is advisable that an analysis is carried out for the worst possible condition);
- verify the operation start date, out of service periods, and start date of the last operative period; and
- analyze thermal cycles involved, when applicable (thermal tensions).

A tank inspection plan is established in an asset management document, which, at least consists of:

- tank records;
- referential analysis of typical failure cases;
- tank failure records;

- degradation mechanisms;
- failure scenario;
- inspection methods;
- establishment of the inspection frequency; and
- conclusion and recommendation.

8.1. Tank records

Records should include:

- plans and technical data sheets, with the following characteristics:
    - process conditions (fluid, pressure, temperature, etc.);
    - dimensions and manufacturing aspects (type of roof and base, thickness of components, internal accessories, points of entry, floor and floor schemes, etc.);
    - materials used in the construction, including accessories and welding; and
    - design code used.
- protective components used in tanks (cathodic protection, atmospheric protection/lightning conductors, coverings and compound material reinforcements, special protective coatings for roofs, corrosion protection system for the floor in contact with soil such as: covering, cathodic protection or sacrificial anodes;
- operative record of the tank (services to which it was subject to);
- inspections record (dates, inspection types and methods, tests and findings);
- descriptive list of repairing and changes carried out, and change control analysis, if there is one;
- roundness and vertical position verification;
- updating calibration;
- replacement of exterior and interior paint, if there is, showing type and thickness; and
- treatment of the base floor of the tank and characteristics of the concrete ring, if there is one.

8.2. Referential analysis of typical failure cases

The failure analysis in tanks is particularly important for new tanks or for those for which there is no record available. As a reference see "Integrity Management Plan - Hydrocarbon Storage Facilities" (Argentinean Oil and Gas Institute- IAPG). Likewise, API 353 publication presents different quantitative values for the analysis of typical failures.

The most frequent failure causes in tanks, in decreasing order, are:

- atmospheric discharges (a flash of lightning);
- high temperature maintenance repair;
- operational errors;
- bad operation of systems;
- sabotage;
- fissures and ruptures of the tank;
- static electricity;
- natural disasters; and
- internal reactions.

8.3. Tank failures record

A record of all the failures should be kept, that includes – at least- the following information:

- date of failure;

- failure mechanism;
- root cause;
- repairs carried out and their quality control;
- real and potential consequences; and
- recommendations and corrective actions.

8.4. Degradation mechanisms

The degradation mechanisms that affect each component of the tank should be documented. All the mechanisms indicated by the experience should be included in the plan. Some of the possible mechanisms are mentioned below.

- Localized corrosion.
- Generalized corrosion.
- External corrosion as a result of the sea breeze or smog.
- Internal corrosion as a result of water wastes when water is used in the reception operations for product displacement, or by condensation of the environment humidity.
- Rapid corrosion of sharp points or edges, as in those places the paint thickness is smaller than the recommended one.
- Rapid corrosion in manufacture defects that cause the accumulation of humidity and dust from the atmosphere.
- Erosion.
- Material fatigue.
- Differential settlements in the tank base.
- Fragile fracture by low temperature, etc.

***Table 8.4: degradation mechanisms*[1]**

TYPE OF DAMAGE	DETERIORATION MECHANISM	DESCRIPTION
Uniform thickness loss	Atmospheric corrosion	It is a corrosion mechanism of electrochemical nature in which the electrolyte is composed of a water film on the surface. The severity of the corrosion process depends, especially, on the time during which the water film remains on the metalic surface and on the air pollution. It is the most common corrosion process in storage tanks and usually occurs in roofs and shells.
	Soil corrosion	The land or soil, due to its variable humidity, salts and organic matter decomposing, is the most complex electrolyte that can be found. A natural soil contains sand, clay, lime and humus. These components can be combined in different propotions which give rise to different levels of corrosive agressiveness. The corrosion speed is connected with the soil resistivity, presence of oxygen, humidity and microorganisms. Soil corrosion can occur in the lower part of the bottom plates and in some cases it can also be localized.
	Abrasion wearing away	Abrasion is the loss of thickness resulting from friction mechanical action between two solid materials.

[1] *Data based on API 581 and the ARPEL Manual for pipelines integrity management*

TYPE OF DAMAGE	DETERIORATION MECHANISM	DESCRIPTION
	Abrasion and erosion wearing away	Erosion is the loss of thickness of a material through the impact of a dynamic agent like water, wind, sand, etc.
Localized thickness loss	Galvanic corrosion	Galvanic corrosion is an electrochemical process in which a metal corrodes preferentially when it is in electrical contact with a different type of metal. The pair of metals in known as galvanic pile. In tanks, this type of corrosion can occur in the fixing terminal of the tank grounding cable.
	Microbiological corrosion	Microbiological corrosion is a corrosion process in which the metal loss is caused by direct or indirect action of microorganisms. Microorganisms that participate can be aerobic or anaerobic. Most often, their metabolic processes change the chemical characteristics of the electrolyte. This type of corrosion is more frequent in the bottom of tanks, either in the parts that are in contact with the floor or in the parts that are in contact with water accumulated in the bottom.
	Corrosion under thermal insulation	Corrosion under insulations can occur under different circumstances and can be caused mainly by water or fluids that enter the insulations or assembly failures and in the external metal jacket. Once pollution (overflows, vapor or liquid leaks, rainwater, etc.) enters the external protection, it comes into contact with the insulation (fibre glass, mineral wool, calcium silicate), and reaches the equipment surface through the "wick effect" in which corrosion may occur. It can also occur by the combination of insulations that contain chloride wastes in contact with the austenitic stainless steel surface, and especially of the 300 series, where there is humidity and a temperature higher than 140°F (60°C). In these cases it becomes apparent as crackings or fissures.
	Selective corrosion	Type of attack in which one of the components of an alloy is dissolved, generally the most electronegative one. Examples of this type of corrosion are dezincification, dealumination and even intergranular corrosion in stainless steels. This process is not very frequent in storage tanks.
	Erratic currents corrosion	Deterioration due to erratic currents, particularly direct, that escape from electricity systems near the tank and penetrate the bottom metal plates corroding them where they come out to the floor. This type of localized corrosion can lead to deep rusts in a short space of time.

TYPE OF DAMAGE	DETERIORATION MECHANISM	DESCRIPTION
	Aeration and differential concentration corrosion	Environmental conditions in a crack may, with time, become more corrosive than those existing in a clean and open surface. Corrosion intensification, also know as cracking, is generally caused by one or more of the following factors: a) Acidity changes in the crack or fissure. b) Shortage of oxygen in the crack. c) Development of different ions in the fissure. In storage tanks, this type of corrosion can occur under tanks, microorganisms, washers or screw heads, in parts that are in contact with joints or in the interstices between the bottom and the floor plates.
	Pitting corrosion	It is a process that occurs when a passivated metalic surface is exposed to an aggressive environment. During pitting, the attack is localized in isolated spots in passive metalic surfaces and penetrates the metal forming, sometimes, microscopic tunnels. It is a highly localized process that occurs in areas with a low generalized corrosion and in which the anode process (reaction) produces small localized perforations. It can be observed generally in surfaces with a low or almost inexistent generalized corrosion. It occurs as a local anode dissolution process in which the metal loss is accelerated by the presence of a small anode and a much larger cathode. Pitting is the most frequent type of corrosion in stainless steels.
Loss of layers thickness	Exfoliation corrosion	Exfoliation corrosion is a subsuperficial corrosion that starts on a clean surface, but it spreads under it and it is different from the pitting corrosion as the attack has a laminate appearance. Complete layers of materials are corroded and the attack is generally recognized by the flaky appearance, and sometimes with blisters, of the surface. At the end of the attack, the material looks like a pack of cards in which some of them have been taken away. This mechanism is pretty known in surfaces in contact with marine atmospheres and in the upper internal part of tanks which vapors contain sulfur derivatives.
Metallurgical changes	Hydrogen embrittlement	Hydrogen embrittlement can be defined as the loss of resistance and ductility induced by hydrogen. Hydrogen embrittlement is particularly devastating due to the nature of the originated failure. That failure follows very small tensions (in comparison with the necessary ones when there is no hydrogen), it is pretty fragile and has such a variable “incubation” period that is almost unpredictable. This type of damage occurs at temperatures higher than 200°C, under pressures and with the presence of this element. This process is not very frequent in storage tanks.

