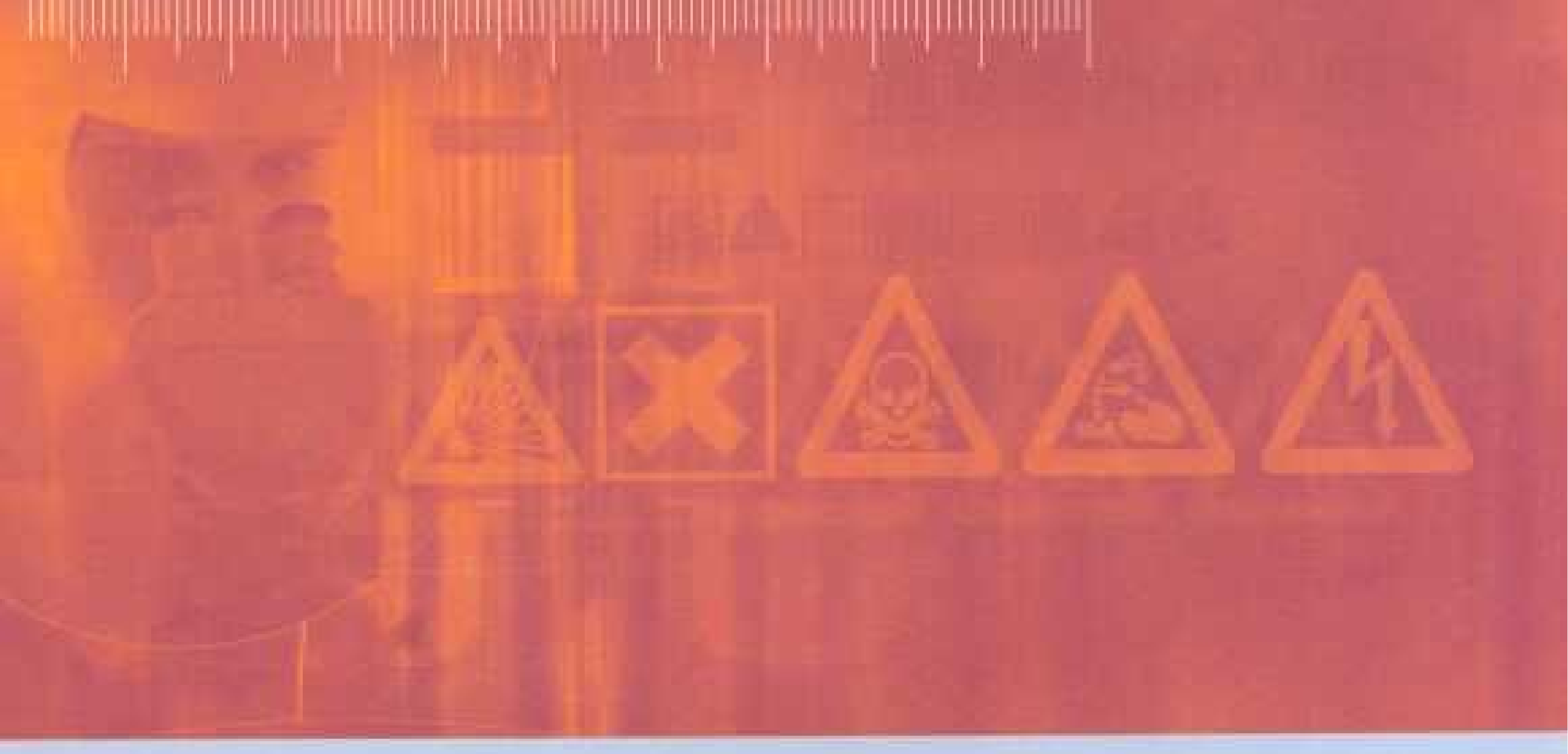


STUDY REPORT 31/12/2009
N° DRA-09-102957-07985C

Final Report - International Benchmark on regulations and practices as regards managing industrial installation ageing

DRA 71 – opération A4
DRA 73 – opération C2.1

DRA71 – OPERATION A4

DRA73 – Operation C2.1

Final Report - International Benchmark on regulations and practices as regards managing industrial installation ageing

Verneuil en Halatte (60)

Contributors: Valérie de DIANOUS, Ahmed ADJADJ, Gaëtan PRODHOMME, Sébastien RICHOMME, Olivier DOLLADILLE, Samuel MAUGER, Frédéric MERLIER, Mathieu REIMERINGER, Aurélie BARBE, Eric DANNIN, Fabrice RICHEZ

FOREWORD

This report was produced on the basis of information provided to INERIS, of available and objective data (whether scientific or technical) and applicable regulations.

INERIS cannot be held liable if the information provided was incomplete or erroneous.

The opinions, recommendations, advice or equivalent that may be offered by INERIS as part of the services entrusted to it, may assist in decision making. Given the mission entrusted to INERIS by the decree creating it, INERIS does not take part in any actual decision making. INERIS cannot therefore take the decision maker's place.

The addressee shall use the results included in this report in full or at least in an objective way. Any use of the report in the form of excerpts or summary memos will be performed under the addressee's sole and exclusive responsibility. The same applies to any modification made to it.

INERIS declines any liability for any use of the report outside of the scope of this service.

The present study report written in English is for information only. The French version shall prevail over any translation that may be made.

	Written by	Reviewed by	Checked by		Approved by
Name	Valérie DE DIANOUS Ahmed ADJADJ Gaëtan PRODHOMME	Frédéric MERLIER Samuel MAUGER Mathieu REIMERINGER	Marie-Astrid SOENEN	Sylvain CHAUMETTE	Yann MACE
Title	Engineers Quantitative Hazard Evaluation Unit (EQRI), Technical Safety Barriers (BT2S) and Structure Resistance (REST) Accidental Hazards Department	Managers DIAG, BT2S & REST units Accidental Hazards Department	Administration Support Delegate Accidental Hazards Department	Head of the Analysis and Integrated Hazard Management Unit Accidental Hazards Department	Director Accidental Hazards Department
Sig- nature	Signed	Signed	Signed	Signed	Signed

TABLE OF CONTENTS

1. INTRODUCTION

1.1 GENERAL CONTEXT: NATIONAL ACTION PLAN AND LIMITS TO THIS STUDY

Following the incidents and accidents that occurred over the past years in French industrial installations, the French Ministry in charge of Ecology launched, through a memo dated 12 December 2008[1] (see Annex A) an action plan on managing ageing as part of the prevention of technological hazards.

As stated in the memo, "*All of the equipment and installations likely to lead to a technological hazard may be covered by actions as part of this plan, whether the equipment and the installations take part in the containment of hazardous or polluting products*" or "*whether they form a safety mechanism by design (e.g. a firewall), whether they play a part in compensating for deviations (e.g. retention, alert or intervention systems) or whether they play a part in managing safety (e.g. command and control systems). Any salient point will receive especially significant attention as part of this plan*".

Discussions took place in working groups (GTs) that gather competent authorities and industrial operators. The working group themes are listed below, the last four being specific to the industrial installation ageing theme:

- flammable liquid regulations,
- pipelines,
- piping and vessels,
- electricity and instrumentation,
- storage tanks,
- civil works.

Furthermore, in its memo dated 11 February 2009[2], the Ministry of Ecology detailed how INERIS would be contribute to the action plan on managing ageing (see Annex B). The Ministry of Ecology finally decided to exclude pipelines from the study.

This document constitutes the report relating to the global study on managing ageing. It is based on a comparison between the regulation and standards in France and abroad, as regards ageing management in industrial facilities (testing and inspecting equipment, qualifying bodies to perform these inspections, etc.). The countries included in this study, beyond France, are the United Kingdom, the United States, the Netherlands and Germany.

---

[1] *Memo BRTICP 2008-601-CBO dated 12 December 2008*

[2] *Memo BRTICP 2009-46/OA dated 11 February 2009*

This report was produced from the following two intermediate draft reports sent to the Ministry end June 2009 and end October 2009 respectively:

- DRA-09-102957-07985A - DRA71 – operation A4 / DRA73 – operation C2.1: Managing industrial installation ageing. This report presents an overview of general monitoring practices in France which are specific neither to a business sector nor to any substances.
- DRA-09-102957-07985B - DRA71 – operation A4 / DRA73 – operation C2.1: Summary memo covering the international benchmark regarding ageing management regulations and practices. This report presents a comparison between the policies used to manage equipment integrity in the following four countries: United Kingdom, United States, the Netherlands and Germany.

The information found in this report comes from:

- A bibliographic analysis of regulation documents, standards and professional guides in France and in the other countries covered by the study,
- Information on practices applied as collected from contacts in the various countries or during conferences,
- Information collected during a survey undertaken by EU-VRI based on a questionnaire that reuses the themes of interest set out in the action plan[3],
- For France, information on practices applied, as collected during 14 visits to certain industrial operators (refineries, flammable liquid depots, LPG filling facilities and chemical plants),
- For France, discussions during exchanges with expert bodies (CETIM, French Institut de Soudure, Bureau Véritas, etc.) and exchanges that took place during the working group sessions set up by the Ministry on the ageing theme.

This report does not aim to guarantee any exhaustiveness in the sources identified (numerous sources that are highly specific to industrial sectors exist), nor in practices seen in the field. It presents a fairly wide but not necessarily exhaustive panorama.

1.2 DETAILS ON THE SCOPE AND LIMITS TO THE STUDY

1.2.1 LIFE CYCLE PHASES TAKEN INTO ACCOUNT

Ageing needs to be managed, especially by monitoring actions that can be performed while the installation is in service or stopped.

Inspections after manufacturing or on setting the equipment or on commissionning it are not covered by the scope of the survey.

This study concentrates on the equipment's operational monitoring phase.

[3] *A first questionnaire was distributed to EU-VRI contacts in the four countries involved in July 2009, but the response rate was disappointing (four in the Netherlands, two in the UK, two in the USA and three with European coverage, and in all responses, only very partial answers). Feedback has shown that the questionnaire was no doubt too long and a second questionnaire was therefore released mid-October with more open questions that made it possible to gain additional responses (one from the US, three from Germany). The responses received to date to both waves of inquiry have been included in this report.*

1.2.2 TYPES OF EQUIPMENT EXAMINED

The equipment covered by this study comprises:

- Pressure equipment (storage tanks or piping in plants),
- Atmospheric pressure storage tanks,
- Equipment (piping or storage tanks in plants) not covered by the pressure equipment field,
- Electrical safety equipment and instrumented safety systems,
- Safety devices that are not electrical,
- Civil works elements such as containment dikes, tank foundations, pipe support foundations.

The equipment excluded from the study, in agreement with MEEDDM, includes:

- Specific process equipment such as reactors, fractionators, heat exchangers,
- Boilers,
- Refrigerating systems and equipment operating at low temperatures,
- Revolving machines,
- Transportation pipelines (excluded from the 2009 study).

This report focuses on general practices that are specific neither to a given field of activity, nor to specific substances.

Two other reports more precisely cover the regulations that are specific to the sectors and substances retained in each of the reports:

- DRA-09-102957-08289B - DRA71 - Operation A1.2 / DRA73 - Operation C2.1: Managing industrial installation ageing - Refinery storage benchmark. This analysis targets two kinds of storage: LPG storage and atmospheric pressure storage tanks for flammable substances.
- DVM-09-102957-08343B - DRA71 - Operation A1.2 / DRA73 - Operation C2.1: Managing industrial installation ageing - Refinery piping benchmark.

For both of these refinery benchmarks, a limited range of substances was retained (see Annex B). Both of these reports set out a panorama of regulations and practices at French refineries. Little information was collected on regulations and practices outside of France.

1.3 ORGANISATION OF THIS REPORT

This report is organised in chapters, as follows:

- Chapter 2: Accidentology,
- Chapter 3: The concept of ageing,
- Chapter 4: Two visions of ageing (for active and passive equipment),
- Chapter 5: Managing ageing - General methodology,
- Chapter 6: Degradation modes and related inspections,
- Chapter 7: General principles for monitoring hazardous equipment: Reference texts,
- Chapter 8: Pressure equipment monitoring policies,
- Chapter 9: Atmospheric pressure tank monitoring policies,
- Chapter 10: Equipment monitoring policies (plant piping and tanks) not covered by pressure equipment regulations,
- Chapter 11: Electrical equipment and safety instrumentation monitoring policies,
- Chapter 12: Non electrical safety accessory monitoring policies,
- Chapter 13: Civil works monitoring policies,
- Chapter 14: Organisation aspects,
- Chapter 15: Conclusion,
- Chapter 16: References,
- Chapter 17: List of Annexes.

Annex C presents a list of abbreviations used in the equipment monitoring field.

The present study report written in English is for information only. The French version shall prevail over any translation that may be made.

.

2. ACCIDENTOLOGY

This chapter aims to provide a statistical presentation of the accidents recorded in France and that are linked with **corrosion and fatigue** phenomena. It is based on accident knowledge recorded by the BARPI ARIA database and linked with installation ageing (www.aria.ecologie.gouv.fr).

Annex D presents a detailed analysis by business sector and type of equipment.

The result is that the accidents recorded cover more corrosion related phenomena than fatigue related ones.

Note: Annex D will provide greater detail on accidentology, with especially attention paid to the Ambès accident.

Note: Please refer to reports on refineries for detailed information on refinery accidents relating to piping and storage tanks. They highlight the sequence of events and the causes identified.

2.1 CORROSION RELATED ACCIDENTS

During the past ten years less than 120 accidents in France with a direct link to corrosion phenomena have been recorded in the ARIA database.

More than half of them relate to piping.

The recorded causes of corrosion affecting the piping are:

- **Internal**: (corrosive substance and lining flaws, e.g. erosion affecting a bend or caused by compressor discharge, deposits low down, etc.).
- **External**: There are a number of different cases:
  - Dripping from a pipe located above,
  - Dripping via supports (racks or pipe supports),
  - Lining flaws (due to wear or works),
  - Corrosion under insulation (CUI),
  - Corrosion under the paint (paint joints),
  - Stress due to poor supporting,
  - Corrosion affecting piping elements (flanges, valves, etc.),
  - Corrosion due to lack of passive protection in the case of underground piping.

An aggravating factor when it comes to the probability of occurrence of these accidents relates to the **possibly difficulties in accessing the piping to inspect their condition** (piping buried or in sheaths, piping up high on racks, piping with insulation, etc.) and the **significant length of sites** (or between sites) making monitoring difficult. The amount of data to be processed is significant.

We note that leaks are often found around the welds.

Accidents affecting <u>storages and tanks</u> are far less numerous (tens).

Causes identified appear most often to be **<u>internal corrosion phenomena caused by defective or missing internal linings</u>**.

We note that in the industries studied, failures affecting tanks related to **crude oil** and **diesel oil**. Sometimes, inspections had taken place previously but the incidents were still able to occur. At the chemical facilities, the tanks involved are mainly **acid tanks**.

2.2 ACCIDENTS LINKED WITH FATIGUE

Ten fatigue linked accidents in France have been recorded in the BARPI ARIA database during the last ten years.

The equipment involved comprises:

- **<u>Tanks</u>** (fatigue cracking affecting a sulphuric acid tank without any link to corrosion), failure of a 1" tapping on a compressor back up tank due to progressive cracking caused by vibration; tank fatigue following successive filling / emptying cycles leading to its cracking; delayed failure (through static fatigue) affecting a tank due to the steel weakening under the effects of hydrogen,
- **<u>Piping</u>**: Failure of a tapping caused by vibration after a failure to reinforce the weld along a pump outlet line, failure of a small diameter drain pipe following successive vibration, failure of a tapping linked to vibration, light fatigue cracking along the edge of a weld in an area where stresses concentrate (especially due to the presence of vibration),
- **<u>Safety systems</u>**: Reactors where the rupture disks open before their correct opening pressure is reached, doubtless due to fatigue; safety pin failure on electric generator units.

These show that vibration causes accidents and that tappings are especially sensitive. The safety systems are also sensitive to fatigue phenomena.

2.3 OTHER SOURCES OF LEARNING FROM EXPERIENCE

During the "Piping and pressure vessels" working group, we note that incidents/accidents occur on pressure equipment every year, including on the equipment that is monitored. Nevertheless, the incidents more often cover piping than equipments and pressure vessels.

From feedback, we learn that leaks are more numerous for piping:

- Made from carbon steel,
- With small diameters,
- That is 30 to 40 years old.

An essential problem is the inability to access some old piping that is hard to inspect or cannot be inspected at all.

3. THE CONCEPT OF AGEING

3.1 AGEING

<u>The concept of a gradual deterioration over time affecting a system's characteristics</u>

In their work entitled "Evaluation et maîtrise du vieillissement industriel – collection EdF R&D"[12]**,** André Lannoy and Henri Procacia define the concepts of **ageing** and **durability**.

Ageing is an ongoing and progressive phenomenon that most often is dependent on a large number of influential co-variables such as operating hours, loads applied, material properties, duty factor, etc. **This results in <u>performance alteration</u> due to a physical or mechanical deterioration mechanism that is specific to the equipment and the materials that it is made up as well as its environmental conditions**.

Ageing may be triggered by other technological or even social or economic causes such as: performance that is less than that of more recent equipment, being passed over by technical progress, incompatibility or obsolescence, a lack of spare parts, economic life limits, changes in regulations, changes to the operating profile, etc. The true service life of equipment or an installation will therefore be dependent on these various technical, economic and regulation considerations.

Ageing is therefore a negative notion that inevitably leads to an entity ceasing to function. This is why, in the industrial field, we pay attention to the service life of an equipment or to its durability.

We can retain the following definition for ageing: the process through which the characteristics of a system, structure or component are gradually modified over time or through use.

<u>Managing ageing</u>

To manage industrial installation ageing, it is essential to identify the primary vectors of ageing, to detect them and to evaluate them as well as to arrange them in hierarchical order and to take the necessary measures to attenuate, defer or eliminate them.

<u>Service life</u>

The true service life is unfortunately a "post mortem" concept. You only ever know the true service life once a major and irremediable failure has occurred. This case is seldom encountered in practice for this is a situation to be avoided and generally it is technical-economic optimisation that determines the service life.

In managing ageing, one seeks to determine **durability**[4], i.e. an item's ability to fulfil a required function under a given set of usage and maintenance conditions, until a limit state is reached. This limit state may be characterised by the end of its useful life, by its unsuitability for technical and economical reasons or for other relevant reasons.

In addition to the true post mortem service life, the period that runs from manufacture to withdrawal from service, there are a number of distinct service lives:

- **Nominal or intrinsic service life or design service life**, the period during which a system, structure or component will work within acceptable limits,
- **Residual service life or remaining service life**, the period that runs from a given time until the system, structure or component is withdrawn from service,
- **Technological service life**: Due to component obsolescence, it is no longer possible to maintain the installation, to replace equipment. In this case, reference is made to technological ageing,
- **Regulation service life**, corresponding to the time when an administrative authority bans continued operation. This service life is a function of technical conditions, operation and maintenance conditions as well as the safety/security reference base,
- **Technical-economic service life**: Beyond a certain threshold, the additional investment spending required may not longer be recoupable in the future, or the industrial risk may be too great. It is generally this criteria that decides whether to shutdown or dismantle an installation or its equipment,
- **Political service life**: A political decision may cause operations to shutdown.

3.2 Terms Linked to Managing Ageing

A certain number of terms and definitions of the terms involved in managing ageing are restated below, based on documents such as "NF EN 13306 – Maintenance terminology – June 2001"[11], "Evaluation et maîtrise du vieillissement industriel – collection EdF R&D"[12], UIC / UFIP guides DT32[39] and DT84[40].

- **Managing ageing**: Technical measures or measures relating to operations or maintenance, aimed at keeping any deterioration due to ageing within acceptable limits.
- **Inspection in service**: An examination or inspection of system, structure or component integrity during operation or shutdown.

[4] *Durability must be distinguished from endurance which corresponds to the robustness of a device and its ability to operate normally during its entire service life, independently of its maintenance. This is therefore a characteristic that is intrinsic to the device.*

Guide DT84[40] restates the definition of the inspection set out by DM-T/P No. 32510[27], par. 3.1: these are *"Predetermined set of measures to be implemented, whether in service or out of service, to ensure the management of the condition of an item of equipment or a group of equipment items under the requisite safety conditions".*

Not to be confused with "periodic inspection" and "requalification inspection" in the regulation sense as stated in the Act of 15 March 2000 modified[22].

- **Inspection plan**: Guide DT84[40] restates the definition provided by the annex to DM-T/P No. 32510[27], par. 3.1. This is a *"Document that defines all of the operations prescribed by the Inspection Service to ensure the management, the status and the conformity over time of pressure equipment or a group of pressure equipment covered by surveillance".*
- **Maintenance**: A set of direct or indirect actions used to detect, avoid or attenuate degradation in a system, structure or component in operation or to restore to an acceptable level, the aptitude of a defective system, structure or component to fulfil its nominal functions.
- **Acceptability criteria**: The specific limit to a functional or status indicator used to evaluate a system, structure or component's aptitude to fulfil the function for which it was designed.
- **Non Destructive Testing** (NDT): The term **Non Destructive Testing** or **non destructive examinations** (with the latter better covering the industrial quality aspect that the former that rather makes reference to laboratory examinations) covers all of the techniques and processes that are used to provide information on the **fitness** of a part or a structure without this resulting in any **alterations that are detrimental** to the part's future use. The term fitness although stressing a degree of closeness with the field of medical diagnostic examinations such as X-rays or scanner examinations, properly delimits the aim behind non destructive testing which is to highlight all of the **defects** that are likely to alter availability, safety in use and/or, more generally a product's conformity with the usage it is intended for. To this end, Non Destructive Testing **(NDT)** stands out as a major component in any equipment **integrity check** process.
- **Service conditions**: These are the **real-life conditions that have an impact** on the system, structure or component (normal conditions, transitory operational variations, errors, accidental conditions).
- Guide DT84[40] defines the service conditions as being *"Service conditions comprising **normal operating conditions** including the start up, shutdown, return to serve and transitory conditions"*.
- **Failure**: A system's inability or a breech in the aptitude of a system, structure or component to operate within the limits set by the acceptability criteria.
- **Degradation**: An immediate or gradual deterioration affecting a system, structure or component that could impact its ability to operate within the acceptability limits. If this degradation is progressive, then this is ageing and it is caused by service conditions.

- **Ageing or degradation mechanisms**: A specific process that gradually modifies the characteristics of a system, structure or component over time or with use.
- **Ageing effect**: Clear cut modifications to the characteristics of a system, structure or component that occur with time or use and that are due to ageing mechanisms.
- **Critical Operation Limit Conditions (COCL)**: The annex to DM-T/P No. 32510[27], par. 3.1 defines COCL as a *"Threshold set by a physical or chemical parameter (temperature, pH, fluid speed, contaminant concentration) that when exceeded may have a notable impact on the behaviour or condition of the equipment or may damage it or that may lead to the appearance of a new degradation phenomena".*
- **Obsolescence**: In economics terms, **obsolescence** is when a product is time expired and has therefore lost all of its value simply because it has been passed by by technical evolution or fashion, even if the product is in perfect operating condition. On the other hand, some companies manufacture products with so-called "**programmed**" obsolescence built-in. This form of obsolescence will occur at a set time during the product's life due to its very design or manufacture. These products are generally designed so that some of their vital components, when they fail, will cost more to replace than the market value of the equivalent new equipment, making replacement unattractive to the consumer. Furthermore, manufacturers often ensure that the standards covering the assembly of the component parts in these devices change more often than the nominal operating life of the vital components, again with the same idea of forcing installed base renewal.