TYPE OF DAMAGE	DETERIORATION MECHANISM	DESCRIPTION
	Hydrogen blistering	The damage mechanism is caused by hydrogen that penetrates the material and is recombined in the most sensitive areas: matrix-inclusion and matrix-carbides interfaces, grain cavities and limits; causing an increase of the internal pressure and material decohesion in these areas. This phenomenon is known as blistering. This type of damage is most commonly found in low mechanical resistance steels that work in environments that promote a strong hydrogen intake to the material.
High temperature	Oxidation	Mechanism that is not very frequent in storage tanks.
	Sulfidation	Mechanism that is not very frequent in storage tanks.
	Thermal fatigue	Mechanism that is not very frequent in storage tanks.
Mechanical failures	Ductile fracture	The ductile fracture of a metal occurs after an intense plastic deformation and is characterized by a slow crack propagation. It may occur in tanks as a consequence of border or shell settlements.
	Fatigue fracture	It is a phenomenon by which the breakage of materials under cyclic dynamic loadings (forces repeatedly applied to the material) is produced faced with loadings which are below the static loadings that would cause the breakage. Its main risk is that it may occur at a smaller tension than the traction resistance or the elastic limit for a static loading and appear without warning, causing catastrophic breakages.
	Fragile fracture by low temperature	The fragile fracture occurs along cristalographic planes called fracture planes and has a fast crack propagation. Most of the fragile fractures are transgranular, that is, they travels through the grains of the material. But if the grain limits constitute a weak area, there may be an intergranular propagation of the fracture. Low temperatures and high deformations favor fragile fracture. In tanks, they can occur more frequently due to pressure tests carried out at temperatures under 20°C.
Processes assisted or related among themselves	Stress corrosion cracking, SCC	It is a corrosion process that occurs when there is interrelation of two essential factors: the material surface exposed to the corrosive environment should be under tensile stress and the corrosive environment should be specifically a cause of the stress corrosion. Most of the alloys are liable to suffer this attack, but fortunately, the number of combinations alloy-corrosive that cause this problem is relatively low. Tensile stress can be the result of applied loads, internal pressure in the system or residual stresses from previous welding or bending. For carbon steel, the corrosive environments that can cause this corrosive phenomenon are those that contain chlorides, caustic soda and sulphides at high temperatures. If the temperature is under 50°C, stress fracture corrosion rarely occurs.

TYPE OF DAMAGE	DETERIORATION MECHANISM	DESCRIPTION
	Fatigue corrosion	Failures because of breakages due to the combined action of a corrosive environment and mechanical tension cycles. This process may occur in the bottom of tanks near the floating roof legs support.
	Erosion corrosion	The joint effect of the corrosive and abrasive action of a fluid moving at a high speed, which causes the constant destruction of the corrosion products protective layers. The presence of suspended particles speeds up the process.
	Abrasion corrosion	Corrosion in the interfase of two metalic surfaces in contact, sped up by the relative sliding between them. It is considered that corrosion plays one of the following roles: the friction heat rusts the metal and then oxide wears away; or the mechanical removal of the oxide protective particles, or the resulting corrosion products. This erosion may occur in the internal shell surface in floating roof tanks due to the constant sliding of the seal.

8.5. Failure scenarios

For each pair "degradation mechanism-component", all the possible scenarios that may lead to a failure in the tank should be described. Some potential failure scenarios are listed below:

- Localized corrosion due to a failure of the paint because of an inadequate preparation of the surface or bad paint application.
- Failure in the tank shell welding.
- Floor failure because of external attack of the soil to the floor metal sheet.
- Floor failure because of internal attack of the fluid contained in the tank. Tank shell failure due to internal corrosion.
- Shell failure due to external corrosion.
- Roof failure due to internal and external corrosion.
- Equipment and accessories failure: stairs, handrains, reception connections, dispatch and purges, vents.
- Leaks at joints or damages in the sealing settlements.
- Vacuum deformation.
- Deformation due to excessive pressure, etc.

A probability and a consequence are assigned to each scenario and its risk is expressed.

In order to express the risk, a risk matrix scheme is used, for example, a matrix like the one proposed by API 353 is suggested, with probabilities from A to E (decreasing) and consequences from 1 to 5 (increasing).

Consequences should be evaluated in 4 categories: fire risk, explosion risk, spill risk and economic risk (derived from the spill remediation cost, repair cost, and the logistics cost due to the non-availability of the tank).

When the initial risks of each scenario are assigned in the matrix (without mitigative measures) it will become evident which of them are not acceptable (those in the high, medium-high and medium risk zones). For these non-acceptable risks, preventive and/or mitigative measures should be developed to reduce risk to acceptable levels.

8.6. Inspection and testing methods

There are several inspection and testing methods. Each of them has its advantages and disadvantages, so it is advisable that they are used jointly. The main inspection and testing methods applicable to storage tanks are:

8.6.1. Visual inspection

It consists of a detailed visual verification of the tank's surface and its auxiliary systems. The visual inspection can be carried out with the tank in normal operation conditions or on the occasion of tank stoppage. The inspection with the tank in operation allows to identify leaks, freezing, overheating, etc. that would not be usually detected with the tank out of operation.

The internal visual inspection, on the occasion of tank stoppage, is of great importance for the identification of internal damage mechanisms in the roof, the shell and the bottom, which characteristics are not uniform and that are difficult to detect through external non-destructive testing. For the inspection to be objectively carried out, the inspector should follow the inspection plan and complete each of its steps.

The visual inspection should include, at least, the following aspects:

8.6.1.1. Thermal insulation

If the tank is insulated, a visual inspection of the whole area should be carried out identifying moisture infiltration places from rain or sprinkler systems.

The insulation lining joints that are defective or with cracking or fissures are areas that have a tendency to experience infiltrations. The inspector should identify them even though there is no loose tape or area with deformations. In tanks that have been out of operation for a long time, the entire insulation should be removed as, under these conditions, corrosion is intense.

Regions under the platforms, as well as regions close to connections and supports, if any, tend to have insulation failures.

It is recommended to remove parts of the thermal insulation to evaluate the conditions of the shell plates, mainly in low pressure tanks that operate at low temperatures. For those tanks, it is advisable o take a larger sample or even the entire insulation as experience shows that there could be humidity condensation between the tank wall and the insulation with a corrosive process in localized areas.

8.6.1.2. Protection paint

The most common defects found in tank protection paints are the following:

8.6.1.2.1. Blisters

The main causes of paint blisters are:

- Humidity, oils, greases, or dirt during application. It appears in the short term, after the application.
- Tank operation, even during short periods at temperatures above the resistance limit of the paint. It appears immediately after deviation.
- Incompatibility between coats that make up the paint scheme.

– Inadequate intervals between the paint coats, causing adhesion problems between coats.

To identify the probable cause of blisters, some of them should be broken and the inner part of it should be observed, verifying if there is water or other liquid. In the case of hydrogen blisters, the inner surface will always be clean and dry.

The inspector should also verify if blisters are limited to the finish coats or if they are also in the first coats. In the first case, the recomposition of the finish coats should be recommended and, in the second, the recomposition of the entire paint.

8.6.1.2.2. Chalking

In order to take a decision, the intensity of the wearing away should be evaluated. For example, redo the finish paint or specify a more adequate scheme.

8.6.1.2.3. Abrasion/erosion

Wearing away in localized areas, due to the action of solid particles moved by the wind or the friction between two solid parts. Floating roof tanks are particularly sensitive to abrasion in their intermediate rings.

8.6.1.2.4. Crackings, wrinkles and corrosion points scattered across the painted area.

The appearance of these defects suggests:

- In recent paint: incorrect application;
- In relatively new paint: inadequate paint scheme;
- In old paint: conclusion of the useful life of the system.

For all defects, the repairing requires the complete application of new paint. ASTM D 610, D 659, D 661 and D 714 standards show photographic examples that can be used as an aid in your evaluation.

8.6.1.3. Cathodic protection

The evaluation of the cathodic protection system should be carried out according to API RP 651 and NACE RP 01-93 recommended practice. Tank (exterior part) – soil potentials should be measured, and the operation conditions of the cathodic protection rectifier units should be evaluated as well as sacrificial anodes and their connections. These inspections are carried out more frequently than tank inspections. If applicable, dielectric joints should also be inspected and the possible interference with other protection systems should be evaluated.

8.6.1.4. Electrical grounding

It is frequent that an intensive corrosion process occurs in the fixing terminal of the tank grounding cable. The inspection hammer should be used to verify the joint integrity. Besides, the grounding resistance should be measured, taking the precaution to previously disconnect the impressed current for cathodic protection, if there is one. The grounding integrity is important to avoid the effects of static electricity.

8.6.1.5. Stairs and platforms

The most common problem found in stairs and platforms is corrosion due to the deterioration of the protection paint. Steps and stair parapets should be attentively verified as the safety of the staff that has access to the tank depends on their integrity. For platforms, it should be verified if there are areas with signs of rainwater accumulation. In these regions, it is advisable to make a hole in the metal sheet to drain water, so it does not accumulate.

8.6.1.6. Safety devices

It should be verified:

– the apparent condition and signs of leaks or obstruction of components; and
– for devices like safety or relief valves, or vacuum and pressure valves, if the adjustment pressure corresponds to the one specified in the tank design.

8.6.1.7. Tank base inspection

The inspection of this component should always be considered in the visual inspection planning. Some points should be verified more carefully as the area is subject to localized corrosive processes due to cracking. The anchorage exposed area should be also verified and, with the help of an inspection hammer, the integrity of the equipment jetnuts should be evaluated. During this inspection the aspects that may show settlement problems of the base and, therefore, of the tank, should be carefully verified. For more details see item 8.6.13 – Settlement evaluation.

8.6.1.8. External inspection of shell and roof

It consists of the detailed visual verification of the external surface of the tank and its systems, in order to detect any anomaly in relation to its design, such as deformations, external corrosion, etc.

8.6.1.9. Internal inspection

In an internal visual inspection of a tank, the inspector should focus on the following:

- When the tank is opened, the existence of deposits, wastes and inlays should be verified; observing their kind, quantity and location.
- The shell, bottom, weldings and connections should be inspected as for deformations, fissures, corrosion and erosion, and damages due to cleaning or maintenance. In some cases, it may be necessary to remove internal components of the tank.
- The internal condition of connections as for corrosion and obstruction should be evaluated.
- The integrity of the inner liner should be verified, if there is one.
- The location, securing and integrity of internal components should be evaluated, if there are, such as: distributors, support points, coils, articulated drains, anti-rotational, etc. It should be verified that there are no deformations in the floor due to a wrong support of the roof legs.
- Places to be prepared for non-destructive testing should be identified.

8.6.1.10. Roof evaluation

The structural condition and the support system should be verified, as well as the pontoons tightness in the case of floating roofs, the floating membrane, if there is one, the roof drains, the perimeter seal system, and the venting systems. Moreover, evidence of corrosion should be sought and it should be verified that its position is correct in relation to the shell. The mobility of the roof support legs should also be verified.

8.6.1.11. Auxiliary systems evaluation

The following systems should be visually inspected: fire protection system, dams, pipings, flanges, steam system for coils, electrical connections, pressure caps, double bottom leak detection system, emergency vents, etc.

8.6.2. Inspection with hammer

It is used as a complement of the visual inspection by means of a ball hammer hit on those surfaces that are found suspicious by the inspector, evaluating the sound and the movement of components such as rivets, studs, bolts and nuts.

In this way, debilitated areas, structural problems, detachments and loose components are detected in the tank itself, as well as in auxiliary systems.

8.6.3. Penetrating liquids

Testing method based on the capillarity phenomenon that, in other words, is the penetration power of a liquid in cavities or narrow fissures due to the physical and chemical characteristics, like surface tension.

The penetrating liquids testing is used to detect discontinuities which are open to the surface in suspicious areas.

8.6.4. Magnetic particles

It is a non-destructive method for detecting discontinuities in ferromagnetic materials.

It is based on the principle in which the magnetic field lines in a ferromagnetic material are distorted by an interruption of the material continuity. It consists in the following three steps:

1. Identifying an appropriate magnetic field in the object to be tested.
2. Applying magnetic particles to the surface of the object to be tested.
3. Examining the surface of the object to be tested to detect accumulation of particles and evaluate the ability of the object to remain in service.

The method can detect any discontinuity in the surface and, under certain conditions, those completely located under the surface. It detects discontinuities such as: fissures, inclusions, lack of penetration, lamination, pores, etc.

It depends on the magnetic properties of the object to be tested and it is only suitable for metallic materials that can be considerably magnetized. Non-ferromagnetic materials that can not be strongly magnetized can not be inspected with this method. Some examples are: aluminum, magnesium, brass, copper, bronze, lead, titanium, and austenic stainless steel. In appropriate ferromagnetic materials, the magnetic particle inspection is highly sensitive and shows the condition of the surface to be tested quickly and noticeably. An experienced inspector may –when the characteristics of the area and the indication degree of the testing are examined- interpret their causes and evaluate discontinuities.

8.6.5. Ultrasound

It detects internal discontinuities in materials based on the acoustic waves reflection phenomenon when obstacles for its diffusion are found in the material.

Ultrasound is also used to measure thickness and determine corrosion very easily and precisely. The traceability and identification of the measuring points are important for the calculation of the corrosion rate and the remaining life monitoring. Measuring points should include different areas of the tank such as the water level area, the operative area, the product level area, and the vapors area. Thickness measuring is the most commonly used method to establish the remaining life of the tanks that have a uniform thickness loss.

There are several additional techniques that are an evolution of the basic principle, such as TOFD and phased array, among others.

8.6.6. Radiography

It is a method based on the change of intensity of electromagnetic radiation (X or gamma rays), caused by the presence of internal discontinuities, when the radiation goes through the material and the image is saved in a radiographic sensor, a film or a digital sensor.

Radiographic testing is used in tanks to detect discontinuities in welded joints, especially in their construction and repairing.

8.6.7. ACFM (Alternative Current Field Measurement)

This electromagnetic technique may be particularly used in the detection of fissures in the bottom of tanks.

8.6.8. Magnetic flux leakage (MFL and LFET)

Allows for a quick scanning of big surfaces, detecting corrosion in the external as well as in the internal part of the tank floor sheet. It provides information about the location and the relative severity.

The probability of detecting isolated rusts is higher than in the case of ultrasonic testing, as the scanning area is of around 95% of the inspected area. It is always necessary to perform at least one cross checking of the MFL results with ultrasound before trusting the probability evaluation.

MFL (magnetic flux leakage) and LFET (low frequency electromagnetic technique), characterize the corrosion degree and provide qualitative values according to the nominal thickness, that is why for an accurate verification, it is complemented with the ultrasound technique which does provide a quantitative value.

There is a considerable variability in the quality of these inspections. Experience shows that they can be very effective with appropriately trained and experienced operators using equipment with the appropriate detection capacities.

8.6.9. Thermography

Method that detects the infrared radiation emitted by surfaces and allows to observe differential patterns of temperature distribution, in order to give rise to information regarding the operational condition of a component, equipment or process.