4. TWO VISIONS OF AGEING (FOR ACTIVE AND PASSIVE EQUIPMENT)

From the point of view of managing ageing in industrial installations, a distinction will be made between:

- The equipment that will follow preventive maintenance programs so as to maintain a relatively constant failure rate. In this case, any end of service life is generally accidental and sudden. This equipment is more often classified in the **active equipment** category and covered by a so-called **reliability based approach to ageing**.
- Equipment that will age naturally and degrade more or less quickly depending on the dominant physical phenomena affecting them. These are inspected or monitored regularly. This equipment is generally classed in the so-called **passive equipment** category and they are covered by a **physical approach to ageing**.

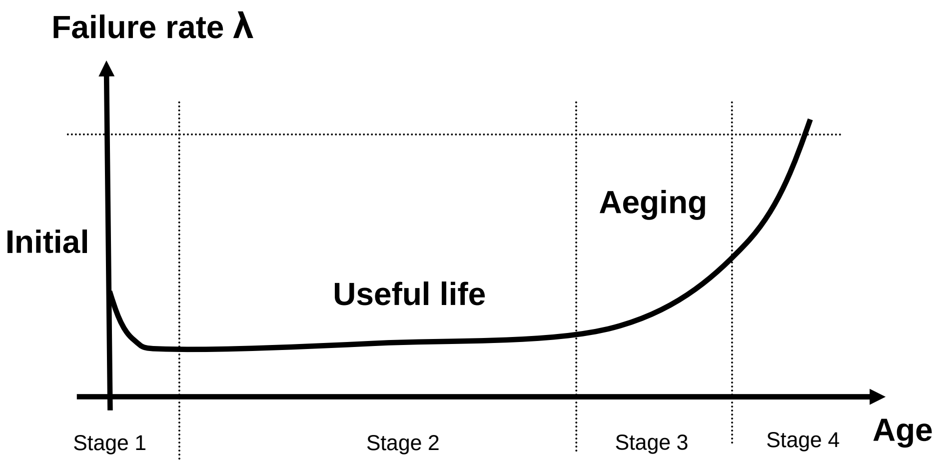
The following table provides a comparison between the two visions.

Type of equipment	Active equipment	Passive equipment
Approach to ageing	Reliability based	Physically based
Ageing appearance rate	Relatively quick, sometimes catalectic	Quick, an ongoing phenomena
Modelling	Probabilistic (searching for a service life rule from an observed failure sample)	- Physical, if knowledge is sufficient, where the single degradation mechanism is known, - Statistical, from degradation data observed at more or less regular time intervals
Main data	Failures (loss of function)	Degradation (e.g. inspection data, wear depth data, etc.)

It is important to note that an analysis of these two visions of ageing requires learning from experience. Learning from experience therefore appears to be an unavoidable strategic element when it comes to managing industrial installation ageing.

4.1 RELIABILITY BASED VISION OF AGEING

An equipment service life, from service introduction to scrapping, generally comprises three main phases that are characterised by a random function and specific failure rates, as presented in the following figure. This illustration is usually referred to as a “bathtub curve”.



- An **initial period** (Stage 1) resulting in a failure rate that decreases with operating time or the number of actions. During this period, the most fragile equipment or any equipment with flaws will be eliminated. This is the “burning in” period for electronic equipment or the “running in” period for mechanical equipment.
- A **technical maturity period** (Stage 2), the so-called “useful life” characterised by a constant failure rate where failure is random, accidental and sudden. This is the normal equipment operating period and they should be designed in such as way that this period should exceed or at least equal the duration of the mission assigned to them.
- Lastly, a third **so-called ageing period** (Stages 3 and 4) during which the equipment failure rate will rise over time or based on the number of it is used.

A useful ageing indicator is therefore observing the rise in the failure rate. **Two parameters will then be important for characterising ageing: the moment when the ageing appears and the way it performs once it has appeared.**

Knowledge of the first parameter (the moment of appearance) will allow optimising preventive maintenance while the second parameter (the way it performs) will allow evaluating the rate at which the change of failure increases once ageing has started.

The active components are therefore maintained preventively or periodically refurbished. **Learning from experience with the equipment makes it possible to confirm preventive maintenance programs or on the contrary, periodically adapt them in line with the observations made.**

Design modifications, maintenance modification (relating to preventive or conditional maintenance), renovation, replacing defective parts or even all of the equipment, correspond to cures to ageing.

Periodic tests, or inspection while in service or simply monitoring equipment reliability parameters make it possible to highlight any start in ageing and provide help in determining when to apply these remedies.

4.2 PHYSICAL VISION OF AGEING

The physical approach to ageing especially relates to passive equipment (structures, piping, pressure vessels, storage tanks, etc.) or “structural” subcomponents of active components (e.g. a motor stator). The ageing process is linked to a component materials degradation mechanism.

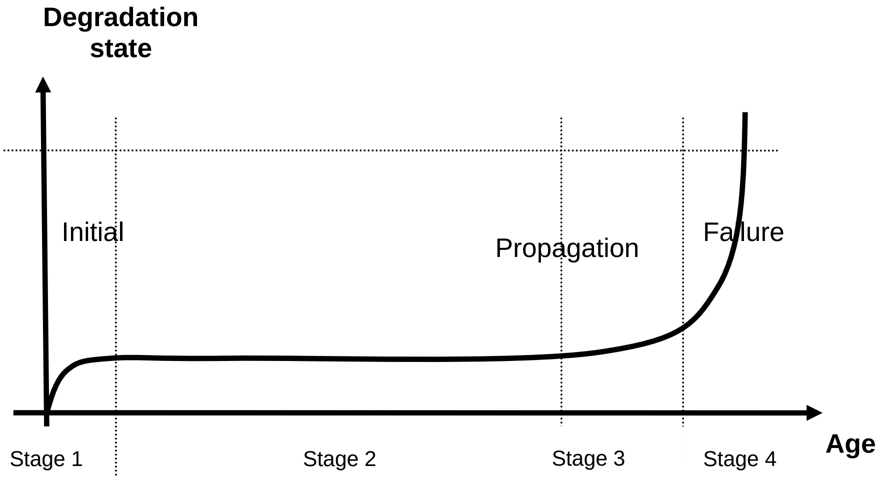
In this approach, the aim is to stop any degradation triggered from causing a failure and stopping the equipment from fulfilling its mission: for example, the corrosion mechanism that causes a straight through crack that may cause a major leak, or more seriously, a sudden equipment failure.

When the degradation is observed, it will be monitored and all that is required then is to act preventively (repairs, changes, etc.) to avoid a complete failure.

In this approach to ageing, in line with the definition set out by HSE in Plant Ageing[66], a distinction is also made between three main phases:

- An **initial or running-in period** (Stage 1) when degradation may progress rapidly if the materials are not suitable (sizing, design, manufacturing or installation errors). During this period, the most fragile materials, those having flaws or that are unsuitable, will be eliminated.
- **A priming or maturity period** (Stage 2). During this stage, the way the equipment behaves is predictable and safe. It is assumed to have a low failure rate, one that is pretty well constant and few problems that will require special attention. Its operation is within its design limits. It is also necessary to have a certain degree of knowledge of the equipment’s design and manufacture. If this is not the case, it should be considered that the equipment passes directly into the propagation or ageing period (in line with the definition set out by HSE in the Plant Ageing[66] document). Examination, inspection, maintenance and NDT operations allow validating these slow degradation assumptions. The frequency of these operations and their type are determined by a criticality based approach that includes learning from experience, with the interval between two inspections tending to increase. At this stage, the inspections are intended to confirm the absence of any degradation.

* A **propagation or ageing** period that may go as far as breakdown (Stages 3 and 4), when the equipment has reached a certain level of degradation and its degradation rate increases. Deterministic monitoring is implemented. Inspections become more precise and should allow better quantification of flaws. At this stage it becomes possible to implement Fitness For Service type methods to ensure that the equipment can safely be kept in service.



The challenge in this situation relates to optimising conditional maintenance or in service inspections. These actions should allow preventively detecting the start of any deterioration initiated by a degradation process and its propagation before failure, as shown in the diagram below.

The table below presents the type of inspection linked to the various phases in equipment degradation evolution.

Degradation evolution	Related inspection
Initial phase (for new equipment only)	Post-commissioning (validating equipment condition on receipt)
Priming	Inspection based on criticality
Propagation	Deterministic monitoring
Failure is highly probable	Continuous monitoring

For electromechanical equipment materials as well as for concrete, electric wire lining polymers…, the main degradation mechanisms comprise:

- Heat fatigue linked to the temperature cycles endured by the equipment,
- Stress corrosion,
- Erosion,
- Mechanical wear,
- Fragilisation due to irradiation,
- Loss of concrete prestressing,
- Etc.

Identifying the degradation mechanism involved requires an advanced knowledge of physical phenomena. A physical or statistical knowledge of the degradations linked to this mechanism are required to determine their initiation and propagation processes and to detect and anticipate their evolution: This is partially the scope of structural reliability.

Managing this kind of ageing therefore requires checking failures integrating an inspection and monitoring method. Checks can be based on criticality criteria or defined in a regulation way. In the former case, optimisation is performed by targeting inspection actions on equipment that shows the greatest risks (major seriousness in the event of failure and/or a high occurrence probability).

Inspection in service and on-condition maintenance are the key factors in defending passive equipment in relation to the degradation process.

Note*: The "HSE – Plant ageing* [66] *report also introduces the concept of ageing as a* ***lack of information on equipment condition****. As a result, equipment is old if this is equipment for which any degradation is identified or may occur since it was set into service or if this is* ***equipment for which not enough information exists to determine its condition****.*

5. GENERAL METHODOLOGY FOR MANAGING AGEING

Operators who put into place an ageing study covering their installation have two major concerns:

- **Safety**: Ageing must not affect components that are important for safety. The actions required to manage any ageing issues must absolutely be put into place. Any ageing that may arise must be managed so as to correct for it.
- **Loss of production or availability, maintenance, repair or replacement costs**: Component ageing must not penalise profitability. Consequently, it is important to detect components that may cause ageing, to plan for the evolution of this ageing and to take the necessary measures and countermeasures.

Therefore the importance of anticipating ageing can clearly be seen and its appearance must be anticipated so as to manage it. Anticipation refers to identifying potentially penalising events before they happen so as to evaluate the risks that they present and to prepare and implement suitable monitoring, preventive maintenance or replacement actions.

Managing ageing can therefore be based on an approach comprising three major phases:

- **Phase 1**: Identifying components for which an ageing study is necessary,
- **Phase 2**: Evaluating ageing for these important / critical components,
- **Phase 3**: Implementing the necessary countermeasures for managing ageing.

5.1 PHASE 1: IDENTIFYING IMPORTANT / CRITICAL EQUIPMENT

5.1.1 PRINCIPLE FOR IDENTIFYING IMPORTANT EQUIPMENT

An industrial installation comprises a mass of equipment, but all do not require examination from an ageing point of view.

Only those considered as critiques will be examined. The equipment that is considered to be important will require an evaluation of any effects of ageing.

Equipment may be identified in a regulation way (e.g. the thresholds set by pressure equipment regulations determine which equipment requires in-service monitoring). Equipment criticality is then defined in a regulation way in relation to the pressure related hazard (including the concepts of hazardousness of substance, volume, pressure).

For other equipment and for facilities that comprises a very large amount of pressure equipment covered, criticality based approaches are applied to optimise monitoring actions. Equipment that is considered critical is monitored as a priority, with greater inspection frequencies.

Learning from experience naturally comes into the identification of the equipment to be monitored (because any given equipment is subject to degradation or because learning from experience gained within or outside of the facility shows that this type of equipment may be subject to degradation identified on another type of equipment similar to that at the facility or at another facility).

Generally these components are known ones. Safety studies have made it possible to produce a list of these important components. Working from expertise and learning from experience is also possible when producing a list of important equipment.

Nevertheless, working only on the basis of expertise and learning from experience is not a correct approach. In an ageing study, the aim is to define **present and future** ageing mechanisms and how they will evolve. This is therefore a projection into the future, from the current observation time to an instant on the horizon (an anticipation approach), whereas knowledge covers the period from setting into service until the observation instant.

This is why important component identification must be based both on expertise and learning from experience as well as on safety studies.

5.1.2 EQUIPMENT TO MONITOR: ISO-DEGRADATION LOOPS AND MARKER EQUIPMENT

Iso-degradation loop

The UIC/UFIP DT84[40] guide defines an *"iso-degradation loop as a set of interconnected equipment with similar service conditions (pressure, temperature, fluids in contact, etc.) and that are made from materials with similar behaviour in relation to fluids in contact. This equipment is said to have a common degradation mode".*

Implementing an analysis using an iso-degradation loop is often performed at facilities. This approach is used to formalise the degradation analysis and to bring a certain degree of coherence to degradation studies. It corresponds to a single inspection strategy.

Marker equipment

For guide UIC/UFIP DT84[40], this means the one or more marker equipment items in a set of identical equipment which would be the first to be affected if any damage was to occur.

A set of similar equipment corresponds to equipment:

- Of similar design and manufacture (same materials, identical or similar manufacturing processes),
- Belonging to the same iso-degradation loop or calling on the same inspection plan,
- Used under the same conditions,
- With a common degradation mode.

For this equipment, this same guide states that:

"For a set of similar equipment, inspections (checks, examinations, inspections) undertaken more or less completely on a number of items of marker equipment, may partially or totally replace the inspections that should be undertaken on every item of equipment in the whole system. The one or more marker equipment items chosen by SIR are the ones most affected by any damage that is likely to occur. Their choice is justified and is covered by a record in the inspection plans for the equipment in the entire system affected".

It is possible to use this marker equipment concept, **but great care must be applied to the choice of this equipment**. This is because experience shows that for equipment that looks to be similar and subject to the same conditions, disparities may appear, linked for example to different external conditions (direction of the wind that impacts one item of equipment more, a pad under tanks that behaves differently, the presence of different stray currents under equipments. This marker equipment concept appears actually to be seldom applied to industrial facilities (based on facility visits already made).

5.2 EVALUATING AGEING FOR EQUIPMENTS RETAINED AS IMPORTANT

Any evaluation of equipment retained as important (critical) is based on two steps:

- Collecting the necessary information,
- Understanding and evaluating ageing.

5.2.1 COLLECTING INFORMATION

To evaluate ageing and understand its evolution, a certain amount of information needs to be collected on the studied component.

- **Design data**: Equipment design, sizing, technical diagrams, any modifications, regulations, technical specifications, general operating rules, possibly a safety report, preventive maintenance program, etc.
- **Data on materials and their properties**: Type, composition, properties, origin, manufacturing conditions, heat treatment, etc., any defects that may exist on setting into service.
- **Operating conditions**, namely the complete operating history since setting into service (operating transitory levels, temperature and stress variations, characteristics of the substance contained, etc.).
- **Outdoor conditions,** namely the environment conditions (atmospheric dampness, environmental corrosiveness…).
- **Operational Safety goals assigned to the component**: For example a critical constant failure rate or a downtime value not to be exceeded.

- **Maintenance and surveillance history**: Information on failure modes, observed degradation mechanisms, observed constant failure rates, their trend, etc. The aim is to learn from operating experience, which will provide the most important raw material in any ageing study. This information will allow determining service life laws, detecting unfavourable evolutions, identifying degradation mechanisms, judging their relevance and their criticality.
- **Inspection data from the inspections** performed during installation shutdown periods.
- **Data learnt from experience with analogous or similar equipment**: This data relates to both identical components installed at similar production plants or other components that are designed pretty much the same (with the same materials) under the same operating, environment and maintenance conditions. This analogous data also comprises the data that can be found in the reliability records.

Collecting this data (**in an equipment file**) from setting into service is essential for managing critical equipment ageing. If this data does not exists or if it is impossible to rebuild it, then component replacement becomes a must if there is any doubt on ageing or when extending its service life is desirable. This is because without the history, it is impossible to determine the service life already used up or any residual duration.

5.2.2 UNDERSTANDING AND EVALUATING AGEING

The information collected in the equipment file will serve to evaluate equipment ageing. This evaluation requires:

- A knowledge of degradation mechanisms, their impact on the material properties of the equipment studied, given operating and environment conditions,
- An analysis of the causes of the degradations observed,
- An evaluation of degradation initiation and kinetics,
- An anticipation or forecast of future degradations and potential consequences, given the operating policies envisaged and the environment.

When a failure or degradation is observed, the first task of the analyst is to explain the reasons for it. If the reason (cause) is known, then it will be possible to find any cures that may exist.

The goal is to determine the degradation mechanism responsible, with a sufficiently high degree of confidence, but also any influencing factors. This analysis is not always an easy one to undertake due to a lack of information (information is either incomplete and/or unavailable).

5.3 IMPLEMENTING AN ADEQUATE MONITORING POLICY

A list of equipment that is important for safety reasons or for avoiding production losses and that is to be evaluated as regards ageing has been determined. The relevant degradation mechanisms have been identified and prioritised. The one or more causes of these mechanisms have been analysed. Degradation kinetics have been calculated and the factors that influence this degradation are considered to be known.

Now the point is to find ways to differ, avoid or eliminate ageing.

The existing methodologies intended for managing ageing may be:

- **Inspection** (which may be visual or may comprise non destructive testing or re-testing operations, etc.),
- **On line surveillance**, generally founded on monitoring a physical parameter that is characteristic of ageing (monitoring pH levels, pressure, etc.),
- **Monitoring reliability indicator**: Any unfavourable change in these indicators may indicate ageing.

These approaches must be able to detect any degradation in time so that action may be taken before this breaks down into a loss of function. They must be sufficiently reliable, precise and efficient. The industrial must seek to show their efficiency.

Other more “radical” actions may be used to protect against ageing:

- **More aggressive maintenance**,
- **Component replacement** with an identical component or one with better performance and better technology,
- **Component renovation or repair**,
- **Changes in operating conditions**.

The aim of these actions is to act on a significant degradation mechanism so as to eliminate or delay ageing.

It is important to stress that these maintenance operations are additional to regular maintenance and therefore trigger additional costs that are all the higher if the equipment or one of its components requires replacing.

All of the protection methodologies must focus on on-condition maintenance, detecting the time required to initiate ageing, diagnostics and interpretation.

Monitoring degradation due to ageing comprises continuously or periodically measuring a physical indicator that is characteristic of ageing and that can be used as a basis for judging any detection of a change in degradation and of the imminence of any failure occurring. The data analysis is made by comparison with a physical signature. The acceptation thresholds must be known ones.

The fundamental question is to know the right physical indicator to follow, one that is able to summarise the component’s behaviour and performance.

It is also necessary to **determine the remaining service life of the component**:

- The acceptance criteria must be known,
- The mechanism involved must have been precisely identified,
- Effects and factors that favour this must be known.

Depending on the inspection results, we will come to **conclude on whether or not to retain the equipment** (it may safely remain in place for a set duration with the idea that its initial service life may possibly be extended) or whether “radical” operations are needed as mentioned below:

- **Component replacement**,
- **Component renovation or repair**,
- **Changes to operating conditions**.

6. DEGRADATION MODES AND RELATED INSPECTIONS

The French Association for the Quality of Equipment under Pressure (AQUAP in French for “Association pour la Qualité des Appareils à Pression”) notes during the "Piping and pressure vessels" working group that professional guides, dedicated standards or codes cover, except for exceptional cases, all of the ageing mechanisms and propose suitable countermeasures.

There are therefore a number of guides relating to degradation and non destructive testing to be implemented depending on the degradation that is identified.

Sometimes they also provide information on sensitive areas for which special attention is required.

This chapter comprises two parts:

- The first part presents a **list of sensitive areas** identified either by their accident record (on-site incidents recorded from visits or accidents taken from the ARIA database) or by professional guides,
- The second part presents **degradation modes and NDT implemented**.

6.1 SENSITIVE AREAS IDENTIFIED

In the following chapters the sensitive areas that are identified during visits, in ARIA accident data (see Chapter 2) and/or identified in professional guides are summarised.

6.1.1 AREAS COMMON TO PIPING AND TANKS

The critical degradations modes comprise:

- **External corrosion under insulation**: Sometimes defects in the design or in the installation or at the (invisible) support level explain the flaws found in old insulations.
- **Corrosion through dripping**: These degradation modes are hard to detect and facility operators have an important role to play in reporting them. It is however important to take into account the piping environment when it comes to analysing hazards and detecting product leaks (condensates, steam, etc.). Dripping relates to leaks on piping that is located close by or run-off onto racks and supports.

In an Annex, guides DT32[39] and DT84[40] detail the hazard areas that may require partial or full removal of insulation from equipment. It identifies the following hazard areas where special attention must be paid from the periodic inspection operations and that may require partial insulation removal (if not, no insulation is removed for inspections):

- **Retention areas, areas that emerge from insulation** (drains, purge points.),
- **Mounting points** for equipment subject to **vibration or fatigue cycles**,

- Areas likely to be affected by **corrosion or cracking with a mechanical or thermal origin**,
- **Expansion compensators**,
- **Welds** that are complex or likely to be a home to stress concentrations,
- Heterogeneous **welds** or major or specific **tappings**.

Furthermore, in line with guides DT32[32] and DT84[40], partial insulation removal will be applied for periodic requalification purposes in those areas previously identified as well as in the following areas:

- *"**Low parts**: lower radius, low points, bases,*
- ***Segments that are representative of circular and longitudinal welded joins**."*

Guide DT32[32] goes further and also identifies the following areas for periodic requalifications:

- *"Representative parts of **reinforcing binding bands** for equipment operating in a vacuum,*
- *Representative parts of **insulation support rims** if these are directly welded onto the collar and not via shoulder brackets."*

6.1.2 PIPING SPECIFIC AREAS

Specifically for **piping**, sensitive areas and identified degradation modes are (in addition to the modes defined previously in subsection 6.1.1):

- Internal corrosion under deposits in dead legs,
- Internal corrosion along slop lines (and therefore by nature, with variable products that can trigger different degradation modes),
- Underground piping or ones that are in sheaths and are hard to inspect.

The report on refinery piping benchmarks lists sensitive areas along piping.

ARIA accidentology data also shows up the following sensitive areas:

- **Lining flaws** (due to wear or work),
- **Corrosion under insulation (CUI)** or **corrosion under the paint** (paint touch ups),
- Stress due to **poor supports**,
- Corrosion on **piping elements** (flanges, valves, etc.),
- Corrosion due to a **passive protection flaw** in the case of underground piping.

Guides DT32[32] and/or DT84[40] identify other sensitive areas:

- *"Specific points and any lack of continuity,*
- *Supports and ends,*
- *Retention areas under the insulation,*
- *Tappings, vents, purge drains and dead legs."*

Guide DT84[40] also states that in the case of piping, special attention is paid to the following possibilities:

- Erosion,
- Cavitation,
- Support degradations,
- Water hammer possibilities.