Thermographic inspection (thermography) is a useful testing to detect piping obstruction, tank levels, insulation failures, gas leaks, freezing in the base of cryogenic tanks, etc.

8.6.10. Acoustic emission

It is a non-destructive testing method that is based on the detection of sound waves emitted by diffusion discontinuities in the material. It is necessary to apply a load or stress (usually pressure), to cause the diffusion of discontinuities.

Acoustic emission testing results are not conventional. In fact, this method should not be used to establish the type or size of discontinuities of a structure; but to register the evolution of discontinuities during the application of tensions if loads are enough to cause localized deformations, increase of discontinuities, friction or other physical phenomenon.

The acoustic emission is applied when the dynamic behavior of defects in complex metallic parts or structures is intended to be analyzed or studied, as well as to register their location. The acoustic emission testing allows for the location of the failure, picking it up with sensors installed in the structure or in the equipment to be monitored. The experience in the interpretation of signals results is important, as this test also detects other types of acoustic emissions from the environment or auxiliary equipment. Likewise, it is necessary to complement this test with ultrasound or other techniques, to measure discontinuities. In the specific case of tanks, testing is used to detect defects or leaks in the bottom of the tank.

This method has the advantage of not having the need to take the tank out of service; however, a good correspondence with the results obtained by other non-destructive testing has not been proved yet. In addition, it only detects diffusion discontinuities, which is a limitation for the objective of performing preventive inspections. Nevertheless, developments for optimizing its use in the inspection of tanks are being carried out.

It proved to be very useful as a support for hydrostatic tests, in which it allows to detect diffusion discontinuities and stop the test before a rupture occurs.

8.6.11. Tightness

This type of test is carried out for the detection and location of possible leaks. There are different types:

a) with lime and penetrating hydrocarbon: it is used for detecting leaks in the first interior welding between the shell and the floor of the tank.

b) with vacuum compartment: generally used for welding in internal roof and floor.

c) pneumatic test of floor: used for the floor test in its entirety. It is not recommended as it requires a very precise control of the pressure to avoid floor deformations that may damage welding.

d) hydrostatic test: it is a test of the tank in its entirety. It is usually carried out together with the pressure test described later. In the case of fixed roof, cryogenic or low pressure tanks (API 620), the hydropneumatic test can also be carried out.

e) helium test: this test is used in cases of highly dangerous products, like ammonia, due to its high sensitivity.

f) acoustic emission: acoustic emissions generated by leaks are detected by correctly placed sensors. This method can also be used for the detection of discontinuities, as it was previously explained.

It is also recommended to carry out tightness tests to coils and articulated drain arms (or drains).

8.6.12. Resistance test

In the case of new tanks, or at the end of inspection and maintenance services in which repairs that could have affected the structure of the tank were recommended or performed, it is necessary to carry out resistance tests, that could be carried out with water or another incompressible fluid that provides the same pressure effect, as long as it is compatible with the material of the tank. For the specific case of low pressure tanks, resistance or hydropneumatic tests are usually used.

Because of the elevated tension levels in resistance tests, it is necessary to take the room temperature into account. Under these conditions, a fragile fracture usually occurs, which shows no deformation due to the quick crack propagation. This phenomenon is favored by the thickness and the quality of the construction material of the tank. In general, resistance test in tanks should be avoided when the temperature is under 15°C.

8.6.13. Settlement evaluation

The determination of the soil settlement effects in storage tanks is a very common practice to control the tank bottom settlement. In most cases, a monitoring program is started during the construction and continues during the hydrostatic test and the operations. During service, settlement measurements should be carried out with a programmed frequency.

If at any time, settlement is considered to be excessive, the tank should be emptied and releveled.

The methods used to correct tank settlement include techniques such as localized repairing of bottom metal sheets, partial re-leveling of the tank perimeter, among others.

The main types of settlement are related to the tank shell and the floor metal sheets. These settlements can be registered through the adoption of level measures (using levels, theodolites, plumb lines, water level, or other appropriate elements) around the circumference of the tank and in its entire diameter.

8.6.13.1. Shell settlement

The settlement of a tank is the result of one or a combination of the three types of settlements detailed below:

a) Uniform settlement: this type of settlement is generally predictable, with enough accuracy, from soil testing. It can vary in magnitude, depending on the characteritics of the soil. The uniform settlement does not provoke tensions in the tank structure. However, pipings and accessories should be taken into acount to avoid problems caused by this type of settlement.

b) Flat slope: this settlement makes the tank turn and causes its inclination. The inclination causes an increase in the liquid level and, therefore, an increase of the circumferential tension in the tank shell. Besides, the excessive inclination may cause the floating roof peripheral seals to join together and block its movement.

c) Differential settlement (out-of-plane): due to the fact that a tank is a more flexible structure, it may settle in a configuration which is not plane, causing additional tensions in the shell. Out-of-plane settlements of the shell may cause roundness problems in its upper part, which, depending on their extension, they may interfere with the correct operation of the floating roof. This out-of-roundness could also affect the internal structures of the tank, such as roof support structures, columns, girders, etc.

8.6.13.2. Edge settlement

The edge settlement occurs when the tank shell is strongly settled around the perimeter of the tank, which causes a deformation of the bottom metal sheet, next to the shell-floor joint.

8.6.13.3. Other types of settlements

Floor settlements next to the shell, as well as away from it, can be found in storage tanks. For a detailed analysis of them please see API STD 653, Appendix B.

8.6.13.4. Establishing acceptable settlement

For each of the aforementioned settlements, an evaluation should be carried out, through level testings, of the critical nature of the settlement and its influence on the storage tank integrity. For details please see API STD 653, Appendix B.

8.6.13.5. Assessment to be carried out during the hydrostatic test

8.6.13.5.1. Initial study

In the case that a settlement is predicted, the foundation settlement should be evaluated during the receipt hydrostatic test. The tank settlement should be initially studied with the tank empty with an even number of measuring points uniformly distributed around the circumference. This analysis provides basic readings for the assessment of future settlements. When this initial study is not available, the tank is supposed to be initially leveled.

The tank settlement measurements should be evaluated for acceptance according to API STD 653, Appendix B.

8.6.13.5.2. Study during hydrostatic test

Settlement shall be measured during filling and when the water reaches 100% of test level. Excessive settlement, in accordance with API STD 653, Appendix B, will be enough cause to stop the test for foundation investigation and/or repair.

8.7. Summary of testing methods

Table 8.7 shows a summary of the techniques used in the research and detection of damage mechanisms.

Table 8.7: summary of inspection and testing methods and techniques

Method	Type of failure mechanisms or discontinuities that can be detected	Advantages	Limitations
Visual inspection	Wearing away, corrosion, erosion, abrasion, fissures, deformations, blisters, paint chalking, general condition of different components, etc.	It can be carried out on-site and does not need special equipment. It only requires illumination and cleaning and can be easily registered through photographs.	Only what is accessible to the inspector´s view is detected. It requires a lot of experience.
Inspection with hammer	Structural damages, debilitated areas, loose rivets, studs, bolts or nuts, detachments.	It is simple and easy to implement. Good complement to visual inspection.	It provides limited information. Spoils paint. It is not advisable with the tank in service (do not implement under pressure).
Penetrating liquids testing	Discontinuities which are open to the surface, especially fissures and pores in welding.	It is highly portable, does not require electricity.	It loses efficiency if cleanning is not appropriate, if the superficial preparation closes discontinuities to the surface or if they are full of corrosion products.
Magnetic particles testing	Discontinuities which are superficial or very near the surface, especially fissures and pores in welding.	It has a high sensitivity to detect superficial discontinuities, even when the superficial preparation can close them in the surface or when they are full of corrosion products. Better resolution and sensitivity than the penetrating liquids testing.	It does not detect internal discontinuities. Can not be used in non-ferromagnetic materials.
Ultrasound	Internal discontinuities, especially in welding.	It is highly sensitive to fissures, lack of fusion and lack of penetration.	It requires personnel with a lot of experience and who are highly reliable.

Method	Type of failure mechanisms or discontinuities that can be detected	Advantages	Limitations
Ultrasonic thickness measurement	Generalized corrosion. Thickness verification in localized corrosion areas located by MFL (especially rusts in the lower part of the floor).	It is a highly portable and quick testing for which personnel can be relatively easily trained. If thickness measurements are carried out in the same areas, corrosion speed can be calculated and the remaining life can be estimated.	There can be false readings if an instrument that only shows one number is used. The testing for the detection of remaining thickness in rusts requires an instrument with scan A screen, a specific training of the operator and is limited to small areas where the scan is carried out.
Radiography	Internal discontinuities, especially in welding.	It allows to evaluate the radiographic recording after the execution, which can be reevaluated. Allows to test extensive areas in a relatively short time, so it is commonly used in construction.	The thickness to be x-rayed is limited depending on the radioactive source available. The detection of fissures and lack of fusion is limited, depending on the orientation. It requires radiological protection special cares (exclusion area for personnel foreign to the execution).
ACFM (Alternating Current Field Measurement)	Superficial discontinuities or very near the surface.	It does not require direct contact, it allows for less demanding superficial preparations than the penetrating liquids and the magnetic particles testings and can be carried out without removing paint. It can be used in non-ferromagnetic materials.	It requires highly qualified and experienced personnel.

Method	Type of failure mechanisms or discontinuities that can be detected	Advantages	Limitations
Magnetic flux leakage MFL and LFET	Thickness loss, especially of the floor.	It allows to detect thickness losses in the interior as well as in the exterior side of the tank floor. It allows to identify the places in which there is rust in the lower part (not visible) of the floor, testing up to 95% of the floor surface in a relatively short time. MFL and LFET allow to obtain comparable data, which have been proved by later ultrasonic measurements.	It requires to be complemented by ultrasonic testing to obtain measurements of the floor thickness, as results depend on the volume and on the geometry of the missing material. It has difficulties to detect very localized thickness variations (for example, holes made by a drill may not be detected).
Thermography	Insulation failures.	It is relatively simple and effective. Especially suitable for qualitative determination of areas with different temperatures.	It requires special instruments. Limited to surface. Influence of the surface emissivity which affects temperature values.
Acoustic emission	Active discontinuities (which are increasing as the equipment is subjected to a growing charge).	It can be carried out in service trying to identify those tanks in worst conditions in order to be opened and to localize, through acoustic emission, the areas in which other NDT should be implemented to evaluate discontinuities.	Interference with noises and difficult interpretation. Its efficiency has not been proved yet. There are reports of cases in which acoustic emission test predictions have not been confirmed when tanks were opened.
Tightness testing, technique with lime and penetrating hydrocarbon	Passing discontinuities in the base welding pass between the tank shell and floor.	It is simple and effective as intermediate testing in the manufacturing and repairing that involve welding between the tank shell and floor.	Sensitivity is reduced if the superficial finish of the welding is not adequate.
Tightness testing, technique with vacuum compartment	Passing discontinuities in the tank floor and shell weldings.	Simple and highly sensitive testing. It allows to carry out the welding quality control as it is being done.	It requires a constant control of vacuum conditions in each location of the compartment. It requires special compartments to adapt to areas which are not flat.
Tightness testing: pneumatic test of the floor	Passing discontinuities on the floor.	It tests the entire floor at the same time.	It requires a very precise control of pressure to avoid floor deformations.

Method	Type of failure mechanisms or discontinuities that can be detected	Advantages	Limitations
Tightness testing, hydrostatic test technique	Passing discontinuities. Especially used in construction and welding repairs.	A tightness test and a resistance test which allow to evaluate the entire tank are carried out simmultaneously.	Relatively low sensitivity (lower than the vacuum compartment test).
Tightness testing, helium technique	Passing discontinuities.	Highly sensitive test.	It requires special equipment and specific personnel training.
Tightness testing, acoustic emission technique	Passing discontinuities.	It is highly sensitive. It allows to detect leaks in hydrostatic tests as pressure rises, with the possibility to stop the test to avoid rupture.	It requires the use of specialized material and personnel.
Resistance test: hydrostatic testing	Discontinuities that prevent the tank from supporting required loads.	It allows to verify the tank´s ability to resist load. It allows to carry out an overall test of the tank. It lightens residual tensions.	It requires enough water and may take a considerable time for water filling, inspection and water discharge.
Settlement evaluation	Differential settlement.	Relatively simple. It allows to detect serious structural problems which lead to tensions or damage auxiliary systems.	It should be implemented periodically in order to detect deviations in advance, as settlement problems can be hard to solve.

8.8. Effectiveness of testing methods

Each method has certain effectiveness and therefore, a reduction of the failure probability. The effectiveness depends on the limitations of the method itself (inherent effectiveness), but also on the area covered, instruments, methods, personnel, frequency, special analysis and conditions. In table 8.8 below, the effectiveness of several inspection methods is compared.

Table 8.8: example of inherent effectiveness of some inspection methods for the detection of some typical discontinuities

Inspection method	Discontinuities						
	Localized thickness loss	Generalized thickness loss	Superficial fissures	Internal volumetric discontinuities	Internal planar discontinuities	Dimensional change	Blisters
Visual inspection	1-3	3-5	2-4	5	5	1-3	1-3
Penetrating liquid	5	5	2-3	5	5	5	5
Magnetic particles	5	5	1-3	5	5	5	5
Ultrasound	1-4	1	2-4	1-3	1-3	5	1-3
Radiography	1-3	1-3	5	1-3	4	3-5	5
MFL - LFET	1-2	3	5	5	5	5	5
Acoustic emission	5	5	2-4	4	5	5	4-5
1= highly effective; 2= moderately effective; 3= satisfactory; 4= not very effective, 5= ineffective (rarely used)							

In general, a combination of inspection and testing methods and techniques should be used to get the desired effectiveness. API 581 recommended practice provides some guide tables for assigning the inspection effectiveness for the most frequent failure mechanisms and inspection strategies in storage tanks.

Based on the effectiveness and the inspection frequency of each tank in particular, and following the guidelines of that recommended practice, it is possible to estimate the probability reductions for failure mechanisms identified as probable.

9. Analysis of inspection results

9.1. Calculation of remaining life

The remaining life is calculated in relation to the main damage mechanism and depending on its respective failure characteristic.

Damage mechanisms with characteristics that are not related to the age (for example, stress corrosion or environmental cracking) have a limited scope in the calculation of the remaining life and require a special approach oriented towards the control and monitoring of the variables that may cause damage.

The remaining life of the damage mechanisms that lead to thickness loss can be calculated based on the inspection results.

The objective of an inspection is to determine the remaining life of the inspected component. For example, when the thickness of the shell metal sheet is measured over time, its corrosion rate can be established in mm/year, generalized as well as localized (as pitts) corrosion, and its remaining life can be determined until the withdrawal thickness is reached.

If the corrosion rate controls the tank's life, the remaining life (RL) should be calculated in the following way:

R L = (TMEA- TREQ)/CORRR

Where:

– RL is the remaining life, in years;
– TMEA = thickness measured during inspection, in the section used to determine the TREQ, in millimeters (inches);
– TREQ = minimum acceptable thickness in the tank's section or area under analysis, in millimeters (inches); and
– CORRR = corrosion rate that indicates the amount of metal removed as a result of corrosion, in mm/year or thousandth of an inch/year.

For new tanks or for those that changed their operation conditions, one of the following methods can be used to determine the estimated corrosion rate:

The corrosion rate is established through data gathered by the owner, or by tank users in the same or similar operation conditions, available in specialized literature. If data for the same or similar operation conditions is not available, the corrosion rate may be estimated by the inspector's experience and knowledge.