According to the SAFed Guide – Guidelines for Competent Person – In-service examination of pressure systems pipework[59], the degradations to be taken into account for piping comprises:

- **External corrosion under protection** (heat, cold or fire insulation, etc.),
- **External corrosion** (if the temperature conditions are between -4 and 120°C for carbon steel), especially in specific areas such as ground/air interfaces, supporting areas that may cause lining damage by friction and areas that are hard to access and where the linings may be less effectively applied,
- **Internal corrosion** that is dependent on the fluid,
- **Erosion**, especially downstream **injection points or changes in cross section or in tight elbows**,
- **Stress corrosion cracking**: Especially caustic cracking on steam piping or stress corrosion cracking on austenitic stainless steel piping due to chlorides,
- **Fatigue due to the application of cyclic loads**, especially if piping motion is restricted by anchorages…
- **Heat fatigue** in cases of rapid temperature changes,
- **Corrosion fatigue**: If cyclic stresses are applied in a corrosive environment,
- **Mechanical damage**, including thread wear,
- **Vibration fatigue**, especially in the presence of pumps or compressors and especially for small bore connections (e.g. instrumentation tappings),
- **Creep** affecting high temperature piping,
- **Leaks** from flanges and seals,
- **Support and anchorage failures** may trigger unacceptable stresses,
- **Bellows and expansion joints** are also areas that are often sensitive.

API 581[76] also identifies factors that lead to increasing the probability of any failure (e.g. injection points, Tees, etc.) and this for the many failure modes identified in the guide.

6.1.3 AREAS THAT ARE SPECIFIC TO TANKS

Guides DT32[39] and/or DT84[40] identify other sensitive areas in generators and recipients:

- Tapping bases and supports,
- Impurity concentration areas,
- Tappings, purges, drains and dead legs,
- Insulations in retention areas.

Specifically for **pressure tanks**, the identified sensitive areas and degradation modes comprise (in addition to the previously defined modes):

- Spherical tank bottoms,
- Tappings and welds.

According to the SAFed - Guidelines on periodicity of examinations[58] guide, critical pressure vessels comprise those that present the following conditions or features:

- Contents which cause rapid corrosion/erosion,
- Potentially corrosive external environment,
- Vessel subject to significant vibration,
- Vessel subject to significant cyclic pressures, cyclic temperatures and/or thermal shock,
- Safety valves or other protective devices susceptible to blockage,
- Rivetted seams,
- Inwardly dished ends,
- No reinforcement of mounting plates,
- Removable covers for charging purposes.

The AQUAP[30] guide called “Inspection réglementaire des équipements sous pression revêtus extérieurement ou intérieurement[5]" also provides a list of sensitive areas. Please refer to the benchmark on refinery storage for identifying these areas (Chapter 3.1.2.1).

---

[5] *"Regulation inspection of pressure equipment with an outside or inside lining" in English*

Specifically for **atmospheric pressure tanks**, the sensitive areas and degradation modes identified during the visits comprise (in addition to the previously defined modes):

- **Corrosion between steel sheet and wall** with which the steel sheet was in contact,
- **Corrosion on fixed tank roofs (by condensation)** which may require a change in the roof,
- **Rainwater drains** (should they become holed, hydrocarbons leak into the dike).

Contacts made during the study showed up three failure causes affecting storage tanks:

- **External corrosion** (possibly under insulation),
- **Foundation settling** (an accident at Kallo, Belgium in October 2005),
- **A loss of support for marginals** (the horizontal supports placed at the tank ends for passing on the forces due to circular wall buckling).

The sensitive areas identified on the atmospheric storage tanks used for flammable liquids are detailed in the report on monitoring refinery storage (see Chapter 4.1.2.1). Note that the guides used for these kinds of storage (API 653[79], UFIP[45], EEUMA 159 guides)[56] also identify sensitive degradation areas.

6.1.4 LPG SPECIAL CASE

It should be noted that for facilities carrying LPG, **internal corrosion is not an issue**, insomuch as the products do not present a corrosive nature. Corrosion therefore comes only from the ambient air (external corrosion).

Neither are there any **specific issues linked to equipment fatigue** insomuch as flexible pipes to absorb vibration have been installed between the fixed piping and the compressors that generate vibration. Where vibration led to incidents, this related to flange slackening but no damage to the related piping.

6.2 NON DESTRUCTIVE TESTS IMPLEMENTED

This subsection presents NDT approaches (a non exhaustive list) adapted in line with certain degradation modes.

Before performing a check, the inspector must collect all of the information relative to the equipment involved (construction and service data, history, etc.) so as to choose the most suitable NDT technique. The table below presents a match between the degradations that may be suffered by the equipment in an industrial installation and the test/inspection techniques used to detect them. This match is taken from document DT75[41] dated May 2002 in the inspection guide called "Guide for choosing material and equipment inspection methods". This table aims to provide a general vision of known inspection methods. It does not claim to be exhaustive.

Note: API 581[76] makes allowance in failure probability evaluations for the efficiency of the inspection measures applied. As a result, depending on the degradation mode, the efficiency of the measures is evaluated by taking into account the type of measurement and inspection coverage (see Annex K for principles and an example). Guides DT32[39] and DT84[40] in their Annexes also present a graduation of the efficiency of the measures depending on the possible degradation modes. This information is not repeated in this report.

Degradation	Test/inspection techniques
Loss of thickness	Visual examination
	Ultrasonics: Longitudinal waves with a straight sensor
	Eddy current
	Radiography-Gammagraphy
	Dimensional checks
Visible cracks	Visual examination
	Ultrasonics: Transversal waves with angle sensor
	Magnetoscopy
	Dye penetrant examination
	Acoustic emissions
	Eddy current
Hidden cracks	Ultrasonics: Transversal waves with angle sensor
	Acoustic emissions
Micro cracks, gaps (creep cavities)	Acoustic emissions
Metallurgical modification	Replicated metallography
Dimensional modifications	Visual examination
	Dimensional checks
Blistering	Visual examination
	Radiography
	Ultrasonics: Longitudinal waves with a straight sensor
Localised corrosion caused by spots	Visual examination
	Acoustic emissions

Implementing these different inspection techniques requires specific expertise and a good knowledge of operating modes so as to achieve reliable results. The following table summarises various inspection techniques and presents the implementation principles applied and their potential efficiency.

Information relating to efficiency is taken from facility visits and from information released by the French Petroleum Institute (IFP).

Testing/inspection techniques	Principle	Remarks
Visual examination	Checking the overall appearance. Compliance with dimensions and the macroscopic condition of surfaces is observed with the naked eye or with magnifying glass type instruments.	This is the "simplest" check, nevertheless it requires a very extensive knowledge of the equipment to be effective.
Ultrasonics: • Longitudinal waves with straight sensor for measuring sidewall thicknesses and for finding faults in planes parallel to the sidewall. • Transverse waves with an angle sensor for finding core defects (in welds, de compactness, cracks, etc.). • Waves with focused sensors for achieving optimal sensitivity at a preset distance from the sidewall.	An internal examination and thickness measurement. Very high frequency (ultrasonic) sound waves are transmitted to the structure and their reflection off the material is analysed. The internal flaws are highlighted by a modified reflection and wave diffraction.	Well suited to steels. Not suited to cast iron, copper alloys and alloy steels. Difficulties linked to interpreting signals from a propagation anomaly. Detects very small size flaws and reaches areas not accessible by other methods.
Magnetoscopy	Surface quality check. A ferromagnetic powder is applied to the surface to be tested before subjecting it to a magnetic field. Surface defects that show up, that are plugged or underlying are highlighted by the appearance of a leakage field.	Detects emerging or underlying cracks in ferromagnetic materials. Compliance with the magnetising time.
Dye penetrant examination	Surface quality check. A penetrant liquid is applied to the surface, then it is cleaned off. Then a developer is applied evidencing any discontinuities that show up (that the liquid penetrated) on the surface.	Detects emerging cracks, pitting, unsticking and cohesion breakdowns. Surface preparation.

Testing/inspection techniques	Principle	Remarks
Acoustic emissions	An internal examination and thickness measurement. US waves produced locally in a material that releases energy in wave form with a part as acoustic emissions. The structure is “listened to” during loading (i.e. when pressurised). Evolving flaws (cracking, local plastic deformation, etc.) generate acoustic emissions that allow locating and qualifying them.	Searches for active defects: evolving cracks, active corrosion. Easy to implement without having to access the inside of the equipment. A partial or overall structure check. Used to locate low intensity emissive sources. Used to monitor fault evolution.
Eddy currents	Electromagnetic induction. A metal part is subjected to action by an alternative field created by a coil that is crossed by a sinewave current. This alternating field gives rise to induced currents called “eddy currents”. When the path of the eddy currents is modified by the presence of a physical discontinuity (a structure) or a geometric one (a loss of thickness, surface defect) affecting the part checked, then the impedance of the inductive coil varies. The various discontinuities or defects: hole, pit, crack, loss of thickness, etc. all cause different forms of interference that may be characterised by comparison with so-called “master” defects.	Conductive materials, whether magnetic or not. Detects flaws on the surface and under the skin.

Testing/inspection techniques	**Principle**	**Remarks**
Radiography	An internal examination. Structural compactness is checked using X or gamma rays. Internal defects such as blowholes, porosities or internal cracks are revealed this way. The radiation passes through the part to be checked. Its intensity is modified by the defects encountered along the way. The emerging radiation is collected on a photographic film or using a digital imaging system.	Diameter of up to 8”. Through the heat - cooling insulation. Applicable to a hot circuit (over 200°C). All kinds of flaws can be detected except for defects in planes that are perpendicular to the radiation axis that do not change the photographic picture.
2D or 3D dimensional checks	Checking the compliance of product dimensional and geometrical characteristics in relation to definition documents (drawings, specifications, manufacturing ranges).	Optical 2D or 3D digitising makes it possible to achieve a dense and ordered cloud of surface spots over the part to be checked. Factory sensor calibration and checks on the geometric benchmarks allow a good estimate of uncertainty relating to measured points.
Replicated metallography	This technique comprises first polishing the area to be examined, then attacking it to create a micro-relief on the surface, applying a microfilm to capture this relief and lastly taking off the film and examining it under a microscope. The microstructure of the studied area will then appear.	Examining the metal structure under optical and electronic microscopes allows highlighting structural anomalies as well as checking the condition of superficial heat treatments, structure homogeneity, identifying composites or phases, etc. This method is used to assess the state of the metal structure and to analyse its evolution in its environment.

Testing/inspection techniques	Principle	Remarks
Guided US waves (Lamb waves)	Analyses reflections from flaws (metal losses).	.Long distance piping inspection. Propagation stopped by flanges, bends (shadow areas). Does not detect in shadow areas. Detects but does not size.
LORUS (Long Range UltraSonics) multi-bounce technique	Reflects transverse US waves/acoustic saturation of the thickness to check.	Searches for corrosion in inaccessible areas. Detection limited to 1 m. No discrimination between internal and external defects. No detection of pitting type corrosion. No residual thickness measurement. An overall method requiring more precise measurements in corroded areas.
"FLOORSCAN" US test	A method based on magnetic flow leaks.	Limited to ferromagnetic materials. Requires a tank base that is clean and sandblasted. Checks are not possible with linings present. Areas found to be corroded require more precise US checks. Fast method: 350 sq. meters per day (equivalent to a 21 m diameter tank).

Testing/inspection techniques	Principle	Remarks
SLOFEC (Saturation LOw Frequency Eddy Current) method.	Eddy current and magnetic particle inspection principle.	Checks coated tank bottoms. Possible on ferromagnetic or non ferromagnetic materials. No surface preparation necessary.
INCOTEST (Insulated Component TEST) method.	Pulsed eddy currents principle (measuring pulse fall-off).	Thickness measurements through non conductive and/or non magnetic materials (e.g. spherical tank supports (through the fireproof concrete), underground piping, rack supports, etc.). Fast check: Up to 1000 pts per day. Does not detect pitting corrosion only generalised types of corrosion. No differentiation between internal and external defects. Requires fitting a protection sheet if steel or galvanised steel is used.
TOFD (Time Of Flight Diffraction) method.	US method. Wave diffraction at the ends of the defect (two transducers generating an image representing the lateral cross section of a weld).	Detects and measures flaws in welds: In the case of faults that exceed tolerance, allows a “Fitness for service” study and possibly shows whether or not it is acceptable. Alternative solution to radiography for very thick metals (< 300 mm).

Testing/inspection techniques	Principle	Remarks
ACFM (Alternating Current Field Measurement).	Checks welds and surfaces. Electromagnetic technique developed from voltage drop measurements. A sensor measures interference with the magnetic field around a defect. An electromagnetic inspection technique able to detect surface defects and to size them for length and depth. Applying an alternating current to the tested surface causes an induced magnetic field. This shows up distortions in the presence of cracks or open defects. This method is also called eddy current detection.	Detects and sizes the depth of surface cracks in welds. An alternative to dye-penetrant examinations and magnetic particle inspections. Inspects welds in magnetic or non magnetic materials. No surface preparation required.
Gammametry	Gamma ray absorption by materials: density measurements on liquids or solids.	
PMI (Positive Materials Identification).	X ray emissions.	Identifying/checking the makeup of alloy steels.
Sealing tests using helium tracing.	Leak detection. The fluid carried is “marked by a helium content that depends on a number of parameters (flow rate, pressure, pipe burial depth, type of ground, minimum leakage rate sought). The gas is sampled by pumping out from the ground through small 10 cm deep perforations dispersed every 3 to 5 meters along the pipe route.	Checking underground pipes for leaks. The detection threshold is extremely low: approx. One millilitre per hour.
Sealing tests: To water, air, etc.	Leak detection.	
Destructive tests		Used exceptionally.

7. GENERAL PRINCIPLES FOR MONITORING HAZARDOUS EQUIPMENT: REFERENCE TEXTS

The problem of control of ageing ageing is an important theme that is indirectly approached in the regulations enacted by the various countries. They usually approach management aspects or more generally a "management of integrity" policy.

Demands relating to management of integrity come from various regulations and consequently may be handled by various authorities within a given country (Ministries of the Environment, of Labour, etc.).

Here Chapter 7 presents the general principles and the reference texts. The following chapters (8 to 13) present a summary of monitoring policies by type of equipment. Please refer to Annexes E, G, H, I and J that present the regulations and professional guides that apply in the studied countries. Annex F presents the monitoring practices observed in France during the visits carried out by INERIS in 2009.

7.1 OVERVIEW OF SOURCE REGULATIONS IN EUROPE

The general regulations relating to installation monitoring at the European level are primarily based around two main directives:

- **Seveso directive:** Member States have transposed the Seveso II directive No. 96/82/EC[2] (modified by Directive 2003/105/EC). This relates to the control of major-accident hazards involving dangerous substances (accidents with potential impacts on people inside or outside of the facility or impacts on the environment). The relevant installations are those located at **high risk facilities** where the quantities of hazardous substances are notable ones. Regarding the "ageing management" aspects, the following requirements should be noted:
    - The operator needs to draw up a document setting out his major-accident prevention policy (Article 7). The **safety management system** should include the "organizational structure, responsibilities, practices, procedures and resources for determining and implementing the major accident prevention policy" (Annex III). The following issues shall be addressed by the safety management system:
        - **Operational control**: "operational - adoption and implementation of procedures and instructions for safe operation, including **maintenance**, of plant, processes, equipment and temporary stoppages"..
        - "**Management of change**": "adoption and implementation of procedures for planning modifications to, or the design of new installations, processes or storage facilities".

- o "**monitoring performance**" : "adoption and implementation of procedures for the ongoing assessment of compliance with the objectives set by the operator's major-accident prevention policy and safety management system, and the **mechanisms for investigation and taking corrective action in case of non-compliance**. The procedures should cover the operator's system for reporting major accidents of near misses, particularly those involving failure of protective measures, and their investigation and follow-up on the basis of lessons learnt".

  - The operator should produce a **safety report** that especially comprises a demonstration that "the design, construction, operation and **maintenance** of any installation, storage facility, equipment and infrastructure connected with its operation" offer adequate safety and reliability (Article 9).

- **Directive regarding safety and health of workers at work:** Member States have transposed Directive **89/391/CE**[3] the introduction of measures to encourage improvements in the safety and health of workers at work. This restates the employer's duty to ensure workers' health and safety. It does not provide any general elements on aspects relating to monitoring installations over time. It did however give rise to specific directives, two of which at least cover management of integrity. These are:
  - Directive **95/63/CE**[4] amending Directive 89/655/CE[3] relating to the minimum health and safety requirements for the use of work equipment by workers. These directives restate that:
    - o "The employer shall ensure that work equipment exposed to conditions causing deterioration which is liable to result in dangerous situations is subject to **periodic inspections** and, where appropriate, testing by **competent persons** within the meaning of national laws and/or practices".
    - o They must take measures so that work equipment, so long as it is in use, is through **adequate maintenance**, kept at a level such that it preserves worker's health and safety.
    - o "The **results of inspections must be recorded** and kept at the disposal of the authorities concerned. They must **be kept** for a suitable period of time".
  - Directive **1999/92/CE**[5] on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. Employers shall take measures (whether technical and/or organisational) with a view to preventing explosions. "The measures taken shall be reviewed regularly and, in any event, whenever significant changes occur ".

- **Pressure equipment regulations:** Member States have transposed Directive 97/23/CE[1]. This Directive however relates to conditions for placing pressure equipment on the market ; it applies to the design, manufacture and conformity assessment. It does not comprise any specific aspect relating to in-service monitoring for pressure equipment. Every country therefore writes their own requirements.

- Lastly, some countries may retain specific regulations relating to given substances (e.g. flammable liquids, toxic products, etc.). We will not detail these regulations since the scope of the applicable texts would be too great. Nevertheless, we will take a look at texts relating to flammable liquids depots with a view to identifying requirements that are specific to atmospheric tanks storing flammable liquids (refer to the Chapter on atmospheric tanks).

***Note*: Regarding regulations on pollution prevention**, *Directive 2008/1/EC[6] of 15/01/08 relating to the prevention and integrated reduction of pollution replaced Directive 96/61/EC (the so-called IPPC directive). This directive does not comprise a specific heading for management of integrity aspects linked to ageing. It is however necessary to ensure that the installations are operated so as to prevent pollutions, especially by resorting to the Best Available Techniques (BAT). This regulation does not appear (except for the BAT aspect) to be a source of information for any ageing management policy. It is not mentioned by the various contacts we had in the countries covered by this study.*

7.2 Overview of Source Regulations in the USA

Again, in the United States, requirements relating to personal safety and environmental aspects are to be found:

- Federal rule 29 CFR issued by OSHA[6], relating to **safety.** Among the requirements set out in Standard 1910.119[71] is **Process Safety Management (PSM) of highly hazardous chemicals** which under the Management of integrity heading (section j) states that the **operator is responsible for maintaining** in safe condition any equipment containing **hazardous substances or any pressure equipment.** Requirements relating to in-service monitoring are very general and correspond to “goal” based regulations. The **mechanical integrity** section applicable to pressure tanks and to storage tanks as well as to piping systems (including piping components such as valves), to relief and vent systems and devices, to emergency shutdown systems, to monitoring systems (alarms, sensors, etc.) and to pumps, makes the following requirements:

[6] *The Occupational Safety and Health Administration (OSHA) is a US Department of Labour agency*

- The employer shall establish and implement **written procedures to maintain the on-going integrity of process equipment**. The Annex restates (for information purposes) that the first step is equipment identification (see above, the field affected by the “Mechanical integrity” chapter to which should be added fire extinguishing systems). The annex also states that criteria for acceptable test results must also be established.
- They also have to ensure **adequate training for maintenance personnel** working in management of integrity, including knowledge of the installations, of the risks entailed and the applicable procedures.
- **Tests and inspections must be performed on the equipment, in accordance with recognised and accepted practices**.
- Their **frequency** should be determined taking into account the recommendations made by manufacturers and the engineering rules. Inspections may be more frequent if learning from experience justifies this.
- The operator must provide a **complete inspections and tests documentation** including the date of the inspection, the name of the person in charge of the inspection, the equipment identification, a description of the operations performed and the results of these operations.

In 29 CFR 1910.119[71] no further details are provided on the type of inspections, their frequency, the expertise of the persons performing the monitoring operations. **It is just stated that recognised guides must be used**. Nevertheless, in an annex to the document (an annex provided for information purposes), mention is made of guides whose application ensures compliance with general regulation requirements. These guides are especially those issued by the following bodies:

- The National Board Inspection or the American Society for Testing and Material (ASTM),
- The American Petroleum Institute (API),
- The National Fire protection Association (NFPA),
- The American Society of Mechanical Engineers (ASME).

- Federal regulation 40 CFR issued by EPA[7] relate to **environmental rules**. EPA is especially tasked with applying “*Environment acts*” of the “*Risk Management Plan*”. These are complete programs intended to protect the environment. EPA is charged to issue rules relating to managing the quality of air and water (*Clean air act* and *Clean water act*). Especially, in view of protecting waters, regulation 40 CFR 112[72] requires that operators of oil products storages or other facilities write and implement an SPPC (or Spill Prevention, Control and Countermeasure Plan). **The owner or the person in**

[7] *The Environmental Protection Agency (EPA or USEPA) is an agency of the federal government of the United States charged to regulate chemicals and protect human health by safeguarding the natural environment.*

charge of operations is responsible for the plan implemented at the facility. To properly monitor atmospheric pressure storage tanks, this plan requires in particular:

- Creating a **so-called "SPCC" prevention, monitoring and repair program** for equipment likely to be the source of oil seepage and leaks.
- **Plan certification** by a Professional Engineer familiar with 40 CFR 112[72] regulations. The latter may come from outside of the facility but must have visited and examined the facility.
- **Minimum monitoring** which must be instigated at a regular (but unspecified) frequency in accordance with best practices. Details will be presented in the chapter on monitoring atmospheric storage tanks.
- **Recording** evidence to justify preventive, monitoring and repair actions taken for each item of equipment.

For monitoring purposes, using guides is recommended but not mandatory.

- The Department of Transportation (DOT) and especially the Pipeline and Hazardous Materials Safety Administration (PHMSA)[73] is a Federal agency charged to ensure compliance with the requirements of regulations covering the transport of hazardous materials in North America. They are especially charged to ensure safety relating to pipelines and to **related equipment**. The rules therefore apply to **installations at a facility connected** to a pipeline (see chapter on atmospheric pressure tanks). They are therefore mentioned in this report for equipment connected to pipelines although the latter are outside of the scope of our study.

7.3 SUMMARY OF REGULATION REQUIREMENTS

The regulations presented above provide **relatively general information on monitoring methods**. They present general requirements but their practical implementation then remains to be chosen by the operator.

Inspections are made by the relevant competent authorities at variable intervals (ranging from regularly for Seveso type facilities to more one-off inspections for other kinds of installations).

Generally, the regulations comprise the following minimum elements:

- **Operator responsibility** for monitoring facilities.
- **Identifying the equipment** covered by periodic inspections:
    - In Europe, all equipment is theoretically covered under the terms of the Machines Directive. For pressure equipment, the scope is set out in each country's regulations. For Seveso facilities, hazardous installations (with notable quantities of hazardous substances) are covered.
    - In the United States, all pressure equipment and equipment containing hazardous substances are within the scope of CFR 1910.119[71].
- **The existence of periodic inspections** and possibly of **periodic tests** performed by **skilled persons**.
- Maintaining a safe operating condition through **suitable maintenance**.
- **Inspection results must be recorded, retained** for a suitable period and **made available to the authorities** should they wish to check them.