If the probable corrosion rate cannot be established by the previous methods, thickness measurement values can be collected after about 1000 hours of operation. Other subsequent measurements will be carried out, at similar intervals, until the corrosion rate can be established.

9.2. Risk based inspection

The "risk based inspection" is a method that uses risk as a basis to prioritize and manage the efforts of an inspection program.

In an operating plant, in general, a relatively large percentage of the risk is associated with a small percentage of equipment items.

The "risk based inspection" focuses the inspection and maintenance resources so as to provide a greater coverage level to those items that contain the highest risk, and an adequate attention to those with the lowest risk.

The method defines the risk of operating equipment as the combination of two separate terms: the probability of a failure to occur in a certain period and the failure consequence. In mathematical terms, the risk can be expressed as:

Risk = Probability x Consequence

The probability analysis is based on a generic data bank of failure frequency, by type of equipment, which is modified by factors that reflect the difference between the generic and the particular item analyzed.

The analysis of the consequence of fluid release is calculated by estimating the amount released; by the prediction of the way in which the fluid affects the environment and by the implementation of models that allow to evaluate the effects on people, the environment or its economic impact.

The RBI provides a connection between the damage mechanisms and the inspection activities that reduce the associated risks. Even though the inspection does not directly reduce the risk, it is a risk management activity which involves a risk reduction. However, it should be considered that the risk cannot be reduced to zero only with inspection activities, there are factors that may produce a containment loss including, but not limited to, the following:

- Human errors
- Natural disasters
- External events (collisions or hits with objects)

- Side effects of other plants or units
- Deliberate acts (sabotage)
- Design errors

The main deliverable of the RBI methodology implementation is an inspection plan for the different tank components. If there are unacceptable risks, the inspection plan should also include mitigation actions that should be applied to mitigate the risk to acceptable levels.

The process to implement the RBI methodology is shown in figure 9.2 and each step is shortly described below.

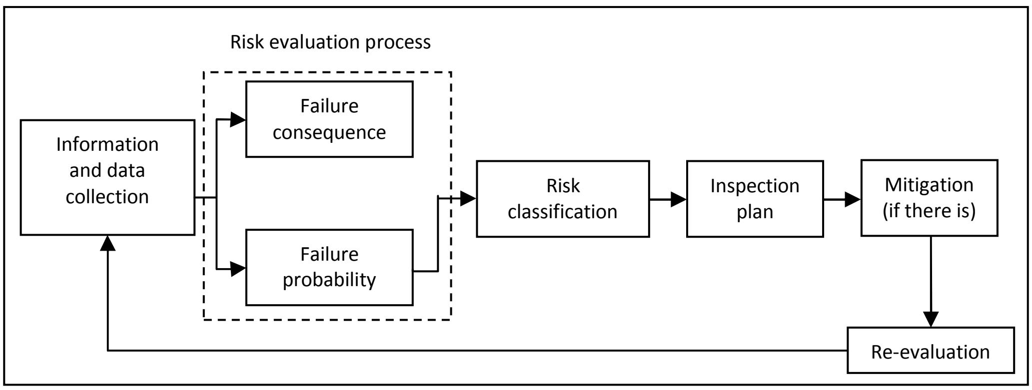

Figure 9.2: implementation process of the RBI methodology

9.2.1. Data collection

Data collection sources should include, but are not limited to:

- Design and construction records.
- Inspection records.
- Process information.
- Change control records.
- Off-site information.
- Failures records.

RBI is a dynamic program and should include a permanent information update; it is important to have a database to keep this information.

9.2.2. Risk analysis

A risk matrix should be defined to establish the probability and the consequences of the failure. A criticality matrix of 5 x 5 is recommended, as shown in figure 9.2.2, or the one already established in each business unit. This guideline recommends the use of a unified risk matrix for assets.

PROBABILITY OF FAILURE					
V	R3	R2	R2	R1	R1
IV	R3	R2	R2	R2	R1
III	R3	R2	R2	R2	R1
II	R3	R3	R2	R2	R2
I	R3	R3	R3	R3	R2
	I	II	III	IV	V
	CONSEQUENCE OF FAILURE CoF				

Figure 9.2.2 [2]: risk criticality matrix

The probability and consequence categories are identified from the lowest to the highest

[2] Reference: ARPEL reference manual for pipelines integrity management

and the combination of these two variables defines risk. It is classified from very high or unacceptable to low. Each company should define its acceptable level of risk.

9.2.3. Inspection plan

As part of the inspection plan, activities with the tank in service as well as activities with the tank out of service should be included. This plan should include:

- Inspection frequency (see item 9.3).
- Inspection technique.
- Inspection scope.

9.2.4. Mitigation

As it was previously mentioned, inspection does not always involve a sufficient reduction of risk or, in some cases, it is not a cost-effective method, so additional risk mitigation actions should be considered. These activities can belong to one or more of the following groups:

- To reduce the consequence severity.
- To reduce the failure probability.
- To improve the survival of people or facilities faced with a failure.
- To mitigate the primary source of the consequence.

9.2.5. Re-assessment:

It is important to keep the RBI study updated to make sure that the recent inspection, process and maintenance activities are included. Every inspection or process or design change will produce a risk variation, which should involve its re-assessment.

9.3. Inspection frequency

The analysis result is introduced in a matrix of five x five that classifies the equipment in levels that go from low risk to high risk.

To guarantee the physical integrity of storage tanks, an external or an internal inspection is recommended taking -for frequency- the results of the last inspections, the project's requirements, the operational conditions, and accordance with the applicable legislation into account. In general, the external inspection should precede –or be carried out together with- the internal inspection.

The interval from the start-up until the first internal inspection should not be longer than 10 years. Alternately, if a RBI study is carried out in accordance with numeral 9.2 and the tank has some of the following protection systems, the initial interval should not exceed what is established in table 9.3.a below:

Table 9.3.a: maximum inspection intervals for protection systems

Tank safeguard	Max. inspection interval
i) Original nominal thickness of the floor 5/16 in. or more	12 years
ii) Effective cathode protection of the floor soil side[1]	12 years
iii) Floor covering product side[2]	12 years
iv) Fibre glass reinforcement of the floor product side[2]	13 years
v) Cathode protection and covering	14 years
vi) Cathodic protection and fibre glass reinforcement	15 years
vii) Leak protection barrier[3]	20 years
viii) Leak protection barrier[3] when a RBI study has been carried out	25 years
1. Effective cathode protection means in accordance with API 651.	
2. Covering of product side means in accordance with API 652.	
3. Protection barrier means a leak detection system in accordance with appendix I of API 650.	

The subsequent interval for internal inspection should be established according to the remaining life described in 9.1 and/or by a RBI study described in 9.2, but cannot exceed the maximum interval described in table 9.3.b below:

Table 9.3.b: maximum inspection intervals according to the procedure used

Procedure used	Maximum interval
i) Calculation of corrosion speed	20 years
ii) RBI study	25 years
iii) RBI study and leak prevention barrier *(see note)*	30 years
Note: protection barrier means a leak detection system in accordance with appendix I of API 650.	

9.4. Advanced analysis methods and adaptation to use – approval criteria

Equipment can have problems such as fissures, localized thickness loss, deformations or others, during the operational period.

There are advanced calculation techniques or methods, such as those described in API 579 and BS 7910, with the purpose of defining the need to repair or alter the frequency and/or the inspection methods.

In these cases, the approval criteria differ from those used by the manufacturing and/or inspection codes, being sometimes more flexible and accepting the existance of damages faced with control conditions.

10. Qualification of inspection and testing personnel

10.1. Introduction

Different types of personnel certifications are applicable to storage tanks. Certifications more frequently used are:

- certification of inspectors in non-destructive testing;
- procedures and personnel certification for carrying out welding;

- welding inspectors' certification;
- paint inspectors' certification; and
- inspectors' certification (ICP API 653).

Procedures and personnel certification for carrying out welding is applicable on the occasion of the construction of the tank or in repairs that imply welding.