Additional concepts appear in some regulations:

- **Establishing inspection plans** (pressure equipment regulations in Europe, SPCC in the US) or **written monitoring procedures**. Especially in the Seveso Directive, the safety report must show that maintenance is sufficient and reliable. The safety management system have to set out each party's responsibilities, the resources, the maintenance procedures, the **performance monitoring procedures** and it has to include implementing **investigations and correction proceduces** should the expected performances levels not be complied with. These procedures are based on **learning from experience**.
- The need to ensure **personnel training** (in the US in CFR 1910.119[71], in Europe in the safety management system for Seveso facilities).
- **Management of change** integrated into Seveso facility safety management systems.

Specific requirements may exist in some regulations (e.g. in the transpositions of the directives on pressure equipment) which will be presented in the following chapters.

Regulations are completed by or based on standards or professional guides developed by professional bodies that provide handy tools (intervals between inspections, what kind of inspections, required skill levels). Use of these guides may be mandatory or be proposed simply as a guide. These guides will be presented in the following chapters.

8. PRESSURE EQUIPMENT MONITORING POLICIES

This chapter presents a summary of pressure equipment monitoring policies. Please refer to Annexes E, G, H, I and J that present the regulations and the professional guides for the studied countries. Annex F presents the monitoring practices observed in France during the visits made by INERIS in 2009.

8.1 GENERAL

8.1.1 CURRENT SITUATION

It appears that pressure equipment is covered by **mandatory inspections**.

To summarise, there are two kinds of regulations:

- **"Prescription" based regulations** applicable in France, the Netherlands and in Germany that set out aspects such as:
    - Mandatory intervals between the various inspections,
    - The types of inspections (external inspection, internal inspection (except for piping and for recipients for which equivalent techniques may be used), resistance tests (hydrostatic or pressure tests, if other techniques are not usable).

  We do however note that there is no longer any purely prescription based legislations but that variants exist that offer the ability to modulate inspections when RBI (Risk Based Inspection) type methodologies are applied. This is the case in the three countries mentioned[8]. However, implementing these methods implies the need for suitable structures and expertise. They cannot therefore be used at all facilities so the basic approach is therefore used in many facilities:

    - o <u>France</u>: possibility for a facility with a "SIR" (Recognised[9] Inspection Department) to extend the intervals between inspections and requalifications by 5 and 10 years or 6 and 12 respectively, depending on the reference base used.
    - o <u>The Netherlands</u>: extended interval pattern that doubles the intervals between inspections (8 to 12 years) and a flexible approach that goes up to intervals between inspections of 16 to 18 years.
    - o <u>Germany</u>: the possibility to extend intervals if the operator can justify this on the basis of a risk analysis.

---

[8] *In Germany, regulations are being changed. There are no longer any specific pressure equipment regulations and existing technical regulations are to be replaced by regulations relating to types of substances.*

[9] *The Inspection Department is recognised by the Competent Authorities*

- **“Target” based regulations** that simply define the operator’s obligation to perform periodic inspections on the equipment. However, in this case (United Kingdom, United States), professional guides exist to provide implementation methods as well as means to demonstrate that these targets have been met. Under these conditions, the intervals between inspections are highly variable depending on the guides and business sectors. The operations to be performed are similar to the ones presented in other country’s regulations. Nevertheless, the general regulations that apply in the US and the UK still set a minimum number of criteria (elaboration and implementation of inspection plans, skills required for the persons who define the plans and perform the inspections, an inspection report written up by a skilled person, decisions to be taken depending on the results).

8.1.2 PERSPECTIVES

It should however be noted that at the European level a thought process is heading towards a **desire to harmonise equipment monitoring practices**. As a result, discussions are ongoing at the GTP (Pressure Working Group) and EPERC (European Pressure Equipment Council) levels.

The RIMAP[17] project has been translated into a European standard. It aims to promote a risk based inspection and maintenance method. The project’s goal is to define a methodology that does however meet a certain number of requirements:

- Be applicable to any industry sector,
- Be accepted by the relevant authorities in each country,
- Be easily understandable at all levels,
- Be accepted by the various kinds of bodies (small or large companies), something that requires different evaluation levels,
- Be identical in its principle for all types of equipment,
- Be auditable by the authorities and by users,
- Enable a link to RBI approaches and generally speaking allow a link to risk management approaches (environment, personal safety, etc.),
- Take into account internal and external degradations,
- Detail personnel qualification requirements,
- Include a description of the effects of the inspection, the techniques used, etc.

Specialised networks exist to cover various headings like FITNET for Fitness for Service. This network has published three documents in 2006 on the Fitness For Service methodology (procedures and case studies) and would like to see BS 7910[64] become a European standard, something that has not been retained so far.

8.2 COMMON POINTS

The common points shared by these regulations relating to pressure equipment monitoring comprise:

- **Operator responsibility**;
- The **competence required of the persons** defining the inspection plans or performing inspection operations. This competence is validated by accreditations that are specific to each country (UKAS in the United Kingdom, the Dutch Council in the Netherlands, accredited bodies such as TÜV in Germany) or certification of competence for using specific inspection guides (e.g. API in the United States). If the site inspectors do not have recognised competence, third party validation is used (Netherlands, Germany). Sometimes this competence is not actually mandatory but simply strongly recommended, especially if the inspections relate to high risk facilities (see United Kingdom). In the same way, **the non destructive tests (NDT) require specific certification**;
- **Drawing up inspection plans** setting out the scope of the equipment to be controlled;
- The **overall nature of the inspections**: An external inspection (after removing the insulation on a one-off basis), an internal inspection (except for piping and for vessels for which equivalent techniques can be used), resistance testing (hydrostatic or pressure tests if other techniques cannot be used). Non destructive tests can be implemented in addition and the techniques used are usual ones (ultrasonics, dye-penetrant examination, radiography, etc.). An examination of safety devices is also always required during the inspections. In some texts that are specific to substances, special terms may be defined (for LPG in France for example, the standards[37]/[38] refer to routine inspections to be performed by the operator in addition to the regulatory inspections, and in the AFIAP[29] guide, periodic requalification waivers are possible if acoustic emissions are used in conjunction with pressure tests);
- **Generally less severe inspections for piping** (less often, with fewer pressure tests) are required than for tanks. Overall, plenty of on-site piping is not covered by the inspection plan. Nevertheless, the definition of the sensitive areas that the measurements are made on is an essential component of any inspection plan. This is why the piping inspection plan must be performed or at least validated by a recognised body (a person identified as being competent in the United Kingdom, an approach which in practice implies a body with specific accreditation and an approved body in France);

- An **action plan** defined after the inspections (keep in service, maintenance, additional investigations, a change in operating conditions, etc.). The guides studied did not provide any indication on common acceptability criteria. In practice, each body sets out their own acceptability criteria on the basis of the calculation codes used, the operating conditions and the date of the next inspection. Sometimes, flaws or damage evaluation guides are used to conclude whether a flaw or damage is compatible with a safed continued service. In the countries studied, the only two guides mentioned are BS7910[64] and API 579[80]. These guides require extensive skills (a certificate is needed for API 579[80] in US);
- A **record of results.**

8.3 DIFFERENCES

Deviations cover the following aspects:

- There is no need **to resort to professional guides** in “prescription” type regulations but this may be compulsory in the other kinds of approaches. Indeed, following some of these guides means compliance with the regulations (ACOP in the UK, API in the US). Other guides only have informative guidance value: Then they give interesting data to define inspection plans while highlighting potential degradation modes and sensitive areas (areas under insulation, injection points, etc.) as well as the examinations to be performed on parts of piping or piping support elements (flanges, supports, flexible hoses, etc.) (Please refer to the professional guides presented in the various Annexes). Consequently they are precious tools for defining the inspection plan (inspection points, non destructive techniques to implement, etc.) in detail.
- The **methodology implemented** to define the plans (basic regimes or more flexible ones). Under flexible regimes, RBI type approaches (as defined in the API 580[75] and API 581[76] guides) may be used. Their use requires high level skills and a high degree of installation knowledge. Inspectors able to undertake this kind of analysis are accredited inspectors. They may belong to the facility (like in France, like at some German chemical facilities, like in the US), or they will necessarily belong to third party accredited bodies (refinery in Germany). Knowledge of the installations and of the degradation modes is a minimal condition when implementing these methods. Other methods exist (SAFed guides[58]/[59], Institute of Petroleum in the UK[60]/[61], API 570[78], API 510[77]… in the US) which also require knowledge of degradation modes. They are easier to use but often require an accreditation.

- The **RBI methods** (developed from guides like API 580[75], API 581[46] or in France, from the UIC/UFIP DT32[39] and DT84[40] guides) **may differ from one facility to another and comprise variations in their implementation** (refer to the experience recorded in France in Annex F and in the United Kingdom in Annexe G). The methods used do not necessarily seem to be transparent and they are hard to be evaluated by a third party. **On the other hand, the Netherlands have validated RBI methods at the Labour Ministry level ; these RBI methods are the only ones applicable when seeking the benefit of the so-called flexible regime**. The study did not however allow qualifying the level of method validation (a general methodology or more detailed elements).
- **Intervals** between inspections. These intervals differ between the guides used and the variability criteria for a given guide are not necessarily the same (this is at least a knowledge of the equipment and learning from experience - parameters that are common to the guides - it is however sometimes the hazardousness and not the risk that defines the interval between inspections. Sometimes equipment age is a factor and intervals are reduced when approaching the equipment's theoretical end of service date).
- **Hydrostatic testing is a French requirement**. In other countries, this is more generally a resistance test that takes the form of a pressure test (which may under some conditions be a hydrostatic test - as in The Netherlands). This is however only required if non destructive testing (NDT) cannot be applied or is not relevant. In the USA, no pressure test is required if no modifications or repairs have been made (information collected from a chemical company).

<u>Note</u>: In the various countries, controls are apparently performed by the relevant authorities, but the study was unable to clarify whether these controls were performed in a systematic way at set intervals or whether the inspections were a part of exceptional national campaigns (like the one launched in the US at refineries to check compliance with 29 CFR 1910.119)[71].

8.4 SUMMARY OF PROFESSIONAL GUIDE SPECIFICITIES

The tables on the following pages summarise the specificities of the professional guides. These tables cover the main professional guides used in the US and the UK.

The body performing the inspections must have the relevant competence to select which guide is suited to the equipment studied and must be able to justify the options retained to the relevant authorities (degradation modes, etc.).

<u>Note</u>: Other guides have been identified (CCPS Guidelines for Mechanical Integrity) that are especially usable in the chemicals field. Unfortunately they were not available at the date of the report,, so they are not included in the comparison.

It is however probable that the inspection intervals at medium sized facilities is a shorter one. A US chemicals company sent us the following regular intervals:

- For tanks: between external inspections, periods of 3 to 5 years, between internal inspections, periods of 3 to 10 years,
- For piping: between external inspections, periods of 2 to 10 years (depending on the type of substance).

Then a comparison between requirements in terms of periods between inspections in the various countries is presented for pressure tanks and piping.

Note: The questionnaire answers confirmed the kinds of operations performed on the pressure equipment and the mandatory nature of controls. Validation and skills aspects do not show up clearly in the answers. Unfortunately no answers were received from refinery operators who probably apply RBI methods. It would have been interesting to see what the true inspection intervals were when RBI methods are implemented.

Note: The tables on the following pages summarise the requirements from the various guides. The terms used (class, grade, etc.) are detained in Annexes G and H.

Pressure vessels - Guides used in the UK (SAFed, IP) and in the USA (API)

	SAFed – Periodicity of examination[58]	**IP – Part 12 – Pressure Vessels**[60]	**API 510 – Pressure Vessel inspection code**[77]
Field of application	*Pressure equipment and others*	*Chemical and petroleum tanks*	*Chemical and petroleum tanks*
Interval between examinations	By class of equipment (knowledge of the equipment and possibility of degradation) Class A: 24 to 26 months Class B: 36 to 48 months Class C: 60 to 72 months Up to 120 to 144 months if extensive, documented experience of satisfactory operation for extended periods without deterioration is available (Includes LPG)	By grade 0 to 3 (knowledge of the equipment and possibility of degradation, but also depending on possible consequences + other criteria) Tanks: 60 to 144 months Accessories: 24 to 72 months	External: 60 months Internal: 120 months max. Pressure test: No interval requirements (may be replaced by NDT)
Special case	If approaching the end of the predicted service, reduced intervals If traceability, documentation, etc., then the interval is extended	If approaching the end of the predicted service, reduced intervals	Possible service life influence If RBI, no maxmum interval
Type of inspections	Not detailed	External and internal inspection Preparation conditions	External and internal inspection Pressure test only after repairs or changes
Safety accessories examination	Yes, at least as often as equipment	Yes, with details on the type of inspections	Pressure relief Valves: 60 months max.

<u>Reminder</u>: PE = Pressure Equipment - NDT = Non Destructive Testing

Pressure piping - Guides used in the UK (SAFed, IP) and in the USA (API)

	SAFed – Periodicity of examination[58]	SAFed Pipework[59]	IP – part 13 – Pressure Piping[61]	API 570 – Piping Inspection code[78]
Field of application	*Pressure equipment and other equipment*	*Excl. complex piping (refinery)* *Pressure equipment and hazardous substances*	*Piping in chemicals and petroleum*	*Piping in chemicals and petroleum*
Interval between inspections	By class of equip. (knowledge of equip. & degradation possibility) Class A: 24 to 26 months Class B: 36 to 48 months Class C: 60 to 72 months 120 to 144 months if extensive, documented experience of satisfactory operation for extended periods without deterioration is available (Includes internal GPL check)	Depending on severity (substance pressure and hazard level, impact on persons, degradation possibility) For pressure piping If corrosion, erosion: 24/26 mths (External + NDT) Else: 36/38 months (External + NDT if needed)	Choice of piping to control in plan depending on human and environmental consequences and depending on failure probability + other criteria) Piping: 36 to 144 months	By class and type of inspection: Piping: 60 to 120 months
Special case	If approaching the end of the predicted service, reduced intervals If traceability, documentation, etc., then the interval is extended	If creep, fatigue: see remaining service life If in good condition despite corrosion: 72 month NDT Beware bellows and flex piping	Pay attention to specific points (bellows, linings, etc.) and supports	Underground piping Injection points
Type of inspections	Not detailed	External inspection (walk along piping) Additional measures (NDT) on targeted areas	External inspection Additional measures	External inspection and thickness measurements including an inspection under the insulation Pressure test only after repairs or changes
Safety accessories examination	Yes, at least as often as equipment - 26 months max.	Refer to SAFed Interval of examination guide	Yes with details on the type of inspections	Valve examination

Pressure vessels - Comparison of intervals between inspections by country

	France		UK	USA		Netherlands			Germany
	Base	**SIR**	**Base**	**API**	**RBI**	**Base**	**Extended**	**Flexible**	**Base**
External inspection	40 months per person deemed competent 36, 60 or 120 months (*) per OH	See plan Max. 60 or 72 months per SIR Max. 120 or 144 months per OH (**)	See plan Guides: 24 to 144 months Per competent person (the level required depends on hazard)	60 months Per authorised person (API)	No maximum interval	48 to 72 months Per OH	96 to 144 months Per OH	16 to 18 years Per OH **RBI validated by Ministry of Labour**	24 months (adjustable ceiling) Per OH *For lesser hazard: expertise - interval to be defined*
Internal inspection (Except special cases)	40 months per person deemed competent 36, 60 or 120 months (*) per OH	See plan Max. 60 or 72 months per SIR Max. 120 or 144 months per OH (**)	See plan Guides: 24 to 144 months Per competent person (the level required depends on hazard)	120 months max. or on stream by NDT under conditions Per authorised person (API)	No maximum interval	48 to 72 months Per OH May be replaced by NDT	96 to 144 months Per OH	16 to 18 years Per OH **RBI validated by Ministry of Labour**	60 months (adjustable ceiling) Per OH *May be replaced by NDT*
Examination - Inspection of safety devices	40 months per person deemed competent 36, 60 or 120 months (*) per OH	See plan Max. 60 or 72 months per SIR Max. 120 or 144 months per OH (**)	See plan At least as often as for vessels Per competent person	Pressure relief valves: 60 months max.	No maximum interval	Same frequency as equipment Per OH	Same frequency as equipment Per OH	Same frequency as equipment Per OH	Yes
Hydrostatic test Pressure test	36, 60 or 120 months (*) per OH (conditional P, V)	See plan Max. 120 or 144 months per OH (**) (conditional P, V)	May be replaced by NDT	May be replaced by NDT	/	May be replaced by NDT	May be replaced by NDT	May be replaced by NDT	120 months (adjustable ceiling) May be replaced by NDT

(*): Depends on the type of substance contained (its toxic and/or corrosive nature)

(**): For facilities with SIR, SIR may be allowed to perform periodic requalifications

Note: A qualified person means a body considered to be skilled (in practice, in France, generally done by recognised bodies, in the UK by accredited bodies)

Reminder: NDT = Non Destructive Testing – SIR = Recognised Inspection Service – "OH" = Body validated in line with a process that is specific to the studied country

Pressure piping - Comparison of intervals between inspections by country

	France		UK	USA		Netherlands			Germany
	Base	**SIR**	**Base**	**API**	**RBI**	**Base**	**Extended**	**Flexible**	**Base**
External inspection + Examination - Inspection of safety devices	Schedule to establish To be performed by person deemed competent Inspection + Validation plan: 36, 60 or 120 months (*) per OH For "large" piping	See inspection plan To be performed by SIR Validation plan: 120 to 144 months per OH (**) For "large" piping	See plan Guides: 24 to 144 months Per competent person (the level required depends on danger)	60 to 120 months Per authorised person (API)	No maximum interval	48 to 72 months Per OH	96 to 144 months Per OH	16 to 18 years Per OH **RBI validated by Ministry of Labour**	60 months (adjustable ceiling) Per OH *For lesser hazard: expertise - interval to be defined*
Hydrostatic test Pressure test (for in service controls)	Hydrostatic test waived	Hydrostatic test waived	Hydrostatic test waived	Hydrostatic test waived	/	May be replaced by NDT	May be replaced by NDT	May be replaced by NDT	60 months (adjustable ceiling) May be replaced by NDT

(*): Depends on the type of substance contained (its toxic and/or corrosive nature)

(**): For facilities with SIR, SIR may be allowed to perform periodic requalifications

Note: A qualified person means a body considered to be skilled (in practice, in France, generally done by recognised bodies, in the UK by accredited bodies)

Reminder: NDT = Non Destructive Testing – SIR = Recognised Inspection Service – "OH" = Body validated in line with a process that is specific to the studied country

8.5 REMAINING LIFE

For all of the countries studied, there **is no predefined service life concept for equipment**. remaining life durations are calculated after the inspections.

Acceptability criteria are defined for each facility, taking into account calculation codes (the service life that may have been defined by design) but especially taking into account inspection results. A control is made to ensure that the equipment can be kept in safe operation until the next inspection.

Sometimes, guides are used where acceptability criteria are achieved: These are essentially guides API 579[80] (Fitness For Service) and BS 7910[64] (the UK equivalent) which thanks to extensive calculations make it possible to ensure that any identified flaw does not compromise equipment safety until the next inspection. Please refer to Annex L for further information.

8.6 REMARK: HARD TO INSPECT EQUIPMENT

Controlling some equipment may be considered difficult and may require specific inspection conditions. As a result, the national action plan identifies the following equipment as being “hard to inspect”:

- Cryogenic tanks where opening may trigger corrosion phenomena (ammonia tanks);
- Hard to access piping;
- Equipment with an inside or outside lining that makes inspection difficult.
- Oxygen tanks.

To inspect “hard to inspect” piping, refer to the refinery piping benchmark. This report identifies the difficulties encountered and the solutions provided for controlling “hard to inspect” equipment such as:

- Insulated piping.
- Piping located in a difficult environment (a high position, in racks, in rows, etc.
- Piping in sheathes or that passes through bunds.
- Specific equipment such as expansion compensators.

In France, for equipment with an inner or outer lining, professional guides have defined special approaches (see Annex E).

For the other tanks (cryogenic ammonia, oxygen tanks), due to a lack of time, INERIS has not performed any research or visits to detail the inspection modes. There are specific guides for ammonia written by the European EFMA association but this document has not been analysed as a part of this study. The questionnaire did not provide any additional answers.

9. ATMOSPHERIC TANK MONITORING POLICIES

This chapter presents a summary of flammable liquid atmospheric storage tank monitoring policies. In practice, it focuses on flammable liquid atmospheric tanks. Please refer to Annexes E, G, H, I and J that present the regulations and the professional guides for the studied countries. Annex F presents the monitoring practices observed in France during the visits made by INERIS in 2009.

9.1 GENERAL

Requirements relating to atmospheric storage tank monitoring come from the regulations relating to Seveso or hazardous facilities (Germany, United Kingdom and United States) that provide the general requirements (see Chapter 7).

More specific information comes from pollution control regulations (US) or corresponds to specific requirements linked to flammable liquids (United Kingdom and the Netherlands). Regulations are based on the fact that atmospheric tanks are covered by a **requirement to maintain mechanical integrity.**

The study also shows up that their monitoring is primarily voluntary, meaning that the conditions are not always clearly set out in the regulations (the survey did not make reference to a minimum tank size).

As a general rule, the regulations do not prescribe lead-time and means of action.

Professional guides or standards serve as the technical reference in terms of best practices.

In more prescription based frameworks (e.g. in the Netherlands)**, a general methodology is set out or the use of a specific guide required.**

A discussion with a US government staffer highlighted a weakness in the administrative monitoring process for tanks in the US. In practice, for US organisations, the number of government inspectors is insufficient to cover the number of facilities to be monitored.

9.2 COMMON POINTS

The common points shared by the regulations in the four countries studied are:

- **Operator responsibility** as regards the integrity of this equipment.
- The **competence required of the players** defining the inspection plans or performing inspection operations. This competence is validated by accreditations that are specific to each country (UKAS in the United Kingdom, the Dutch Council in the Netherlands, accredited bodies such as TÜV in Germany) or certification of competence for using specific inspection guides (e.g. API in the United States). The same applies for **non destructive testing requiring specific certification**.

- **Drawing up inspection plans**.
- The **general methodology recommended for performing inspections** is taken from professional guides recognised by the entire profession. Regardless of the guide, the general structure of tank monitoring comprises:
  - A **routine inspection** performed frequently by the operating staff.
  - An **external inspection** (in service) comprising a complete visual inspection of the equipment and additional non destructive tests performed by **qualified persons. An examination of safety devices is** also called for during the inspections.
  - An **internal inspection** (out of service) comprising a visual inspection of the tank bottom and the inner shell base to which are added thickness measurements for best managing the condition of the equipment and its specific degradation kinetics.
  - **A resistance test (hydrostatic test)** identical to the initial qualification test to be performed after major repairs.
  - **Non destructive tests** may additionally be performed and the techniques used are the usual ones (ultrasonics, dye-penetrant examination, radiography, etc.).
- A **record of testing results**.
- A justification of the **actions** defined after the inspections (retain in service, maintenance, additional investigations, change of operating conditions, etc.).

Note: All of these elements are not systematically found in today's regulation requirements and/or in the monitoring practices for flammable liquid atmospheric storage tanks in France (no expertise level is required of inspection players, the inspections terms are not clearly defined and vary from one facility to another and may not include all of the inspections set out above, variable frequencies, record of actions and action monitoring are not systematic…).

9.3 DIFFERENCES

Deviations cover:

- The **scope of equipments** to be monitored: In the United States, tanks are treated differently depending on the hazard that they represent to safety and to the environment. A common set of recommendations relating to safety is applied to all equipment. Additional restrictions also apply:
  - To tanks that could contaminate North American waters (lake, river, groundwater, etc.) in the area where they are located. **It is up to the authorities to determine the true sensitivity of the relevant sites when it comes to applying these restrictions**.
  - To some tanks that are directly connected to the hazardous materials transportation network (pipeline).

- The **controls performed** during the inspections: While still retaining a common philosophy, the controls may vary between guides and industrial operators. As an example, the magnetoscopic testing method for tank bottom inspections is a controversial one in the United States. This is because it appears that only a part of the steel panels can be checked using this technology and it is therefore necessary to combine this inspection with other methods or to use alternative methods.
- The **frequencies at which the inspections take place**: They may be product related and arbitrarily set or directly linked to the equipment's degradation kinetics. In all of the guides, there is always a limit placed on the intervals between two inspections. The limits set are variable ones. For example, the EEMUA 159[57] guide sets two separate intervals depending on the products (crude, light, heavy) whereas the API 653[79] guide does not make this distinction.

  Sometimes, the RBI[75] and [76] method is used to break away from the limits defined in the guides. In practices however, this method is far from generalised for atmospheric storage tanks.
- The **RBI methods may differ and comprise variations in their implementation** (refer to the experience recorded in France in Annex F and in the United Kingdom in Annexe G). Despite frequent player certification and the use of guides which provide a technical framework for RBI methods, implementation does not necessarily seem to be transparent and may sometimes be hard to judge by a third party. Furthermore, international industrial groups develop their own methods which although they do indeed apply RBI principles, may yield variable results. As an example, some methods introduce two kinds of consequences into the equipment criticality calculation, one is a safety one and the other is a financial one. In other methods, this will involve a set of concatenated factors so as to see a single consequence level.

  The difficulty to achieve evaluation leads to variable recognition of these methods depending on the country. In particular, this recognition is not formally set out in the regulations covering atmospheric storage and may consequently depend solely on the authority in charge.

9.4 SUMMARY OF PROFESSIONAL GUIDE SPECIFICITIES

The tables on the following pages summarise the specificities of the professional guides. This table covers the main professional guides used in the US, the UK and the Netherlands.

The body performing the inspections must have the relevant skills to choose which guide is suited to the equipment studied and must be able to justify the options retained to the relevant authorities (degradation modes, etc.).

Atmospheric storage tanks - Main guides used in the UK, the Netherlands (EEMUA), the US (API) and France (UFIP Guide)

<table>
<tr><th></th><th colspan="5">EEMUA 159[57]: Users' guide to the inspection and repair of aboveground vertical cylindrical steel storage tanks[57]</th><th colspan="3">API 653[79] – Tank inspection, repair, alteration and reconstruction[79]</th><th colspan="4">Guide UFIP[45]</th></tr>
<tr><td>Field of application</td><td colspan="5">Atmospheric and refrigerated tanks</td><td colspan="3">Atmospheric tanks containing petroleum products</td><td colspan="4">Atmospheric tanks containing petroleum products</td></tr>
<tr><td>Type of checks</td><td colspan="5">Routine checks
External inspection
Internal inspection
Hydrostatic test after repairs</td><td colspan="3">Routine checks
External visual inspection
Ultrasonic shell thickness measurements
Internal inspection
Hydrostatic test after repairs</td><td colspan="4">Routine checks
External visual inspection
Ultrasonic shell thickness measurements
Acoustic emissions check
Internal inspection
Hydrostatic test after repairs</td></tr>
<tr><td rowspan="6">Maximum interval between inspections</td><td></td><td>Heated or insulated</td><td>Crude oil</td><td>Light oil</td><td>Heavy oil</td><td></td><td>Known degradation kinetics (N)</td><td>Unknown degradation kinetics</td><td colspan="2"></td><td>Ambient temperature</td><td>Heated</td></tr>
<tr><td>Routine</td><td>3 months **</td><td>3 mths **</td><td>3 mths **</td><td>3 mths **</td><td>Routine</td><td>1 once a months</td><td>1 months</td><td colspan="2">Routine</td><td>Regularly</td><td>Regularly</td></tr>
<tr><td>External</td><td>3 years **</td><td>5 yrs**</td><td>5 yrs**</td><td>8 yrs**</td><td>External</td><td>RCA/(4*N) or 5 years</td><td>5 years</td><td rowspan="3">External</td><td>Base/ Lining</td><td>1 - 3 years</td><td>1 - 3 years</td></tr>
<tr><td rowspan="3">Internal</td><td rowspan="3">6 years **</td><td rowspan="3">8 yrs**</td><td rowspan="3">10 yrs**</td><td rowspan="3">16 yrs**</td><td rowspan="2">External ultrasonic</td><td rowspan="2">RCA/(2*N) or 15 years</td><td rowspan="2">5 years</td><td>Ultrasonics</td><td>3 - 5 years</td><td>2 - 3 years</td></tr>
<tr><td>Acoustic emissions</td><td>0 - 10 years</td><td>0 - 10 years</td></tr>
<tr><td>Internal</td><td>RCA/ N and 20 years</td><td>10 years</td><td colspan="2">Internal</td><td>No limit</td><td>Max. 20 yrs</td></tr>
<tr><td>Accessory examination</td><td colspan="5">Yes, during every inspection</td><td colspan="3">Yes, during every inspection</td><td colspan="4">Yes, during every inspection</td></tr>
</table>

***RCA:** Residual thickness **=** Thickness at last inspection – Minimum thickness required by the code - **N:** Corrosion rate per year*
***(*):** These frequencies should be considered in cases where no RBI method is in place. In such a case, the limits are set by the method.*
(**) All of the frequencies are given for a temperate climate. The guide also provides values for tropical or desert climates.

9.5 REMARKS

9.5.1 REMAINING SERVICE LIFE

For all of the countries studied, there is no predefined service life concept for atmospheric tanks. However residual service life durations are calculated after the inspections based on degradation kinetics.

Simple acceptability criteria are defined for each facility, from a comparison between the thickness measurements extrapolated until the next inspection (taking into account the corrosion rates) and acceptability criteria defined in the calculation codes.

Some industrial groups add an uncertainty factor linked to the measures taken thereby including an inspection reliability aspect. This is done in the RBI method context.

Sometimes, guides are used where simple acceptability criteria are achieved: These are essentially guides API 579 (Fitness For Service[80]) and BS 7910[64] (the UK equivalent). They make it possible to extend the remaining service life on the basis of better knowledge and better modelling of the equipment.

9.5.2 SPECIFIC INSPECTION APPROACH: ACOUSTIC EMISSIONS

These are seldom used in any of the countries reviewed. The results achieved with acoustic emissions are often called into question in at least three of the countries studied (United Kingdom, Germany, USA) especially regarding the following two points:

- They are very difficult to implement, making is practically impossible to validate the results,
- Any interpretation of complex results is closely linked to operator experience.

Consequently and unlike in French practice, acoustic emissions are not used as the sole means for extending the interval between two inspections.

10. POLICY FOR MONITORING EQUIPMENT (PLANT PIPING AND TANKS) NOT COVERED BY PRESSURE EQUIPMENT REGULATIONS

Although the regulations on worker safety sets out requirements in monitoring terms (producing a monitoring plan, monitoring by a competent person, traceability for inspection and test results, etc.), in-service monitoring of equipment other than pressure equipment is most often identified in survey[10] answers as coming under the heading of **voluntary monitoring**.

The criteria taken into account when bringing equipment into the scope of monitored equipment are not precisely set out. Nevertheless, it is clear that the inspection plan produced will be all the more severe, the greater the risk entailed by any serious integrity breakdown. The potential consequences on water of any integrity breakdown are also sometimes mentioned as criteria in identifying the equipment to be monitored.

In the same way, it appears that the monitoring of equipment at **Seveso** facilities can also be identified as **voluntary monitoring**.

The terms of the monitoring are defined by the operator (e.g. by their maintenance department) and do not apparently require any specific competence. In the same way, no third party validation applies. Generally, some industrial operators do not perform formal inspections on this equipment while others do perform these inspections. Two responses to the questionnaire mention inspections on this equipment every 3-5 years (chemicals in Europe) or every 5-10 years (chemicals in the USA). If safety equipment is fitted to this equipment, then inspections will also be performed (every 1 to 5 years).

In this case, the inspections are of the same type as for pressure equipment (external inspection with potential NDT, internal inspection with potential NDT, possible pressure tests).

Furthermore, there are regulations and professional guides that provide specific information on monitoring equipment comprising hazardous substances. However any analysis of these specific regulations is outside of the scope of our study. Especially, one response to the questionnaire (from a chemicals company in the USA) states that regulations cover toxic substances.

In the end, it appears that in the countries we studied, there is a difference between regulation requirements and practice in the field (but the number of responses to the questionnaire remains doubtless too small to be able to draw reliable conclusions). The demands of the various directives (Seveso, safety and health protection of workers) do not appear to have necessarily been applied in as formal a way as they should have been.

[10] *The few responses received to the questionnaire on monitoring this equipment identify monitoring as a voluntary one. Regulation requirements are not mentioned as a reference (USA, Netherlands and UK). In Germany, monitoring is identified as mandatory monitoring under the heading of water protection and/or worker protection.*

In the United Kingdom, HSE observes[68] that the monitoring of atmospheric pressure storage tanks containing hazardous substances is indeed not always compliant with regulation requirements. **They recorded numerous omissions in the monitoring of this kind of equipment** (a lack of documentation, failure to identify the equipment to be monitored, lack of thought as to substance compatibility when different substances are stored successively, no inspection plans, no thought as to degradation modes, highly variable qualification levels for inspectors from one site to another, the inspector's field of action[11] not clearly defined, etc.) **and they also note that many of these tanks are more than 50 years old and are in part of the riveted kind.**

At least in the United Kingdom, the following points are not always complied with:

- Identifying the equipment to be inspected and integrating them into an inspection plan (with criteria to be defined on the basis of a risk analysis, in line with a safety report, etc.)[12].
- Collecting data available on the equipment (identification, construction codes, etc.).
- Defining an inspection plan and the monitoring conditions, including writing out the related procedures (type of inspections (including an internal and external examination), preparing equipment, the kind of NDT used depending on the potential degradation modes, frequencies, scope of inspection that may include foundations, etc.), with reference to recognised guides.
- Non uniform expertise of personnel entrusted with defining inspection plans and with monitoring.
- Result traceability (with good quality reports).
- Defining acceptability criteria.
- Action plans based on inspection results and following of this action plans.
- Defining inspection operations to be performed by the relevant authorities at intervals to be defined.

In France, the need to monitor certain kinds of equipment (equipment subject to voluntary monitoring, known by the French initials ESSV) and the criteria for defining this equipment are under progress. ESSV monitoring is progressing especially at facilities with large scale structures.

[11] *The scope may therefore comprise inspection actions, interpreting the inspections and validating the ability to retain equipment in safe service until the next inspection.*

[12] *The questionnaire shows up the fact that links may exist between danger studies and inspection plans but that this link is not always highlighted.*

11. ELECTRICAL EQUIPMENT AND SAFETY INSTRUMENTATION MONITORING POLICIES

The way electrical equipment and safety instrumented systems are monitored are very similar from one country to another and match French practices:

- **The operator is responsible for identifying the components to be monitored**. They may develop an inspection plan (as specified in the "Management of integrity" heading produced by OSHA[71]).
- The equipment installed on-site are more and more often compliant with the demands of standard IEC 61511[8] and inspections therefore follow the technical specificities defined in this standard.
- The electrical equipement and safety instrumented systems are covered by monitoring operations that take place on line, **at intervals that vary from one site to another and from one type of equipment to another**.
- Functional tests (covering the complete safety loop) are performed regularly at intervals defined by the operators or based on manufacturer's recommendations. These are performed by specialist instrumentation or maintenance departments or by suppliers (gas and flame detectors). Sometimes the intervals are defined by SIL request. The functional test intervals are often aligned with those of the equipment that they are fitted to (the case with instrumented prevention safety systems).
- When the safety systems are fitted to pressure equipment, they must further comply with the monitoring demands that apply to safety devices fitted to pressure equipment. In this case, the intervals vary in line with the national regulations and/or professional guides used (see guides presented in the Annexes. For example, in the SAFed guide - Guidelines on periodicity of examinations[58], the recommendation for mechanisms that prevent any excess rise in pressure (like pressure sensors, overfill systems, etc. and their related actuators) is to align checks with the inspections performed on the related equipment, proposing that a 26 month interval should not be exceeded). In the IP guide – Part 12[60], the inspection intervals for safety systems linked to rising temperatures and overpressure (the safety equipment knowledge function) vary from 24 to 72 months. However, these values are guideline values and learning from experience may weight these values.
- In this case, the inspection department is responsible for monitoring: It checks that the tests are performed and the results recorded in the inspection plans linked to the pressure equipment.
- Test reports are recorded.
- The relevant authorities regularly ensure that the trials and tests have been performed.

The issue of electrical system obsolescence or ageing often arises:

- **When spare parts are not available** (hence policies for retaining spare parts on-site so as to be able to continue to maintain equipment after the vendor has stopped production. In some cases there are agreements with vendors).
- When the **equipment evolves to new higher performance technologies.**
- When the **equipment turns out to be faulty** (poor feedback from experience in service).

Specifically in the United Kingdom, the following aspects were reported:

- New untested equipment is not introduced into service without first being tried.
- Safety instrumented system ageing may affect its SIL (Safety Integrity Level). To correct this, modifications must be managed and procedures developed showing how ageing may affect a SIL of a safety instrumented system.

The few responses to the questionnaire highlight the fact that equipment is not systematically replaced in line with operating life criteria, but rather in line with the results and also taking into account vendor assessments. Repairs or modifications may be made where necessary, depending on the inspection results.

The few opinions expressed on the conditions for monitoring safety systems are positive ones and stress that, to date, monitoring is satisfactory. The only negative point reported relates to possible difficulties in implementation but without further details being offered.

12. NON ELECTRICAL SAFETY ACCESSORY MONITORING POLICIES

Safety devices (pressure relief valves, vents, bursting discs, etc.) are covered by regular inspections. Practices outside of France appear to be the same as in France in their principle.

Inspection frequencies depend on various parameters:

- **They may be aligned with those of the equipment that they protect**. This is especially the case with safety devices mounted on pressure equipment (the case in France and in other countries). In the United Kingdom, PSSR 2000[54] covering pressure equipment states that safety measures must be periodically inspected in line with an inspection plan drawn up by a competent person. Regulations however remain very general ones. The guides provide more information on the frequencies set. For example, the SAFed – Guidelines on Periodicity of Examinations[58] guide recommends that for so-called Category 1 devices (bursting discs, pressure relief valves, vents, atmospheric releases) that inspection frequencies be aligned with those of the tank that they protect, on condition that these are clean, non corrosive systems. Nevertheless, the interval must not exceed 26 months, unless a solid learning from experience background has been built up so as to show that the interval can be extended. For mechanisms that are subject to shocks, deposits, etc, a maximum interval of 14 months will be complied with. Le guide SAFed - Guidelines for Competent Person In-service Examination of Pressure Systems Pipework[59] recommends pressure relief valve inspections on liquid lines at intervals of between 5 and 10 years as appropriate. In the IP Guide - Part 12[60], the maximum pressure relief valve inspection periodicity is 72 months.
- **This may be defined by the inspection plans**.
- **This interval may be aligned with regulations** (especially pressure equipment inspection regulations - See above).

Inspection operations may require disassembling equipment (pressure relief valves for placing on a test bed, bursting discs). Pressure relief valves are seldom systematically replaced, but are repaired before they are refitted and retested. Bursting discs that are more sensitive to ageing (for they tend to open more) are replaced in a more systematic manner. The IP Guide - Part 12[60] recommends checking the opening pressure after disassembly to ensure that the disk has retained its capacity to open at the requisite pressure. It is also stated that inspections must also cover the related piping and isolation mechanisms fitted between tanks and safety devices (where there is a possible blocking hazard).

The few responses to the questionnaire that were received show that the equipment is not systematically replaced in line with any service life criteria but in line with the test results and after also taking into account the recommendations made by suppliers (especially for the more systematic replacement of bursting discs). Repairs or modifications may be made if necessary, depending on the inspection results.

The persons in charge of monitoring are on-site personnel (essentially maintenance staff) or contractors. There may be a third party validation process (by the inspection authority in the Netherlands), depending on regulation requirements.

The few opinions expressed on the way safety devices are monitored are positive ones, claiming that as things stand, monitoring is satisfactory.

13. CIVIL WORKS MONITORING POLICY

According to our bibliographic research and the survey responses, there is no document that specifically details monitoring elements for civil engineering aspects, except for a few demands as to monitoring containment dikes.

In 1997, INERIS produced a study comparing regulations on containment dikes in:

- France,
- The Netherlands,
- The United Kingdom,
- Germany.

At that time, the only country that had introduced an inspection and maintenance concept was France, stating that the containment dikes *"will be monitored and maintained periodically".* Neither quantitative data nor any additional details were provided. Nevertheless, since this study was made, regulations have changed and requirements have appeared in other countries.

In Germany, a contact stated that the following requirements were now in place:

- Construction elements must be monitored in the same way as process equipment. This is the operator's responsibility.
- Regarding containment dikes, it is necessary to ensure that the bottom of the containment remains intact and sealed something that already implies ensuring that no plants, grass, etc. grow up.
- As part of the work to manage changes, it is necessary to ensure that civil works component performance levels are not altered (passing through firewalls with new piping, etc.). Before commissioning any equipment, a visual inspection is called for.

In the Netherlands, Directive 29[95] on flammable liquid storage comprises the following requirements:

- Containment dike walls should be regularly inspected and maintained so that the minimum liquid retention height continues to be guaranteed.
- Any damage observed must be repaired immediately.
- Grass on ditch walls must be regularly mown.
- Inspection and maintenance work on the tank and neighbouring elements (therefore including containment dikes and foundations) must be carried out in line with an inspection program and a maintenance program approved by the relevant authorities.
- Refusal criteria mentioned in publication EEMUA No.159[56] (including some that relate to the foundations and that are detailed below) may be used for

every component part of a tank, independently of the code applicable when the relevant tank was built.

In the United Kingdom, the UKLPG “Code of Practice 1 / Part 3 - Examination and Inspection (2006)”[62] guide covering LPG storage installations recommends the following in its routine inspection stipulations:

- An environment check including the absence of any modifications that may cause ground movement.
- A check to ensure that there is no differential subsidence.
- A check to ensure that there is no corrosion or deterioration affecting the tank and including supports.

Interesting elements were also found in the EEUMA[56] guide on monitoring storage tanks, changing the criteria established in the UFIP[45] guide:

- For subsidence between the tank bottom centre and the shell edges (uniform differential subsidence). UFIP criteria: 30%. EEUMA criteria: A ratio that is weighted in line with material parameters (Young’s module, maximum admissible stress level). A criterion was added on folds at the bottom of tanks.
- Differential subsidence between two points 10 meters apart. UFIP criteria, 100 mm. EEUMA criteria: A more penalising criteria was added depending on the type of tank (diameter, presence of a floating roof).
- The maximum slope criteria. UFIP criteria, 1/100th of height. EEUMA criteria: A criteria was added for the degree of deformation at the tank edge.

Lastly, the EEUMA[56] guide provides indications on how to consolidate and repair foundations. For example:

- A flattening technique for under folds.
- A method for raising and consolidating foundations while retaining tank presence.

In the United States, text 29 CFR 1910[71] mentions **criteria for external inspections** of various parts of an installation, among which the following are mentioned:

- Civil works elements such as foundations and supports,
- Anchor bolts,
- Concrete or metal supports.

This text called 29 CFR 1910.119[71] mentions a list of guides from the following bodies, without specifying which ones may provide relevant information on civil works. These guides are those of the following organisations:

- The National Board Inspection Code or the American Society for Testing and Material (ASTM),
- The American Petroleum Institute (API),
- The National Fire Protection Association (NFPA),
- The American Society of Mechanical Engineers (ASME),

No detailed study of these guides was made.

A US expert mentioned the existence of regulations specific to containment dikes in the US. We have not found any further information on this source.

14. ORGANISATION ASPECT

Managing ageing requires rigorous equipment monitoring, calling on contributions from various departments and areas of expertise from both within and outside of the company.

This chapter sets out some aspects regarding organisation of the monitoring process. These thoughts come from the technical guides and/or visits to industrial facilities in France.

- **A need for upstream inspections**, when the equipment is commissioned. These inspections offer the occasion to check that no flaws are present (poor alignment, abnormal vibration, etc.) which could later lead to accelerated degradation. At this time, the initial thickness controls, for example, will also be made so as to later evaluate changes in time.

- **A need for a file on every item of equipment** ensuring data **traceability**. The file comprises technical data on the equipment (construction file, identification, etc.), the inspection procedure applied, the inspection history and the results and the work performed on the equipment. A zero point should be established for use later on in evaluating change in potential degradations. The measurements should be taken from the same locations to analyse changes. After every inspection, an analysis should be undertaken to evaluate whether degradation rates are stable or evolving.

  The content of the periodic inspections undertaken should allow for learning from experience and detailed risk analyses with special attention paid to risk areas. Thickness measurements should be made in these areas. Result acceptability criteria should be defined.

- **The importance of good coordination between departments**:
  - Between the inspectors and the process team for monitoring COCL[13] aspects. These critical thresholds should be clearly defined and if they are exceeded, the operators must absolutely inform the inspection department (value reached, duration, etc.). An analysis should make it possible to understand why the COCL levels were exceeded so that the situation is not repeated and what the consequences are on the equipment.
  - Between operators and inspectors for reporting all data that seems abnormal and that may be the cause of an accident. Data must be reported by:
    - Facility personnel (operating teams, maintenance department, etc.),
    - Contractors (maintenance, NDT, etc.).

[13] *COCL stands for Condition Opératoire Critique Limite or Operational Condition Critical Limit.*

Everyone needs to be trained on, and given an awareness of, the need to report flaws (unusual vibration, dripping, leaks, poor insulation condition, etc.). The kind of information to be reported could be covered by a check-list. A formal list of checks to be performed during the rounds makes it possible to target areas to look at and where to maintain quasi-full time surveillance. In the same way, personnel must be encouraged not to damage equipment, e.g. by walking on insulated piping.

- Between the inspectors and the safety departments to identify through a risk analysis, any possible cause of damage that are not identified by a conventional criticality approach. For example:
  - Drippings,
  - Internal or external domino effects.

  In the same way, evaluation of the severity of accidents must be performed together with the safety department so as to best assess the consequences on human targets or on the environment, taking into account the potential domino effects between equipment. The modelling performed in the safety reports may be used to feed the severity assessments made in the criticality studies to define inspection plans.
- Between the inspectors, the operators and the safety department to evaluate the impact of modifications and/or work to be performed on the equipment. Implementing a degraded operating mode must be done after discussions. Check-lists showing points to look at should modification occur may be drawn up (ergonomics aspects, safety impact, etc.).

  Generally, all industrial bodies (UIC, UFIP, CFBP) agree with the need to bring together inspection methodologies with the results of risk analyses.