The paint inspectors' certification is applicable for quality control of use of new paint systems or in repairs.

The welding inspectors' certification is applicable for quality control of welding during the construction of the tank or for the control of repairs that imply welding.

The inspectors´ certification according to API 653 is applicable for inspection and repairs of storage tanks.

The non-destructive testing certification is very important as personnel frequently carry out critical evaluations that may affect the safety and integrity of the storage tank. As many non-destructive testing methods do not generate permanent records of results, the certification presents objective evidence that the level of knowledge and skills of the professional that carries out the inspection is appropriate. It also guarantees that the inspection will be carried out with the same quality level regardless of the person who carries out the test.

10.2. Certification methodology

There are many organizations that produced standardization and minimum recommendations for qualification and certification. At present, there are many methodologies, and different among themselves, like for example: certification by an independent organization, sectoral certification, certification of very reduced scope, etc., but all of them are due to the same philosophy, the need for a qualification to carry out NDT, being certification a proof of this qualification.

Only the standardization of the different methodologies will guarantee the same level of competence and quality throughout the countries. The first step for international harmonization was the creation of a common international standard for national standards to be based on. With this purpose, the international standardization ISO 9712 was carried out "Non-destructive testing, qualification and certification of personnel".

The present trend of countries in Latin America and the Caribbean is that, at least an important part of the certification is carried out by independent organizations or by a third party, recognized for their certification in accordance with internationally accepted standards. Examples of national standards: EN 473 (Europe), IRAM-ISO 9712 (Argentina), and NBR ISO 9712 (Brazil).

The NDT certification methodology even more known is the one of the American Society for Non-Destructive Testing – ASNT, which establishes the minimum reccomended requirements in the document ASNT-SNT-TC-1A. It is a first-person certification in which professionals are not certified by independent organizations.

It is advisable to use the existing certification methodology of the country in which the storage tank is located for professionals' qualification and certification of non-destructive testing used in their construction or repair. In the case that there is no methodology, the methodology presented by ASNT should be specified.

10.3. Certified non-destructive testing methods

For storage tanks, the certification for the different non-destructive testing methods listed below can be obtained.

Table 10.3: non-destructive testing methods

Acoustic emission	AT
Electromagnetic test	ET
Sealing test	LT
Penetrating liquids test	PT
Magnetic particles test	MT
Radiographic test	RT
Infrared test	TT
Ultrasonic test	UT
Visual test	VT

10.4. Certification levels

In general, the certification personnel are certified in different levels for each NDT method. The usual levels in almost all the countries are the following:

Level I – inspector qualified to carry out very specific and simple tests and calibrations, in which the approval or rejection criteria are determined by a procedure. The level I inspector should act under the supervision of an inspector of higher level. The level I inspector cannot be responsible for choosing testing methods or the interpretation and evaluation of results.

Level II – inspector with the ability to carry out the calibration of instruments and the inspection following procedures, to interpret, evaluate and register the test results. This level should know the applicable standards and other applicable documents.

Level III - inspector with the ability to develop techniques and procedures, interpret codes, and specify non-destructive testing methods. He/She should also have some knowledge of materials and products manufacturing. These professionals are also responsible for training level I and II professionals.

10.5. Certification and qualification requirements

The candidate for qualification in non-destructive testing should meet minimum formal education, physical conditions (generally vision), training and experience requirements prior to the qualification exam.

The procedures that guarantee that the NDT personnel have the necessary qualifications should include:

- training to acquire the necessary knowledge;
- experience with supervision of more experienced professionals;
- physical condition;
- qualification exams to prove competence; and
- certification to show approval according to the certification system criteria.

The training level and the experience for different specifications are similar for the different systems. Typical requirements are shown in the table below:

Table 10.5: training and experience typical requirements

Test method	Level	Hours required in NDT training (2)	Minimum working experience in the method (months) (3)
Acoustic emission	I	40	3
	II	104	12
Electromagnetic	I	40	3
	II	104	12
Penetrating liquid	I	16	1
	II	40	4
Magnetic particles	I	16	1
	II	40	4
Radiography	I	40	3
	II	120	12
Infrared	I	40	3
	II	120	12
Ultrasound	I	40	3
	II	120	12
	I	16	1
Visual	II	40	4
	I	40	3

Notes:
(1) Reference: ISO 9712:2005
(2) Hours required for level II training courses include training hours for level I
(3) The experience is based on 40 nominal working hours a week, and are totals cumulative.

10.6. Exams

In general, the exams required to prove the knowledge of the candidate on the testing method is subdivided according to:

For levels I and II:

General exam: about the general theory of the main method. Multiple choice questions.

Specific exam: about the specific theory of the implementation of the method to certain products or processes of the sector. May include calculations and questions on codes, norms, specifications and procedures.

Practical exam: it consists in the application of the method in specific pieces, recording and - for level II - interpreting and assessing the results of the test.

For level III:

Level III basic exam: multiple choice questions on 3 aspects:

- technical knowledge on science of materials, process technology and types of discontinuities;
- knowledge of the system of qualification and certification; and
- knowledge of at least 4 methods as required for level 2, including UT or RT, the minimum.

This exam is common to all methods.

Main method exam:

- knowledge on the test method;
- application of the method in the sector, including codes, norms, specifications and procedures; and
- preparation, by the candidate, of one or more NDT procedures in the method in which the certification was requested. The procedure will include the test of some elements or components according to a specific code or norm.

Practical exam: if the candidate has not passed level II exams before, he/she should also approve the level II practical exam in the method.

10.7. Certificates

According to the results of the qualification exams and of the documents provided, the official certification organization of the country decides whether to grant the certification or not and issues, in this case, the corresponding certificates.

Certificates issued will include, at least, the following information:

a) Complete name of the person who is certified.

b) Reference to the regulation, standard or certification process.

c) Certification date.

d) Certification expiry date.

e) Certification level.

f) NDT method.

g) Identification number.

11. Repairs, alterations and quality control

Storage tanks that are in use may need to be repaired or altered. In order to keep the original performance and safety characteristics, it is recommended that these changes are carried out according to criteria and procedures established based on recognized laws and regulations and accepted by the industry.

It is also important that repairs are carried out with such a level of quality so as to preserve its useful life and structural integrity.

Major repairs and changes include:

- to carry out a penetration of the shell larger than NPS 12 beneath the design liquid level;
- to carry out a penetration in the lower part of the tank within 12 inches of the shell;
- to remove, replace or add a shell plate under the design liquid level when the largest dimension of the replacement plate is greater than 12 inches;
- to remove or replace the annular plate ring material when the largest dimension of the replacement plate is greater than 12 inches;
- to remove or replace completely or partially more than half the thickness of the vertical weld joining shell plates, or the radial weld joining the annular plate ring;
- to install a new complete bottom. If a partial installation of a bottom is carried out, without changing/modifying the critical area of the tank, it will not be considered as a major change/modification. See API 653 12.3.3.3;
- to remove or replace part of the shell welding of the inferior part, or the annular plate ring, additionally to what is specified in API 653 12.3.2.5.1 a; or
- to lift a tank shell.

It is recommended that as part of the instructions to establish a repair and alteration plan, a plan to guarantee the quality of materials, repair procedures, personnel, equipment, electrodes, source rods and analysis and testing methods to be used is also established. This quality plan should be internally approved within the organization and reviewed in detail by the key actors. In the case that other companies or contractors are selected to carry out repairs, it should be required that they provide a quality assurance plan.

A quality plan should include, at least, the following elements:

1. Identification of a Quality Manager, and Quality Chiefs to work on-site.
2. Quality objectives.
3. Deliverables and key processes of the project to be reviewed to meet a satisfactory quality level.
4. Quality standards.
5. Quality control and assurance activities.
6. Quality roles and responsibilities.
7. Identification of quality tools and testing methods.
8. Plan to report quality control and assurance problems.

11.1. Materials

The materials used in repairs or alterations should meet the requirements of the original code.