- **Generalising the sharing of experience**. This must be done within the plant but also beyond it to take advantage of experience gained. This sharing of experience must not only be verbal for should staff change, a loss of knowledge is inevitable and updating inspection plans will become difficult and uncertain.

  Within the plant, records of inspections and operations performed on equipments must be accessible to the departments involved (operators, safety and inspection). They must be as precise as possible and the information provided should allow reuse for evolutions, for example. A common base by type of equipment would allow providing elements for assessing the probability of any given degradation.

Outside of the plant, information must be passed on for inclusion in plan revisions. A summary of instructive accidents may be produced at each facility by the inspection departments.

The way best practices are shared (relating to organisation or technical elements) may take place through:

- Users groups convened with suppliers, especially for safety systems,
- Participating in technical days or tradeshows,
- Relations between industrial players during meetings held under the auspices of associations like EXERA or ICSI for safety systems or such as GEMER days for other equipment,
- Professional federations (UFIP, GESIP, UIC, etc.).

- **Maintaining competence to ensure and guarantee that equipment is monitored**. Depending on the organisation in place (SIR[14], SI[15] or not), the necessary competence are very different. Nevertheless, the operator remains responsible for monitoring equipment. Their knowledge of the terrain and their ability to keep up their competence through training actions are very important elements.

  Facilities that do not have a SIR call on the support of recognised bodies to validate inspection plans (inspection areas, performing NDT, making decisions on what to keep in service). However a critical analysis may be undertaken by the facility if they have the necessary competence. To do this, professional guides may assist them in identifying sensitive areas, which NDT modes to use and in defining acceptability criteria in relation to the inspection results.

  When the facility has a SIR, personnel expertise should be ensured by their own experience. A corrosion engineer must be present to develop inspection plans so as to guarantee degradation mode identification.

  To perform NDT, a COFREND qualification is required. The operator must ensure that the contractor has the right qualifications as regards the NDT performed, as well as the requisite experience.

  For welding, welder approvals must be checked (for welding on steel and/or stainless steel).

  Generally, because facility knowledge is important when putting together inspection plans, sufficient overlap should be ensured should an inspection staff member leave so as to ensure the on the ground training for the person replacing him.

---

[14] SIR means "Recognised Inspection Service"

[15] SI means "Inspection Service"

UIC-UFIP states that their aim is to have certified inspectors everywhere where a SIR is present (forecast job and skill management). DRIRE offices report inspector population ageing and the time required to train new ones as well as the need to plan hiring well ahead of time.

For inspection departments that are not recognised, each group defines their own rules. Some inspectors are certified. AFGC states that there are training reference guides but this approach is a voluntary one.

- **Supplier and outside contractor expertise** (in maintenance, performing inspections, etc.) to be guaranteed and checked. Expertise is one of the best practices in inspections. This aspect is deemed a fundamental point by all of the operators.

  Some practices that are called quality practices by operators stood out during our visits:

  - Long terms contracts ensuring the player’s expertise,
  - Checks on player certification,
  - Regular audits conducted on players,
  - One-off checks on work performed by “third party checkers”,
  - Privileged data use in-house,
  - Working in internal/external player pairs,
  - Collaborative maintenance/inspection work,
  - Having sensitive actions performed by in-house inspectors.

- **Rigorous monitoring of actions to be performed (inspections, work required after inspections, etc.)**. The industrial operators have every interest in using software to assist them in scheduling inspections. When work slips are issued to operators, to maintenance or outside companies, ensuring lead-times in line with the critical nature of the situation must be done. Priority must be given to operations based on how critical they are.

- **Transparency in inspection choices** must be ensured. This transparency ensures that decisions taken are understood. This desire for transparency is all the more necessary as software may be used and is often taken to be a black box. It is necessary to know the assumptions made in the evaluations so as to validate them (choice of break sizes, dispersion conditions, how cut off systmes are taken into account, etc.).

- Inspection plans must be based as much as possible on field work (observations made in the field rather than on drawings). **Direct involvement by inspection services in monitoring operations is a condition for maintaining their knowledge of the field. "Procedure" aspects that are often considered complex, especially for small SIR structures, must not become an obstacle to inspector involvement in the field**. UIC like CFBP restates the need for a selective approach for small plants, where the diversity in size, organisation and processes at the industrial facilities involved does not make it possible to envisage generalising SIR/SI or equivalent type structures.

- **Independence and the guarantor concept**. A SIR's credibility comes from its true independence. Consideration is being given this subject at the central administration level so as to ensure this independence. The concept or a guarantor for monitoring facilities that do not have a SIR must be detailed.

15. CONCLUSION

Recent accident data remind us that ageing industrial installations require setting up rigorous equipment monitoring so as to manage ageing.

An analysis of equipment monitoring principles (regulations, guides and real-life situations) in France and elsewhere (UK, USA, Netherlands and Germany) has highlighted the existence of highly variable monitoring methods depending on the industry involved, the types of equipments monitored (pressure equipment, storage tanks, electrical and instrumented safety systems, safety devices, civil works, other equipment not subject to pressure equipment regulations) and related regulations. A comparison with the other countries has shown up common points and differences.

Regarding equipment monitoring methods:

- **Pressure equipment is the subject of rigorous monitoring** based on regulation requirements and professional guides. In France, **monitoring methods are different depending on site structure**. At sites with Recognised Inspection Services (SIRs), risk based inspection (RBI) methods are used but their **implementation turns out to be variable from one site to another**. At other sites, monitoring is performed in line with regulation deterministic requirements. **In practice, piping monitoring may give rise to a certain number of problems** (a significant extent of piping to monitor, difficult accessibility, etc.). In other countries, monitoring complies with prescriptive or “target based” regulations.
- **Atmospheric storage tank monitoring may be partially based on regulations** that are not prescriptive. Professional guides or standards serve as the technical reference in terms of best practices. Nevertheless, **the extent and type of inspections remain highly variable from one site to another**.
- **Instrumented system monitoring is being improved** by progressively taking into account the requirements of operating safety standards.
- **Safety devices are often monitored at the same time as the equipment** that they are mounted on, possibly based on related regulations (e.g. pressure equipment). Consequently **the variability in inspections from one site to another is the same as in equipment monitoring.**
- **Monitoring other equipment** not covered by pressure equipment regulations (hazardous substance tanks, piping, etc..) remains highly variable but **is not generally done at industrial facilities other than those which have a specific inspection structure**. The criteria for integrating this equipment into a monitoring plan are not generally formally set out.
- **Monitoring for civil works components is not generally formalised**.

Furthermore, for all equipment, four aspects appear to be fundamental: Identifying sensitive areas that are especially prone to loss of integrity hazards, choosing the inspection techniques, defining acceptability criteria and evaluating remaining service lives. The result is that the methods implemented are highly variables depending on the industries and the equipment involved.

From an organisational aspect, the analysis was also able to highlight the importance of exchanges between the inspection department and other departments:

- With HSE in charge of safety reports: A closer link may make it possible to complete the identification of equipment to be monitored by including the risk prone equipment identified in the safety reports and this may allow identifying the specific causes of accelerated ageing (possibility of drippings, etc.).
- With facility operators and maintenance specialists including contractors: Systematically reporting back to inspection any drifts identified on-site makes it possible to better anticipate any failures linked to these drifts (critical operating conditions, unusual situations, etc.).

The analysis has also highlighted the importance of sharing the learning from experience gains both on-site but also extended to cover other sites and the need to guarantee and check the expertise of suppliers and outside contractors (maintenance, performing checks, etc.), to rigorously monitor the actions to be performed (checks, work required following inspections, etc.), ensuring transparency in inspection choices.

The discussions that took place in 2009 in France on the theme of managing industrial installation ageing and involving government agencies, experts and industrials, has made it possible to identify strong points and weak points in the monitoring of some forms of equipment.

The implementation of an installation modernisation plan[16] was therefore decided by the French Ministry in charge of Ecology as well as managing their ageing. A total of 38 actions were decided on, starting in 2010 and enabling better equipment monitoring.

.

[16] *Cf.* *http://www.developpement-durable.gouv.fr/IMG/pdf/PlanModernisation_vdef.pdf*

16. REFERENCES

General references

1. Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

2. Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances

3. Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work

4. Council Directive 95/63/EEC of 5 December 1995, amending Directive 89/655/EEC concerning the minimum safety and health requirements for the use of work equipment by workers at work (second individual Directive within the meaning of Article 16 paragraph 1 of Directive 89/391/EEC)

5. Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999, on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual directive within the meaning of Article 16, paragraph 1, of Directive 89/391/EEC)

6. Directive No. 2008/1/EC of 15/01/08 concerning integrated pollution prevention and control

7. IEC NF EN 61508 "Functional safety of electrical/electronic/programmable electronic safety-related systems"

8. IEC 61511 "Functional safety - Safety instrumented systems for the process industry sector"

9. NF EN ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories

10. NF EN ISO/IEC 17020: General criteria for the operation of various types of bodies performing inspection

11. NF EN 13306 - Maintenance terminology - June 2001

12. Evaluation et maîtrise du vieillissement industriel – collection EdF R&D – André Lannoy et Henri Procacia – Lavoisier 2005

    Translation in English : "Evaluating and managing industrial ageing"

13. Bilan de l'application de la DM-T/P 32510 du 21 mai 2003 concernant les dispositions de reconnaissance du service inspection d'un établissement industriel – Marc PIC – DRIRE Bourgogne (document downloaded from the Internet)

    *Translation in English : "*Results of applying DM-T/P 32510 of 21 May 2003 relating to the measures for recognising the inspection department at an industrial facility"

14. Presentation note by Ed Haynes and Guy Baylac - Israël conference - September 2007.

15. Extracts from Procédures d'évaluation de la durée de vie résiduelle des structures : pratiques industrielles - Remaining life assessments for structures: industrial practice - A. Chaudouet - Cetim - 2007.

16. Evaluation de la nocivité des fissures – comparaison des procédures BS7910, API 579-1/ASME FFS-1, RSE-M et FITNET - Anne Chaudouet – Cetim – 2007

    Translation in English "Evaluating crack noxiousness - Comparison between procedures BS7910, API 579-1/ASME FFS-1, RSE-M and FITNET"

17. RIMAP articles

18. *Corrosion in refineries – European federation of corrosion – Publications Number 42 – J.G Houston and F. Rapital*

References in France (regulations and guides)

	PRESSURE EQUIPMENT

19. Décret initial du 18 janvier 1943 modifié portant règlement sur les appareils à pression

    Initial decree of 18 January 1943 modified regulating pressure equipment

20. décret n° 99.1046 du 13 décembre 1999 relatif aux équipements sous pression, modifié ensuite par les décrets respectifs 2003-1249 du 22 décembre 2003 et 2003-1264 du 23 décembre 2003

    Decree No. 99.1046 of 13 December 1999 relating to pressure equipment, subsequently modified by decrees 2003-1249 of 22 December 2003 and 2003-1264 of 23 December 2003

21. Arrêté du 21 décembre 1999 relatif à la classification et à l'évaluation de conformité des équipements sous pression

    Act of 21 December 1999 relating to the classification and conformity evaluation of pressure equipment

22. Arrêté du 15 mars 2000 modifié, relatif à l'exploitation des équipements sous pression (modifiés par l'arrêté du 13 octobre 2000 et par l'arrêté du 30 mars 2005)

    Act of 15 March 2000 modified, relating to the operation of pressure equipment (modified by the Acts of 13 October 2000 and of 30 March 2005)

23. Décision BSEI n° 06-080 du 06/03/06 relative à la réglementation. Conditions d'application de l'arrêté du 15 mars 2000 relatif à l'exploitation des équipements sous pression

    BSEI Decision No. 06-080 of 06/03/06 relating to regulations. Application conditions for the Act of 15 March 2000 relating to the operation of pressure equipment

24. Décision BSEI n° 08-159 du 04/07/08 portant approbation d'un guide professionnel relatif à l'établissement de plans d'inspection

    BSEI Decision No. 08-159 of 04/07/08 approving a professional guide relating to the establishment of inspection plans

25. Décision BSEI n° 06-194 du 26/06/06 portant approbation d'un guide professionnel relatif à l'établissement de plans d'inspection

    BSEI Decision No. 06-194 of 26/06/06 approving a professional guide relating to the establishment of inspection plans

26. Décision BSEI n° 07-107 du 13/04/07 relative au remplacement de l'épreuve hydraulique, lors de la requalification périodique de certains équipements sous pression, par un essai sous pression de gaz contrôlé par émission acoustique

    BSEI Decision No. 07-107 of 13/04/07 relating to the replacement of the hydraulic test when periodically requalifying certain kinds of pressure equipment, by a pressure test using gas checked by acoustic emissions

27. Instruction DM-T/P n° 32510 du 21 mai 2003 relative à la « reconnaissance d'un Service Inspection d'un établissement industriel »

    Instruction DM-T/P No. 32510 of 21 May 2003 relating to the "Recognition of an Inspection Service at an industrial establishment"

28. Arrêté du 22 juin 2005 portant habilitation de l'APAVE Groupe, de l'ASAP et du Bureau Veritas.

    Act of 22 June 2005 approving APAVE Groupe, ASAP and Bureau Veritas

29. Guide AFIAP: « Le guide de bonnes pratiques pour les contrôles par émission acoustique des équipements sous pression » - généralités et annexe 1 de mai 2004 + annexe 3 de mai 2004 (sphères) + annexe 4 de juin 2005 (réservoirs GPL dits petits

vracs) + annexe 6 de mai 2004 (équipements sous pression cylindriques) – approuvés par BSEI n°07-107 de avril 2007.

AFIAP guide: "Guide of best practices for checking pressure equipment by acoustic emissions" - General and Annex 1 of May 2004 + Annex 3 of May 2004 (spheres) + Annex 4 of June 2005 (so-called small bulk LPG tanks) + Annex 6 of May 2004 (cylindrical pressure equipment) – Approved by BSEI No. 07-107 of April 2007.

Note: Annex 8 (reactors) was not retained for the study

30. Guide AQUAP: « Inspection réglementaire des équipements sous pression revêtus extérieurement ou intérieurement » - révision 2 – décembre 2005 – approuvé par BSEI n°06-011 de janvier 2006

AQUAP guide: "Regulation inspection of pressure equipment with an outside or inside lining" - Revision 2 - December 2005 - Approved by BSEI No. 06-011 of January 2006

31. Guide AFIAP: « Le guide de classification des modifications ou réparations de tuyauteries d'usine soumises à la réglementation française » - février 2004 – approuvé DM-T/P n°32 969 de Mai 2004

AFIAP guide: "Guide to classifying plant piping modifications or repairs subject to French regulations" - February 2004 - Approved by DM-T/P No. 32 969 of May 2004

32. Guide AQUAP: « Le guide de classification des modifications ou réparations des équipements sous pression soumis à la réglementation » - révision 3 – mars 2004 – approuvé DM-T/P n°32 969 de Mai 2004

AQUAP guide: "Guide to classifying pressure equipment modifications or repairs subject to French regulations" - Revision 3 - March 2004 - Approved by DM-T/P No. 32 969 of May 2004

Other specific guides used in pressure equipment regulations (CFBP)

33. *Procédure CFBP de requalification périodique de certains réservoirs de GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – novembre 2007 - approuvé par BSEI n° 08-032 de janvier 2008*

CFBP procedure for periodically requalifying some aboveground "small bulk" LPG tanks aged 40 or over (made prior to 1973) - November 2007 - Approved by BSEI No. 08-032 of January 2008

34. *Procédure CFBP d'évaluation des groupes de lots de réservoirs GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – juin 2005 - approuvé par BSEI n° 08-032 de janvier 2008*

CFBP procedure for evaluating groups of aboveground "small bulk" LPG tank batches aged 40 of over (made prior to 1973) - June 2005 - Approved by BSEI No. 08-032 of January 2008

35. *Procédure CFBP d'inspection renforcée de certains réservoirs GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – juin 2005 - approuvé par BSEI n° 08-032 de janvier 2008*

CFBP procedure for reinforced inspection of some aboveground "small bulk" LPG tanks aged 40 or over (made prior to 1973) - June 2005 - Approved by BSEI No. 08-032 of January 2008

36. *Cahier des charges CFBP pour la fabrication et l'exploitation des réservoirs GPL moyen et gros vrac – février 2008 - approuvé par BSEI n° 08-063 de mars 2008*

CFBP specifications for making and operating small and medium size bulk LPG tanks - February 2008 - Approved by BSEI No. 08-063 of March 2008

37. European standard NF EN 12817: LPG equipment and accessories. Inspection and requalification of LPG tanks up to and including 13 m^3 - December 2002, modified in June 2006

38. European standard NF EN 12819 (standard being revised), LPG equipment and

accessories. Inspection and requalification of LPG tanks greater than 13 m^3

General guides for establishing inspection plans (France)

39. Guide pour l'établissement des plans d'inspection (périodicités IP et RP 5 et 10 ans) - UIC/UFIP/CTNIIC document DT 32 révision 2 – juin 2008

    Guide for establishing inspection plans (frequency PI and PR 5 and 10 years) - UIC/UFIP/CTNIIC document DT 32 revision 2 - June 2008

40. Guide pour l'établissement des plans d'inspection permettant de définir la nature et les périodicités d'inspections périodiques et de requalifications périodiques pouvant être supérieures à cinq et –dix ans - UIC/UFIP document DT 84 - juin 2006

    Guide for establishing inspection plans for defining the type and frequency of periodic inspections and requalifications that may exceed five and ten year intervals - UIC/UFIP document DT 84 - June 2006

41. DT 75 – guide pour le choix des méthodes de contrôles des matériaux et équipements - mai 2002

    DT 75 - Guide for choosing equipment and material inspection methods - May 2002

ATMOSPHERIC STORAGE TANKS

42. Arrêtés Ministériels du 9 novembre 1972 et du 19 novembre 1975: Aménagement et exploitation des dépôts d'hydrocarbures liquides

    Ministerial Acts of 9 November 1972 and 19 November 1975: Developing and operating liquid hydrocarbon depots

43. Arrêté Ministériels du 4 septembre 1967: Aménagement et exploitation des usines de traitement de pétrole brut, de ses dérivés et résidus.

    Ministerial Acts of 4 September 1967: Developing and operating plants for treating crude oil, its derivatives and residues

44. Circulaire BSEI 07-206

    BSEI circular 07-206

45. Guide pour l'inspection et la maintenance des réservoirs métalliques aériens cylindriques verticaux d'hydrocarbures liquides en raffinerie – UFIP – Edition Août 2000

    Guide for inspecting and maintaining aboveground vertical hydrocarbon metal cylindrical tanks at refineries – UFIP – Edition August 2000

46. *Note de doctrine du 15 octobre 2008 – BRTICP/2008-514/CBO : effet de vague dans les dépôts de liquide inflammables (y compris stockages au sein de sites industriels tels les raffineries)*

    Doctrine memo of 15 October 2008 – BRTICP/2008-514/CBO: Wave effect at flammable liquid depots (including storage at industrial plants such as refineries)

SAFETY DEVICES

47. Standard NF EN 764-7 (July 2002) - Pressure equipment - Part 7: Safety systems for unfired pressure vessels

References in the United Kingdom (regulations and guides)

48. Health and Safety at Work Act 1974

49. The Control of major Accident Hazards regulations 1999 (COMAH)

50. Management of Health and Safety at Work Regulations 1999 (MHSWR)

51. Management of Health and Safety at Work Regulations 1999 (MHSWR) - Approved Code of Practice (L21) – 2000

52. Provision and Use of Work Equipment Regulations 1998 (PUWER 1998)

53. Provision and Use of Work Equipment Regulations 1998 (PUWER 1998) - Approved Code of Practice (L22) – 2008

54. The Pressure Systems Safety Regulations 2000 – January 2000

55. Safety of pressure systems – Pressure systems safety regulations 2000 – Approved Code Of Practice – – L122 - HSC – HSE books - 2000

56. EEMUA Publication 159, Users guide to the inspection, maintenance and repair of above ground vertical cylindrical steel tanks, ISBN 0 85931 1317, 3rd edition, 2003

57. EEMUA 183, guide for the prevention of bottom leakage from vertical cylindrical, steel storage tanks

58. SAFed Pressure systems: Guidelines on Periodicity of Examinations – November 2003

59. SAFed- Guidelines for Competent person – In-service examination of pressure systems pipework – October 2008

60. Institute of Petroleum – Pressure Vessel Examination – Part 12 of the Model Code of safe Practice in the Petroleum industry – March 1993

61. Institute of Petroleum – Pressure Piping Systems Examination – Part 13 of the Model Code of safe Practice in the Petroleum industry – March 1993

62. UKLPG – code of practice 1 – Bulk LPG storage at fixed Installations – Part 3: 2006 – Examination and Inspection

63. HSG 176 – The storage of flammable liquids in tanks – 1998

64. Guide to British Standard BS 7910:2005 – Guides on methods for assessing the acceptability of flaws in metallic structures, British Standards Institution, London, 2005

65. UKAS (United-Kingdom Accreditation Service – RG2 – Accreditation for In-Service Inspection of Pressure Systems / Equipment – draft version – February 2009

66. HSE report – Plant ageing: Management of equipment containing hazardous fluids or pressure – Prepared by TWI LtD, ABB Engineering Services, SCS (INTL) Ltd and Allianz Cornhill Engineering for the Health and Safety Executive – 2006 – RR509 Research Report

67. HSL – Risk Based Inspection: A Case Study Evaluation of Onshore Process Plant – HSL:2002/20 – W Geary

68. Hazardous installation Directorate – Semi permanent circulars – atmospheric storage tank – integrity of atmospheric storage tanks (available from the HSE website)

69. HSE Report 'Best Practice for Risk Based Inspection as a Part of Plant Integrity Management'.

70. 206 Risk Based Inspection - A Guide to Effective Use of the RBI Process - 2006, ISBN 0 85931 150 3

References in the United States (regulations and guides)

71. OSHA - Regulations (Standards - 29 CFR) – 1910 - Occupational Safety and Health Standards - Subpart H -- Hazardous Materials - 1910.119 Process safety management of highly hazardous chemicals

72. Code of Federal Regulations - Title 40: Protection of Environment - part 112 – oil Pollution Prevention

73. Code of Federal Regulations - Title 49—Transportation - CHAPTER I—pipeline and hazardous materials safety administration, department of transportation – part 190 to 199

74. API 571, DAMAGE MECHANISMS AFFECTING FIXED EQUIPMENT IN THE REFINING INDUSTRY, 1st edition, December 2003

75. API 580: “Risk-Based Inspection” 2002

76. API 581: “Base Resource Document on Risk Based Inspection” 2008

77. API 510: “Pressure Vessel Inspection Code” 2006

78. API 570: “Piping Inspection Code” 2003

79. API 653: “Tank Inspection, Repair, Alteration et Reconstruction” 2008

80. API 579-1: “Recommended practice for Fitness-for-Service”, June 2007

81. API 750: “Management of Process Hazard”, January 1990

82. The National Board of Boiler and pressure Vessel inspectors – National Board inspection Code – 2007 – Part 2: inspection

83. API standard 2510 – Design and Construction of LPG Installations – May 2001

84. API publication 2510A – Fire protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage facilities – December 1996

References in Germany (regulations and technical rules)

85. Störfall-Verordnung dated June 2005 (12th Ordinance on the Implementation of the Federal Emissions Control Act (Major Accidents Ordinance – 12. BImSchV)): Transposition of the Seveso II Directive.