The materials used should be traceable up to the original manufacture source through the required chemical composition and production certificates. It is recommended to carry out a verification of materials and on-site baseline NDT through the "Positive Detection of Materials" to ensure the materials appropriateness.

11.2. Replacement of components

The components to be replaced that will be subject to efforts, made up of new materials manufactured by casting, forging, extruding and other processes that do not use welding, should include identification of the manufacturer, so as to be able to track the original characteristics. Tubes with or without seams, holes and connections, and metal sheets are some examples.

The components to be replaced that will be subject to efforts, and that are premanufactured by welded insulations, should be welded according to the original code of construction. The supplier or manufacturer should certify that the material and the manufacturing are according to the original code of construction.

When tank components are replaced, the replacement should respect the dimensional tolerances established in the original code of construction of the tank. This precaution should be taken in the critical areas as the tank floor, lower part of the shell, roof, and roof support columns.

In the event of a conflict between codes, the stricter code should be taken as reference.

11.3. Welding

Every welding should be carried out according to the requirements of the original code of the project, to the corresponding repair code, or to the code adopted in the case that there is lack of information.

11.3.1. Welding procedure specification

Welding should be carried out according to the welding procedure specification that is qualified according to the original code of construction or, if this is not possible, the code that is recognized and accepted by the community.

11.3.2. Welder qualification and identification

Welders or welding operators should be identified and qualified for the welding procedure used. The owner should have its own database of welders to guarantee that only qualified welders carry out the jobs and have a record of the welder´s performance.

Welders should identify with their registration letter or number all the welding carried out, with indelible marks and they should be identified in the welding registration report. The use of embossed letters or numbers as marks in stainless steels should be avoided, as they could lead to stress corrosion in the material as it is subjected to a corrosive environment.

11.4. Quality control of repairs

Repairs and alterations should be inspected and tested, using recommended methods according to the requirements and specifications of the project. Tests which results are used for the evaluation of the equipment integrity should be carried out by qualified and certified inspectors.

The quality control of repairs should be consistent with the tank repair plan. The tools and the testing methods established in the quality plan for the quality control should be adopted and carried out by trained and experienced personnel. Results should be documented and presented to the project executor.

11.5. Hydrostatic testing

The hydrostatic testing should be carried out for major repairs. It is recommended that the execution of this testing is evaluated by a qualified professional, given the characteristics of damages and repairs in question.

11.6. Records updating

Before putting the tank into operation again, inspection and maintenance records of the equipment should be updated with the recommendations for the next out of service inspection scheduled, and the remaining life of the tank should be re-calculated. The tank inventory records should be updated to make sure that the materials used by the project are replenished. The detailed quality report should be signed by the professionals in charge.

12. Asset management document

The last stage of the integrity inspection/evaluation is the adequate detailed recording and documentation of all that was seen, executed, tested and recommended during the inspection. Inspection records are key components for the subsequent evaluations of the equipment degradation, and also as future references. They work as documents that are part of the operational record, and therefore, they should be organized and kept during the whole useful life of the equipment.

The entire inspection activity should be clearly and completely recorded, usually as an Inspection Report, detailing the scope of the inspection, its extent, the techniques and equipment used, besides including a clear identification of the person responsible for the activities carried out, and other complementary information.

As a result of this exercise, for each tank, the results will be summarized in an asset management document, as the example on the next page.

Tank no. xx

Service	Catalytic naphtha
Year of construction	Xxx
Diameter	Xxx
Height	Xx
Construction material	Xx
Cubage, table certified by authority (date)	Xx/xx
Exterior paint (type, thickness, date)	
Interior paint (partial or total, type, thickness, date)	

Components	Design thickness	Material
Roof		
Floor		
Shell		
Etc.		

Inspection and repairs record

Inspection/repair date	Findings
xx-xx-xxxx Inspected by xx	Today an inspection of the floating roof of Tank xx was carried out, which was floating in the superior part with a product level of 12,509mm and going down. Ultrasound thickness measurements were carried out in some metal sheets to guarantee the safe movement of the cleaning staff, obtaining values between 4.0mm and 5.0mm. No anomalies or product movements were detected by the visual inspection.

Failure modes

Scenario	Degradation mechanism	Initial risk	Mitigation measure	Mitigated risk
Small leak through tank floor. There is perforation in the floor, hydrocarbon leak on the soil. Estimated repair cost < 100,000USD.	Localized corrosion by external attack.	SHE consequence: III ECON consequence: IV Probability C Risk C-III	Scanning inspection of the floor every 8 years.	Probability D D-III

Inspection plan

Component	Inspection frequency	Techniques to be used
Tank floor	8 years	Floor scanning
Tank shell	Every x years	Ultrasound thickness measurement, in operation

The fulfillment of a tank integrity management plan, complemented by an efficient fulfillment of the corresponding planning, allows to guarantee the operative availability and reliability of storage tanks, avoiding unexpected failures that could cause undesired operative pauses, accidents or environmental impacts.

Fulfillment best practices are part of the national framework binding laws, and international reference standards as API 353, 580, 650 and 653.

Therefore, once the plan is established, the historical background is known, the specialized inspection is carried out, the type of failure is identified and the corresponding analysis is carried out, it will provide the necessary tools to take the corresponding actions and avoid failures.

Top executives at organizations should be responsible for the fulfillment of a tank integrity management plan, as for every management. They should provide the resources suitable to their operative areas for this fulfillment to be possible, as the more efforts made for an efficient and optimal inspection, the lower the probability of a degradation event in storage tanks to happen.

13. Implications and legal matters on the inspection of equipment

Engineering activities have a complex nature and inherent risks that may affect people and the entire society with different levels of complexity.

Design should abide by national regulations. In those matters in which there are no technical provisions or national regulations, foreign rules, codes, specifications should be applied, as well as engineering recommended practices, internationally recognized and accepted by the local authority.

Regional Association of Oil, Gas and Biofuels Sector Companies in Latin America and the Caribbean

ARPEL is a non-profit association gathering oil, gas and biofuels sector companies and institutions in Latin America and the Caribbean. Founded in 1965 as a vehicle of cooperation and reciprocal assistance among sector companies, its main purpose is to actively contribute to industry integration and competitive growth, and to sustainable energy development in the region.

Its membership currently represents over 90% of the upstream and downstream activities in the region and includes national, international and independent operating companies, providers of technology, goods and services for the value chain, and national and international sector institutions.

Since 1976, ARPEL holds Special Consultative Status with the United Nations Economic and Social Council (ECOSOC). In 2006, the association declared its adherence to the UN Global Compact principles.

Mission

To foster and facilitate sector integration and development, continuous operational improvement and effective management of environmental and social issues, by:

- sharing, enhancing and disseminating best practices;
- carrying out studies that translate in information of value;
- broadening knowledge and helping build required competences;
- promoting networking, interaction and cooperation among members and stakeholders.

Vision

A growing, competitive and integrated oil and gas industry that achieves excellence in its operations and products, and effectively contributes to a sustainable energy development in Latin America and the Caribbean.

Value proposition

ARPEL offers a unique mean for networking, sharing knowledge, joining efforts and building synergies in favor of the sector's integration, growth and sustainability. Without any distinction, Members have the opportunity to alternatively lead activities and projects, contribute with their know-how to their development, or learn from the experiences of other members.

ARPEL´s value is also reflected in its condition of strategic information center about sector activities in the region and cost-effective vehicle for the development of publications on best practices and benchmarking, as well as on sectoral studies and executive reports aimed at diverse stakeholders. The Association additionally stands out for its regional conferences, forums and seminars of high impact in the industry.

ARPEL is a recognized regional body of representation for the sector that seeks to advocate in favor of the common interests of its Membership and to enhance the industry's public image and reputation.

Socio-environmental sustainability
Operational excellence
Sectoral development

www.arpel.org

Member Companies

Institutional Members