86. Betriebssicherheitverordnung - Ordinance on Industrial Safety and Health – BetrSichV – September 2002 (Ordinance concerning the protection of safety and health in the provision of work equipment and its use at work, concerning safety when operating installations subject to monitoring and concerning the organization of industrial safety and health at work).

87. TRB514 Relating to technical rules, pressure vessels - Periodic inspections.

88. TRB515 Relating to technical rules, pressure vessels - Controls in special cases.

89. TRR514 Relating to periodic controls on piping.

90. TRbF20 Relating to the technical rules applicable to flammable liquids - storage

91. TRbF 50 Relating to the technical rules applicable to flammable liquids - piping

References in the Netherlands (regulations)

92. Warenwet besluit Drukapparatuur: The transposition of the Pressure Equipment Directive.

93. Praktijk Regels voor Drukapparatuur: States the conditions for pressure equipment inspections.

94. Arbeidsomstandighedenwet: The transposition of Directive 89/391/EEC.

95. PSG29 - Richtlijn voor bovengrondse opslag van brandbare vloeistoffen in verticale cilindrische tanks: October 2008 (Directive for above ground storage of flammable liquids in vertical cylindrical tanks).

Note: The documents shown in italics are not covered by a detailed analysis or were not studied in this report. They are shown in view of possible later more in-depth use.

17. LIST OF ANNEXES

Marking	Precise description	Pages
A	BRTICP/2008-601/CBO method memo - Action plans for managing ageing in the prevention of technological hazards	5
B	BRTICP/2009-46/OA memo - Contributions by INERIS to the action plan for managing hazardous industrial installation ageing	6
C	List of the various abbreviations in the equipment monitoring field	2
D	Accidentology: Statistical analysis of accidents	8
E	Presentation of regulations and professional guides in France	38
F	Presentation of ageing management practices in France	15
G	Presentation of regulations and professional guides in the United Kingdom	29
H	Presentation of regulations and professional guides in the United States	16
I	Presentation of regulations and professional guides in Germany	6
J	Presentation of regulations and professional guides in the Netherlands	5
K	Some principles from method API RP 581 - Risk Based Inspection Technology	11
L	Presentation of Fitness For Service methods	3

ANNEX A

Note on method BRTICP/2008-601/CBO – action plans for controlling ageing in the prevention of technological risk.

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE L'ÉCOLOGIE, DE L'ÉNERGIE,
DU DÉVELOPPEMENT DURABLE ET DE L'AMÉNAGEMENT DU TERRITOIRE

Direction Générale de la Prévention des Risques

Service des Risques Technologiques

Paris, le 12 décembre 2008

Note de méthode

Référence : BRTICP/2008-601/CBO

Objet : Plan d'actions pour la maîtrise du vieillissement dans la prévention du risque technologique

Suite à des incidents et accidents survenus ces dernières années dans les installations industrielles françaises, aussi bien dans le domaine des canalisations de transport que dans le domaine des installations classées, dont une des causes pouvait être reliée à la thématique générale du vieillissement des installations, de leur maintenance et de leur surveillance, Jean-Louis Borloo et Nathalie Kosciusko-Morizet ont décidé de mettre en place un plan d'actions pour la maîtrise du vieillissement dans la prévention du risque technologique au cours de l'année 2009.

Ces réflexions se dérouleront concomitamment à la refonte des textes principaux fixant les prescriptions techniques applicables aux dépôts de liquides inflammables, secteur industriel concerné fortement par ces problématiques.

L'objet de la présente note est de fixer des éléments de méthode et de calendrier pour l'élaboration de ce plan.

<u>Périmètre industriel concerné</u>

S'agissant du périmètre sectoriel, de façon générale, l'ensemble des secteurs industriels peuvent être concernés. A ce titre, une à deux structures interprofessionnelles de représentation de l'industrie pourront participer aux échanges.

De façon plus spécifique, l'ensemble de la filière du pétrole et de ses produits dérivés ainsi que le secteur de la chimie sont plus prioritairement concernés par les sujets qui seront approfondis. Leurs représentants seront donc par ailleurs conviés à l'élaboration de ce plan.

Ressources, territoires et habitats
Énergie et climat
Développement durable
Prévention des risques
Infrastructures, transports et mer

Présent pour l'avenir

www.developpement-durable.gouv.fr

20, avenue de Ségur – 75007 Paris Tél. : 01.42.19.20.21

S'agissant du périmètre technique, l'ensemble des équipements et installations susceptibles de conduire à un risque technologique pourront faire l'objet d'actions dans le cadre de ce plan, que ces équipements et installations concourent au confinement de produits dangereux ou polluants (à des fins de transport, de stockage, de process par exemple), qu'ils constituent un dispositif de sécurité par conception (mur coupe-feu par exemple), qu'ils concourent au rattrapage de dérives (rétentions, systèmes d'alerte, d'intervention par exemple) ou qu'ils concourent au pilotage et à la maîtrise de la sécurité (contrôle-commande par exemple). Les points singuliers feront l'objet d'une attention particulièrement importante dans le cadre de ce travail.

Les thématiques traitées porteront plus particulièrement sur les équipements à durée de vie assez longue susceptibles de perdre leurs caractéristiques en terme de sécurité et de fonctionnement par rapport à ce que ces caractéristiques étaient lors de leur mise en service. Les thématiques concerneront moins les équipements fréquemment renouvelés ou l'obsolescence (mise en place d'une technologie à une période alors que d'autres technologies innovantes sont arrivées sur le marché entre temps) à l'exception des contrôles-commandes « IPS ».

Produits de sortie / composition de ce plan

Sans préjuger les résultats des échanges et groupes de travail mis en place, il est à attendre que la réflexion ainsi menée débouche en 2009 sur un ensemble comprenant :

- des guides de bonnes pratiques à établir,
- des engagements volontaires des différentes parties sur la mise en œuvre d'actions d'amélioration,
- des programmes d'inspections approfondies,
- des actions coup de poing de contrôle sur des cibles prioritaires, que ces actions soient menées par les exploitants sur leurs propres installations ou les corps d'inspection de l'Etat sur le parc industriel français,
- des actes réglementaires prescrivant des objectifs à atteindre et des moyens à mettre en œuvre sur la base des législations et outils réglementaires existants qui pourront amenés à être pris ou modifiés d'ici novembre 2009 pour décliner les actions décidées.

Personnes et organismes participant aux échanges

Au-delà des représentants du monde industriel et du ministère chargé du développement durable, des contributions seront demandées :

- aux établissements publics compétents sous la tutelle du ministère, notamment l'INERIS et l'IRSN,
- à des organismes compétents en matière de prévention du vieillissement dans le domaine du nucléaire,
- aux organismes habilités de contrôle des ESP,

- à des experts ou organismes reconnus, en fonction des aspects approfondis,
- aux services déconcentrés chargés de l'inspection des installations classées, du contrôle des canalisations et des équipements sous pression,
- au groupe de travail sur la stratégie d'analyse, d'évaluation et de maîtrise du risque technologique,
- à toute autre personne ou tout autre organisme dont il apparaîtra au ministère, au cours des débats, qu'il / elle est susceptible d'apporter une plus-value aux réflexions.

Calendrier des travaux

L'objectif final est de disposer du plan d'actions (et de projets de révision des textes sectoriels spécifiques aux liquides inflammables) pour l'automne 2009.

Les réflexions seront néanmoins organisées en plusieurs grandes phases qui s'articuleront selon des échéances qui pourront être celles du tableau suivant.

Par contribution, il est entendu et attendu : un exposé du diagnostic de la situation (le cas échéant basé sur des séries d'inspection ou de vérifications sur le terrain), des propositions d'amélioration de la situation pouvant inclure des échéanciers d'actions ou d'investissements, des propositions techniques, une analyse appuyée sur un argumentaire de l'intérêt ou de l'inutilité de certains concepts proposés à la réflexion ou tout autre apport aux échanges en lien avec les thématiques abordées. Les thèmes choisis pour les contributions ne préjugent bien entendu pas une quelconque pré-décision de l'administration quant à leur intégration / développement dans la réglementation et le plan vieillissement.

Echéance	Nature des contributions
30 janvier 2009	Remise par les industriels et leurs représentants de trois contributions portant sur les thèmes suivants : d'une part les pistes générales à creuser pour le plan vieillissement, et d'autre part de façon plus spécifique les propositions (par articles ou par thèmes) de modifications à apporter aux textes encadrant le stockage et la distribution des liquides inflammables (notamment arrêtés de 1972 et 1975 / RAEDHL, instruction technique de 1989...) et les résultats des actions menées sur les points singuliers des canalisations de transport en application de la circulaire du 15 septembre 2008 (ainsi que les anomalies éventuellement relevées).
9 février 2009	Début des échanges sur la base de la contribution ci-dessus des professions et de propositions de l'administration
13 février 2009	Remise par les industriels et leurs représentants d'une contribution sur le thème diagnostic initial et équipements d'intérêt prioritaire : détermination d'un « état zéro » du parc industriel français, diagnostic, proportionnalité aux enjeux, RBIs... Préparation par l'administration du bilan de l'action nationale coup de poing de l'inspection des installations classées sur les contrôles de fonds de bacs, cuvettes de rétention et tuyauteries d'usine.

2 mars 2009	Début des échanges sur la base de la contribution ci-dessus et de propositions de l'administration
27 mars 2009	Remise par les industriels et leurs représentants d'une contribution sur le thème de la surveillance et de l'inspection : fréquence de la surveillance et des contrôles (de routine ou d'arrêt périodique, pratiques actuelles et améliorations à mettre en place, le cas échéant en fonction de l'âge des installations), aspects techniques de ces contrôles (approfondissement, normes, standards, techniques, ré-épreuves,...), aspects humains de ces contrôles et notamment opportunité de la généralisation de services d'inspection et de maintenance sur chaque site ou de structures équivalentes sur tous les sites ou en inter-sites, etc. Cette contribution inclura les conclusions tirées de la réflexion sur l'acceptabilité des méthodes et des périodicités de contrôle des points singuliers en application de la circulaire du 15 septembre 2008 sur la sécurité des canalisations de transport
6 avril 2009	Début des échanges sur la base de la contribution ci-dessus et de propositions de l'administration
30 avril	Remise à monsieur le ministre d'Etat d'un rapport d'étape avec notamment les premières mesures opérationnelles, les premiers engagements notamment en terme de contrôles et les principaux axes appelés à former la structure du plan vieillissement finalisé
29 mai 2009	Remise par les industriels et leurs représentants d'une contribution sur le thème de la durée de vie maximale des équipements (incluant des aspects relatifs à l'obsolescence des équipements électroniques)
8 juin 2009	Début des échanges sur la base de la contribution ci-dessus et de propositions de l'administration
26 juin 2009	Remise par les organismes habilités (structurés au sein de l'AQUAP), l'INERIS et l'IRSN de leurs contributions sur les meilleures pratiques de maîtrise du vieillissement, en France et à l'étranger, dans les domaines relevant de la compétence de la Direction Générale de la Prévention des Risques ou dans d'autres domaines
29 juin 2009	Début des échanges sur la base des contributions ci-dessus
Eté 2009 – septembre 2009	Poursuite des échanges sur tous les thèmes ayant fait l'objet d'une contribution ainsi que sur la refonte des textes sectoriels relatifs aux liquides inflammables
Octobre 2009	Finalisation du plan pour la maîtrise du vieillissement. Le cas échéant, communication du ministère
Novembre 2009	Passage des textes en conseils et commissions supérieures puis signature.

Les contributions des différents partenaires au cours des échanges pourront utilement être enrichies d'éléments de comparaisons avec les meilleures techniques à l'étranger, le retour d'expérience sur les incidents et accidents qui se sont produits en France.

Le directeur général de la prévention des risques,
délégué aux risques majeurs

Le directeur général de la prévention des risques
délégué aux risques majeurs

Laurent MICHEL

Laurent MICHEL

ANNEX B

Note BRTICP/2009-46/OA - INERIS contributions for the action plan on controlling ageing of risk-prone industrial facilities

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE L'ÉCOLOGIE, DE L'ÉNERGIE,
DU DÉVELOPPEMENT DURABLE ET DE L'AMÉNAGEMENT DU TERRITOIRE

Direction Générale de la Prévention des Risques

Service des Risques Technologiques

Sous-direction des risques accidentels

Bureau des risques technologiques et des industries chimiques et pétrolières

Bureau de la sécurité des équipements industriels

Paris, le

Référence : BRTICP/2009-46/OA

Affaire suivie par : Olivier ASTIER
Tél : 01 42 19 14 31 - Fax : 01 42 19 13 93
olivier.astier@developpement-durable.gouv.fr

Objet : Contributions de l'INERIS pour le plan d'actions sur la maîtrise du vieillissement des installations industrielles à risques.

Monsieur le Directeur,

Par note du 12 décembre 2008 ci-joint, le directeur général de la prévention des risques a défini les objectifs du plan d'actions pour la maîtrise du vieillissement des installations industrielles dans la prévention du risque technologique à mettre en place au cours de l'année 2009.

A ce titre, l'INERIS est chargé de participer aux réflexions techniques et méthodologiques qui amèneront à la finalisation de ce plan d'actions pour l'automne 2009. En parallèle à cet appui technique, s'inscrivant notamment dans le cadre du groupe de travail dédié à la refonte de la réglementation relative au stockage et à la distribution des liquides inflammables, plusieurs contributions sur les meilleures pratiques de la maîtrise du vieillissement sont attendues de votre institut pour le 26 juin 2009.

Ces travaux ont été intégrés majoritairement au programme d'appui à l'administration DRA71. Ils se traduiront au travers de l'élaboration des documents suivants :

- une étude globale sur le vieillissement des installations industrielles et des canalisations de transport en s'appuyant sur un état des exigences réglementaires et normatives, en France et à l'étranger, en terme de maintenance, de contrôle et d'inspection des équipements et en terme de qualification des organismes réalisant ces contrôles,

Ressources, territoires et habitats
Énergie et climat
Développement durable
Prévention des risques
Infrastructures, transports et mer

Présent pour l'avenir

INERIS – Monsieur Yann MACE
Direction des Risques Accidentels
BP 2 - Parc technologique Alata
60550 VERNEUIL-EN-HALATTE

PJ : Note de méthode du 12 décembre 2008 relative au plan d'actions pour la maîtrise du vieillissement dans la prévention du risque technologique.

- deux benchmarks visant à mettre en évidence les règles et bonnes pratiques retenues dans la réglementation et des guides professionnels, français et étrangers, et les évolutions de ces pratiques en prenant en compte le retour d'expérience tiré des accidents marquants survenus ces dernières années. Ces benchmarks concerneront respectivement les stockages et les tuyauteries en raffinerie.

Au vu des échéances initialement fixées, il nous a paru utile d'apporter quelques éclaircissements afin d'affiner le contenu des axes de travail liés à l'atteinte des objectifs suscités. Ces éléments sont précisés en annexe à la présente note.

Nous vous informons par ailleurs que nous avons demandé aux services d'inspections des installations classées de vous accorder toute la disponibilité nécessaire à l'organisation d'éventuelles visites de terrain et de mettre à votre disposition les documents dont vous ferez la demande.

Au niveau national, des contacts pourront également être pris auprès des professionnels de la chimie et du pétrole membres des groupes de travail sectoriels (UFIP, UIC, USI, GESIP...), des établissements publics compétents tels que l'IRSN et des représentants des bureaux de la direction générale de prévention des risques traitant de risques technologiques.

Au niveau européen, nous vous invitons à prendre contact avec Madame Maureen Wood du Major Accident Hazards Bureau placé au sein de la Commission européenne afin d'obtenir les coordonnées des interlocuteurs des différents Etats-membres concernés.

Par ailleurs, Cédric Bourillet vous adressera prochainement un courrier similaire pour vous préciser le contenu des benchmarks sur les autres aspects que ceux relatifs au vieillissement.

Nous vous prions d'agréer, Monsieur le Directeur, nos sincères salutations.

Le chef du bureau de la sécurité
des équipements industriels

Stéphane NOEL

Le chef du bureau des risques
technologiques et des industries
chimiques et pétrolières

Cédric BOURILLET

Annexe relative aux contributions à la charge de l'INERIS dans le cadre de l'élaboration du plan d'actions vieillissement

1. Etude globale sur le vieillissement :

La note de méthode du 12 décembre 2008 prévoit pour le 26 juin 2009 la remise par l'INERIS de sa contribution sur les meilleures pratiques du vieillissement, en France et à l'étranger. La recherche des informations sur les pratiques étrangères s'orientera préférentiellement vers le Royaume-Uni, l'Allemagne, les Pays-Bas et les Etats-Unis[1]. Les questions posées devront principalement porter sur :

- De façon générale, la politique adoptée par les administrations en charge de la prévention des risques technologiques pour tenir compte du vieillissement des installations industrielles (en matière de réglementation, d'inspection et d'échanges avec les industriels) avec notamment les aspects suivants :
  - la durée de vie maximale de certains équipements,
  - la gestion de l'obsolescence,
  - les pratiques en terme d'inspection en précisant la fréquence de la surveillance et des contrôles,
  - le recours à des services d'inspections et de maintenance, des experts ou des organismes privés reconnus. Une attention particulière sera portée sur le mode de reconnaissance et de financement de ces organismes.
- Les bonnes pratiques développées par les industriels en terme :
  - d'engagements volontaires,
  - d'inspection, de surveillance et de maintenance,
  - de la gestion de l'obsolescence des équipements (notamment électriques et électroniques),
  - de la prise en compte éventuelle de la durée de vie des équipements, que ce soit au moment de leur mise en service (données de conception) ou en phase d'exploitation en fonction des modes de dégradation auxquels ils peuvent être soumis,
  - de normes de référence.

[1] Les renseignements concernant ces pays peuvent être recueillis au travers de la lecture des textes réglementaires ou des documents normatifs, de contacts au sein du réseau EU-VRI ou de tout autre mode de recueil d'information.

Le périmètre de cette étude se concentrera sur les tuyauteries d'usine, les canalisations de transport, les automates programmables et les capacités de stockage. Les installations et équipements de process (colonne de distillation, réacteurs, etc.) ne seront donc pas pris en compte dans cette étude compte tenu des délais impartis.

Un point particulier concernant les équipements difficilement inspectables devra être abordé, notamment quand une inspection intérieure n'est pas envisageable (cas des réservoirs cryogéniques d'ammoniac à pression atmosphérique).

Par ailleurs, vous étudierez dans quelle mesure les pays cités précédemment ont mis en place des systèmes de surveillance ou de protection (confinement, détection...) ayant pour but de compenser les effets du vieillissement de l'installation en cas d'avarie ou d'accident.

2. Benchmarks sur les raffineries :

Les réflexions concernant la thématique générale du vieillissement des installations, de leur maintenance et de leur surveillance, se dérouleront concomitamment à la refonte des textes principaux encadrant le stockage et la distribution des liquides inflammables. Ainsi, la réalisation de deux actions de benchmark relatives aux capacités de stockage et aux tuyauteries de raffinerie a été lancée début 2009.

Au même titre que l'étude globale sur la maîtrise du vieillissement, les travaux conduiront à identifier les méthodes d'identification et de prise en compte du facteur temps sur ces installations en comparant les méthodes d'analyse, de surveillance, d'inspection et de maintenance telles qu'elles sont décrites dans les réglementations et les guides ou normes, en France et à l'étranger.

Au vu des différentes échéances de remise de ces deux études (proposition de canevas du rapport pour fin mars 2009, projet de rapport pour le 26 juin 2009 et rapport final pour fin novembre 2009), je vous propose d'en limiter le périmètre d'étude selon les critères suivants :

- Communs aux deux benchmarks :
  - Substances concernées : toxiques et inflammables, sous forme liquide, gazeuse ou de gaz liquéfié. Pour les substances toxiques, l'attention sera portée sur l'acide fluorhydrique et l'hydrogène sulfuré. Concernant les liquides inflammables, seuls les produits généralement présents en dépôt seront pris en compte, à savoir, les essences, les gazoles (comprenant les FOD) et l'éthanol. Enfin, concernant les gaz inflammables liquéfiés, les études se limiteront au butane et au propane.

- Modalités de ré-épreuve, contrôle (destructif et non destructif), inspection et requalification périodiques des équipements et de leurs accessoires (ex : périodicités fixées à 5 et 10 ans pour les ESP).
- Modalités d'examen des accessoires de sécurité et des accessoires sous pression selon des dispositions comparables à celles des équipements auxquels ils sont attachés ou spécifiques à la famille d'accessoires (ex : vannes, indicateurs de niveaux…).
- Prise en compte des mécanismes de dégradation des équipements comme la corrosion (humide, chimique ou à haute température) ou les divers modes de dégradations mécaniques ou métallurgiques.
- Comparatif des plans d'inspection mis en œuvre et des requalifications découlant des études de criticité, le cas échéant, avec prise en compte du retour d'expérience sur chaque type d'équipement (accidentologie notamment), des dérives des conditions de service maximales admissibles et des anomalies relevées sur le terrain.
- Mode de reconnaissance des services d'inspection interne ou des organismes extérieurs équivalents (périodicité de renouvellement de l'habilitation ou de l'agrément).

▪ Spécifiques au benchmark « stockage » :

  - Type de réservoirs concernés : réservoirs aériens métalliques en priorité (comprenant l'ensemble des points singuliers cités ci-dessous). Les réservoirs enterrés pourront être traités si le temps disponible le permet.
  - Périodicité des contrôles au niveau des points singuliers constituant les zones de dégradation les plus probables (pied des piquages et des supports, zones de concentration d'impuretés, purges, bras mort…)[2].
  - Modalités de requalifications périodiques.

▪ Spécifiques au benchmark « tuyauteries » :

  - Type de tuyauteries concernées : tuyauteries aériennes en acier en priorité (comprenant l'ensemble des points singuliers cités ci-dessous), réglementées ou non. Les tuyauteries en composites ou en fonte et les tuyauteries non aériennes pourront être traitées si le temps disponible le permet.
  - Périodicité des contrôles au niveau des points singuliers et des discontinuités constituant les points faibles des tuyauteries (supports et

[2] Par exemple, dans l'industrie pétrolière française, certaines mesures d'épaisseur des tôles sont réalisées au maximum tous les 5 ans, voire tous les 3 ans suivant le type de dégradation observée lors d'un contrôle précédent.

butées, zones de rétention sous calorifuge, piquages, purges, bras mort…).

- Modalités de requalifications périodiques.

ANNEX C

List of the different acronyms in the field of control of ageing

The table below shows the different acronyms usually encountered in the field of monitoring of equipment (non-exhaustive list).

ACFM	Alternating Current Field Measurement
ACOP	Approved Code Of Practice
AFIAP	Association française des ingénieurs en appareils à pression (French Association of Engineers in Pressure Equipment)
AFNOR	Agence Française de Normalisation (French standardization agency)
APAVE	Association des Propriétaires d'Appareils à Vapeur et Electriques (Electric and steam appliance owner association)
API	American Petroleum Institute
APITI	Association pour la Promotion de l'Inspection Technique chez les Industriels (Association for promoting technical inspection in industries)
AQUAP	Association pour la qualité des appareils à pression (Association for pressure apparatus quality)
ARIA	Analyse, Recherche et Information sur les Accidents (Analysis, Research and Information on Accidents) (French Database on accidents)
ASAP	Association Spécialisée dans les Appareils à Pression (Pressure apparatus specialized association). It groups the French Institut de Soudure, SGS, SOCOTEC and NORISKO
AUBT	Attenuation Ultrasonic Backscattering Technique
BARPI	Bureau d'Analyse des Risques et Pollutions Industrielles du Ministère de l'Ecologie, de l'Energie, du Développement durable et de l'Aménagement du territoire (Bureau for analysis of risks and industrial pollutions of the French Ministry of Ecology, Energy, sustainable Development and Land use planning)
BRTICP	Bureau des Risques Technologiques et des Industries Chimiques et Pétrolières (Bureau of technological risks and of the chemical and petroleum industries)
BS	British Standards
BSEI	Bureau de la Sécurité des Equipements Industriels (Bureau for the safety of industrial equipment)
BV	Bureau Veritas
CCAP	Commission Centrale des Appareils à Pression (Central pressure apparatus commission)
CE	Communauté Européenne (European Community EC)
CEN	Comité Européen de Normalisation (European normalization committee ENC)

CETIM	Centre Technique des Industries Mécaniques (Technical Centre of Mechanical Industries)
CFBP	Comité français du butane et du propane (French butane and propane committee)
CLAP	Comité de Liaison des Appareils à Pression (Pressure Apparatus Liaison Committee)
CND	Contrôles Non Destructifs (Non-destructive testing (NDT))

COCL	Conditions Opératoires Critiques Limites (Limits of Critical Operating Conditions)
CODAP	Code de construction Des Appareils sous Pression non soumis à l'action de la flame (Construction code for pressure apparatuses not subject to the action of a flame)
CORMAT	Code de Construction des Récipients sous Pression intérieur ou extérieur non soumis à l'action de la flame (Construction code for inner or outer pressure containers not subject to the action of a flame.
COVAP	Code de Construction des. Générateurs de VAPeur, d'eau. surchauffée et à Fluides thermiques (Construction code for steam, over-heated water and thermal fluid generators)
CTNIIC	Comité technique national de l'inspection dans l'industrie chimique (National technical committee for inspection in the chemical industry)
CTP	Cahier Technique Professionnel (Professional technical booklet)
DESP	Directive des Equipements Sous Pression (97/23/CE) (Pressure equipment directive (PED (97/23/EC))
DM-T/P	Décision Ministérielle Technique Pression (Pressure technique ministerial decision)
EEMUA	Engineering Equipment and materials Users' Association. Created in 1983, this association includes leading national and multinational companies in the petroleum, gas, chemical and energy industries and engineering contractors that act on behalf of these companies. It includes ABB Engineering Services, AstraZEneca, BASF, BP, Chevron, ConocoPhillips, Dow Corning, TOTAL, etc…
EPERC	European Pressure Equipment Council
ESP	Equipement sous pression (Pressure equipment (PE))
ESSV	ESP ainsi que tout autre équipement sous pression soumis à une surveillance volontaire de la part de l'exploitant (cas de la surveillance par un SIR) (PE as well as any other pressure equipment subject to voluntary monitoring on behalf of the operator (case of monitoring by a SIR)
FITNET	European FITness for Service NETwork
GAPAVE	Groupement des APAVE (APAVE group)
GEMER	Groupement d'Etude des Matériaux en Raffinerie (Group for refinery material studies)
GESIP	Groupement d'Etude de la Sécurité dans les Industries Pétrolières (Group for studying safety in the oil industry)
GPL	Gaz de Pétrole Liquéfié (Liquefied petroleum gas (LPG))
GT	Groupe de Travail (Working group (WG))
GTP	Groupe de travail Pression (Pressure working group (PWG))

HSE	Health and Safety Executive
IFP	Institut Français du Pétrole (French petroleum institute)
ImechE	Institution of Mechanical Engineers
INERIS	Institut National de l'Environnement Industriel et des Risques (National institute for industrial environment and risks)
IS	Institut de soudure (Welding institute)
LPGA	LP Gas Association
MEEDDAT	Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire. French Ministry for ecology, energy, sustainable development and land use planning)
NACE	National Association of Corrosion Engineers
NF EN	Norme Française et européenne (French and European standard)
PSSR 2000	Pressure System Safety Regulations
RBI	Risk-Based Inspection
SIR	Service Inspection Reconnu (Recognized Inspection Service)
SNCT	Syndicat National de la Chaudronnerie, de la Tôlerie et de la Tuyauterie Industrielle (National syndicate of boiler work, metal sheet work and industrial pipework)
TOFD	Time Of Flight Diffraction
UFIP	Union Française des Industries Pétrolières (French Union of Petroleum Industries)
UIC	Union des industries chimiques (Union of chemical industries)

ANNEX D

Accidentology: statistical analysis of the accidents

This annex statistically presents, on the basis of accidents recorded by the ARIA base of BARPI, the accidents related to ageing of the installations (www.aria.ecologie.gouv.fr).

In order to conduct this study, the search was not carried out on the term of ageing, too generic for giving results, but on two words:

Corrosion: more than 250 accidents are recorded between 1973 and the end of 2008 in France and abroad;

Fatigue: less than 25 accidents are listed between 1973 and the end of 2008.

1. GENERAL PRESENTATION OF THE ACCIDENTS IN CONNECTION WITH CORROSION

THE ARIA base of BARPI lists more than 250 accidents having a relationship with corrosion phenomena between 1973 and the end of 2008, in France or abroad.

The number of reported accidents before 1999 is not very large; with the assumption that accidents before 1999 and accidents of broad are not systematically indicated as accidents in France after 1999, we retain the **period 1999-2008 as a period of observation**.

After having set aside accidents for which corrosion does not directly appear as a cause of accident, the number of accidents in connection with **corrosion phenomena is of 117 accidents in France over the last 10 years**.

The accidents were distributed per activity sector:

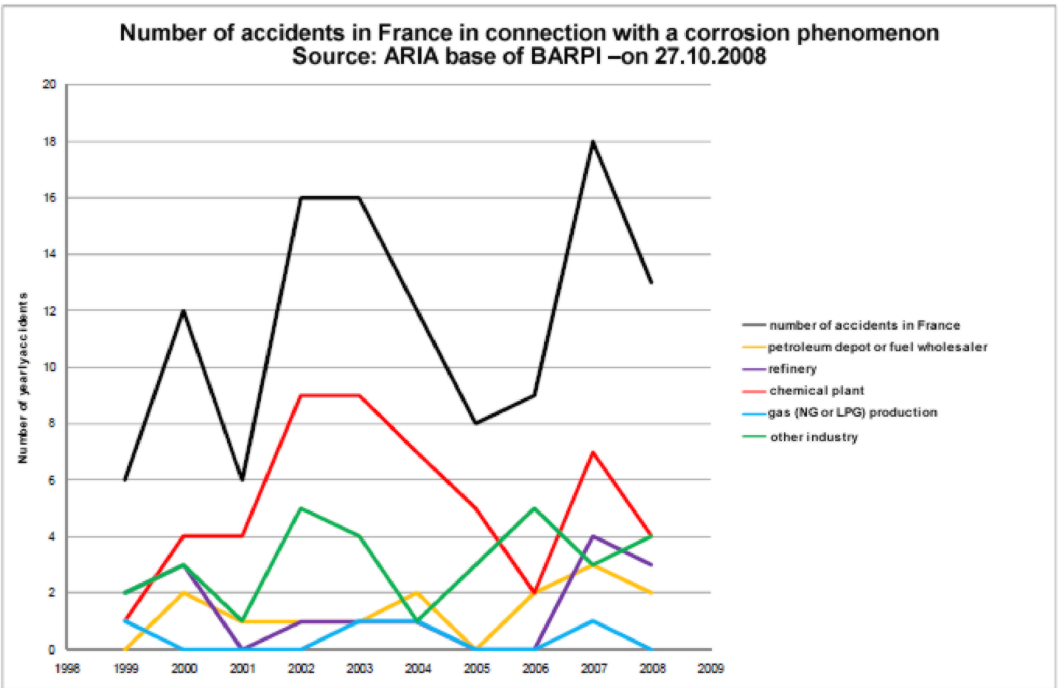
- **Refinery** (14 accidents);
- **Flammable liquid storages** (14 accidents); the accidents concerning connection pipelines between wharfs and depots are included in this heading;
- **Chemistry** (52 accidents);
- **Production of gas** (natural gas or liquefied petroleum gas) (4 accidents);
- **Others**: this group gathers those from the other classified installations (pipeline…) (31 accidents).

This analysis represents a **statistical analysis** of accidents in France over the last ten years. Noteworthy accidents in refineries, in France as abroad will be developed in the reports relating to refineries.

The information contained in the chapter except if indicated otherwise comes from the ARIA accidentology base of BARPI[1].

The yearly distribution by activity sector is shown on the next page.

[1] *Base accessible at www.aria.ecologie.gouv.fr*



1.1 ACCIDENTS LISTED IN FLAMMABLE LIQUID STORAGES

On 14 accidents which occured in flammable liquid storages over the last 10 years.

- 9 relate to pipings;
- 5 relate to storage containers and tanks and/or associated units.

1.1.1 PIPINGS

The identified causes for failures of pipings are:

- **For aboveground pipings (steel pipes):**
  - **External** corrosion on the pipe itself, generally due to external coating flaws:
    - Significant external corrosion notably along the supports; the outer lining of the pipeline is not very suitable with respect to marine corrosive action, friction of ships, etc., (ref. 34990);
    - External corrosion localized on a weld bead due to an external coating flaw (ref. 33128);
    - Corrosion due to an outer coating flaw following work carried out on them (ref. 22833);
    - Corrosion upon passing a dike (ref. 31370);
  - **Corrosion of metal hanger** which supported the pipe, itself corroded and not emptied (out of service pipe) (ref 22730);
  - **Internal corrosion in one case**: probable deterioration of the pipe upon filling the container with water, at the end of inspection work; corrosion of the tubing although equipped with protections (inner and outer lining, cathodic protection) and which had been replaced in 1997 (ref. 28247);

- **For buried pipelines,** corrosion would be responsible but not much information is available (ref. 34368, 26978, 25385).

In all the cases, the accidents caused pollutions (of rivers, of networks or of the ground), sometimes attenuated by the existence of containment dikes which fulfill their function. The amounts of rejected hydrocarbons (petroleum, fuel, oil) are generally small (Q1 scale of the BARPI scale) except in one case (a rejection volume close to 1,000 m^3 for a drain pipe).

There is no information available as to the size of the breach on the pipes.

1.1.2 STORAGE CONTAINERS AND TANKS

The leaks identified on the storage tanks relate to **crude oil**.

The most notable accident relates to the one of **Ambès**, with **failure of the container bottom** (on one 1/8th of the surface area of the metal sheet) which causes a massive discharge of crude oil. The containment dike withstands the wave effect. However 2,000 m^3 of oil pass over the dike, which causes strong pollution of the soils and water tables, with an impact on the river (ref. 32675 in January 2007). According to the operator and the inspection, a 2006 inspection report stated that corrosion was present at the bottom of the tank and indicated thickness loses attaining 80 %.

According to information from the SPPPI « Ambès peninsula »[2], after the accident, a reinforcement in the inspection procedures for monitoring tanks was recommended with:

- Acoustic inspection of the bottoms of tanks, tanks full;
- Frequency and type of geometrical inspection of the tanks (verticality, roundness, conicity , heel, differential settlement…);
- Creation of a tool for managing the integrity of the containers (100 relevant containers) with determination of the parameters and definition of alert thresholds for the monitoring;
- The base of the containers should be monitored. A « seismic » method is being evaluated. The use of sonic methods (sonar) is contemplated;
- Visual inspection of all the containers, including those without any activity to be carried out.

Another accident (ref. 32443) relates to **corrosion of metal sheets at the bottom of tanks.** The latter were only inspected on the occasion of ten year inspections contrary to the recommendations of the parent company. The stored product contains salt water and the stirrers intended to avoid this corrosion phenomenon were sometimes faulty. A leak occurred.

Other accidents relate to **fuel oil** tanks (ref. 19347 and 17255) for which corrosions in the lower part are noticed in one case due to bad design of the insulation and to the bad condition of repair of the tank). Another case should be noted when corrosion of the drip pot of the tank (breach on a diameter of 1.5 mm) caused a fuel oil leak (ref. 34249).

Note: the ARIA base does not identify any other accidents in France from before 1999 in flammable liquid storages.

[2] Source: Report of the conclusions of the meeting of the SPPPI of the Ambès peninsula on October 17th 2007 – a document available on Internet.

1.2 ACCIDENTS LISTED IN REFINERIES

On the 15 accidents which occurred in flammable liquid storages over the last 10 years,

- 9 relate to pipings;
- 2 relate to storage containers and tanks;
- 4 relate to other pieces of equipment (heat-exchangers, reactors…).

1.2.1 PIPINGS

9 accidents relate to pipings in refineries between 1999 and 2008.

The causes identified for failures of pipelines are:

- For aboveground pipelines (steel pipes):
  - **External** corrosion on the pipeline itself:
    - Corrosion Under Insulation following a water leak from a water pipeline located above the pipe (ref. 34351);
    - Corrosion on a pipe located in height leading to rupture of the pipeline (8") at the support; this corrosion is due to trickling of water from the upper structures causing accumulation of water which deformed the insulation (ref. 33071);
    - Corrosion on a 14” flare line leading to a leak and a fire (ref. 33638);
  - **Internal corrosion**: a leak of fuel on a fuel supply line for trucks/lorries running along the site is due to internal corrosion (ref. 33098); internal corrosion along a weld, upon flow reversal from a compressor, causes a rupture of the LPG 8” pipeline (ref. 19538).
- **For buried or sheathed pipelines**, corrosion would be responsible for a leak on a buried sheathed pipeline (ref. 25346; ref 35402); the absence of a sand bed around the buried pipeline would have caused it to be corroded (ref. 23175); adhesive bonding of a half-shell on piping in a trench caused accelerated corrosion leading to a fuel leak (ref. 19522).

Losses of containment caused pollutions (of rivers, of networks or of the soil) but also explosions and fires. The amounts of discharged hydrocarbons (fuel, fuel oil, petroleum, LPG) are generally small (Q1 or Q2 scale of the BARPI scale) but may also be very large in the absence of rapid detection of the leak (ref. 34351).

There is systematically no information available on the sizes of the openings, but a breach size of 16 cm^2 is noted for the accident of ref. 34351. Two ruptures are observed on the 8” pipings (ref. 33071, ref. 19538).

Sometimes, local thickness loss was first observed but changes in the operating conditions (pressure rise) were able to explain the loss of containment (ref. 33368).

1.2.2 STORAGE TANKS

2 accidents relate to storage tanks in a refinery.

This is an **external corrosion** phenomenon at the floating roof, causing hydrocarbon spill (ref. 34360), and **internal corrosion through the lack of an anti-corrosion internal coating** on a crude oil HTS container (ref. 33077).

1.3 LISTED ACCIDENTS ON CHEMICAL SITES

Almost 50 accidents were recorded in the ARIA base distributed as about twenty accidents on pipelines and about thirty on other pieces of equipment.

1.3.1 PIPINGS

Accidents relative to pipelines may be classified in four categories:

- **Loss of containment of the aboveground pipeline itself,** because of the corrosion condition on this pipeline. For example:
    - Corrosion on a longitudinal weld (ref. 34007 – nitric gas), corrosion having caused a small hole (ref. 31094 – phosgene), corrosion at the level of a bend on a sulfuric acid pipeline connecting storage to the water demineralization line (ref. 21783); a hydrogen pipeline has a 30 mm crack due to corrosion/erosion and stresses due to insufficient support which have embrittled the bend (ref. 21196); internal corrosion a priori caused by sulfides and external corrosion under the insulation on a hydrogen sulfide pipeline downstream from the flare drum of a steam cracker (ref. 23065);
    - **Explicit internal corrosion**: corrosion in the low part of the pipeline, in an area with deposits of sediments (ref. 30852 – hydrogen sulfide); corrosion on piping between a sulfuric acid tank and its foot valve by a slot bordering a weld bead (ref. 22571); internal corrosion of nitrogen piping, probably due to condensation of acid in proximity to the wall of a pyrolysis oven (ref. 35264);
    - **Explicit external corrosion**: external corrosion on a fuel oil transportation pipeline (ref. 24164); corrosion on a thermally insulated methyl chloride pipeline due to copper/steel galvanic corrosion (tracing by a cracked copper tube) (ref. 23898); corrosion on an H_2S pipe at 20 cm from its emergence from the ground at the limit of the stopping of the coal tar coating intended to ensure passive protection (ref. 35293); corrosion on a 4" propylene pipe leading to a breach of 50 mm by 20 mm, due to melting ice dripping from the cooled ethylene pipe passing above (ref. 35146); .
- **Loss of containment on a buried pipeline:** corrosion of the pipeline upon its entry into the ground, would be the origin of the failure. This corrosion may be due to detachment of the sealed protective coating following a fault during laying, to the presence of chloride ions in the ground (snow removal salt?), to a lack of cathodic protection detected several months after its damaging by a storm (ref. 27937). Another older accident relates to an ethylene pipe with a leak by electrochemical corrosion between an aboveground portion and a buried portion protected by a sheath (ref. 3325). It should be noted that external corrosion on a hydrogen chloride transfer pipe between two sites was due to infiltration of water between the pipeline and paint touch-ups (ref. 35286);
- **Loss of containment on the pipeline related to degradation of the supports**: fall of a chair supporting a pipeline at a column head due to humid and slow corrosion in the water stagnation points, such as in the holes of bolts and the existing lumens of the chair mounting brackets (due to sulfur-containing derivatives contained in the fumes from the chimney of the aromatic unit oven) (ref. 26370).
- **Confinement loss on elements of the pipeline** (valve and joint): on hydrochloric acid piping, rapid corrosion of the bolts and probable leak at the joint in expansed PTFE (ref. 25477); corrosion on metal joints on a nitric acid sectional valve by mismatch of the joint (ref. 33311); a leak on a bypass valve of a condenser on an ammonium carbamate line. The tap of the bypass is detached from its connecting flange on the pipeline causing tearing of the tubing. Disassembling of the damaged bypass has shown that the screwed flange was abnormally bearing upon the shoulder of the collar flange of the pipeline. Ammonium carbamate was therefore in contact with the screwed flange in carbon steel, causing its corrosion and then failure of the tap/flange assembly (ref. 29603);

It is noted that for certain accidents, inspections had taken place beforehand and had enabled detection of thickness losses. However maintaining the operation of the line had been decided for a given period, work having to take place subsequently (ref. 34007).

The relevant pipings are both pressure pipings and pipings which do not enter the field of pressure equipment.

Sometimes, it is a restarting operation which promoted acid corrosion following an accidental inflow of water when putting the installation back into operation, followed by erosion (ref. 4788).

The sizes of the leak are generally small, with less consequences (spreading, cloud formation) but sometimes if domino effects are possible, worsening of the consequences is noted (ref. 3325). As regards the breach sizes by corrosion, little information is available (in one case, a diameter of 1 inch, another time, a 30 mm crack on piping with a DN50 diameter).

The consequences remain very related to the applied retentions and collecting networks and to the possibilities of isolation upon detecting a leak.

1.3.2 STORAGE CONTAINERS, TANKS AND OTHER INSTALLATIONS

The equipment affected by loss of containment are:

- **Storage tanks**: collapse of a vertical tank (mixture of sulfuric acid and lactam) due to **fatigue** due to filling cycles and the use of isophthalic resin, the acid resistance of which is limited (ref. 32538); hydrochloric acid leak on a container due to corrosion on the container by **degradation of an ebonite coating** on a steel storage container (ref 33341); Corrosion on the piping of a sulfur tank, perhaps related to a slight increase in temperature of the sulfur of the container, accompanied by an acceleration of the temperature-maintaining device upon receiving a ship (ref 24550); corrosion by weak acid on a sulfuric acid container causing, following an inflow of hydrogen, an explosion and opening of the dome (ref. 31082);

- **Other equipment** (non-exhaustive list)**:**
  - **Boilers and/or oven**: erosion is responsible for corrosion on the tubes of a boiler (sulfur vapor and steam exchanger portion) (ref. 33438); corrosion on a dichloroethane oven tube (ref 33096);
  - **Fall of chimney**: corrosion in a humid medium leads to the falling of a chimney which is normally not used (therefore cold) by a hydrogen chloride leak at the closure member (ref. 34623);
  - **Corrosion on different pieces of equipment such as a pump – a pump for recirculating** H_2SO_4 causing separation of the turbine and of the body (ref. 27584); **such as oil filters**: electrochemical corrosion (ref. 20305);
  - Perforation of **tubes** on a solvent/phosgene **exchanger**;
  - **Reactor**: an explosion occurs due to a dichloromethane/hydrogen mixture (resulting from acid corrosion of an unprotected metal surface) enriched with oxygen because of multiple degassings; a leak by corrosion upon tapping with an intrusion flow meter probe, in the low portion of the leg of the dinitration reactor (ref. 32733);
  - **Column for purifying** hydrochloric acid (ref. 25481);
  - **Etc…**

The consequences are variable (pollution, toxic cloud, fire, explosion…) depending on the substances.

1.4 CONCLUSION

Over the last 10 years, the accidents in France in direct relationship with a corrosion phenomenon, amount to at least 120.

They relate to pipings for more than half of them.

The causes of corrosion on pipings maybe:

- **internal** (corrosive substance and lack of coating, erosion in a bend for example or upon compressor reversed flow, deposit in a low portion…);
- **external**. Several cases are encountered:
  - drippings from a pipeline located above;
  - drippings via supports (racks or piping support);
  - lack of coating (by wear or during work on them);
  - corrosion under insulation;
  - corrosion under paint (paint touch-up);
  - stresses due to poor support;
  - corrosion on elements of the piping (flanges, valves…);
  - corrosion by lack of passive protection in the case of buried pipes.

A worsening factor for the probability of occurrence of these accidents relates to **possible difficulties in accessing the pipings in order to check their condition** (buried or sheathed pipings, pipings in height on racks, thermally insulated pipings…) and the **great length on the sites** (or between sites), which makes their monitoring difficult.

It is noted that the leaks are often located at the welds.

Accidents on containers and tanks are much less numerous (about ten).

The causes most often seem to be internal corrosion phenomena by **lack or absence of internal coating.**

It is seen that in the investigated activity sectors, the faults on the containers affected **crude oil** and **gas oil** tanks. Sometimes, inspections had taken place beforehand but incidents in spite of this were able to occur. On the chemical sites, the relevant containers are **acid tanks**.

2. GENERAL PRESENTATION OF ACCIDENTS RELATED TO FATIGUE

Less than 25 accidents are listed in the ARIA base between 1973 and the end of 2008. After extracting accidents having occurred abroad, there remain 10 accidents in France related to fatigue and affecting fixed installations.

The relevant pieces of equipment are:

- **Tanks** (fatigue-cracking on a sulfuric acid container without any relationship with corrosion) (ref. 34968), failure of a 1" branch connection on a compressor discharge drum by gradual cracking resulting from vibrations (ref. 32611); fatigue of a tank following successive filling/emptying cycles causing cracking (ref 32538); deferred failure (by static fatigue) of a tank by embrittlement of steel under the effect of hydrogen – ref. 437);
- **Pipework**: failure of a branch connection by vibration following no reinforcement of the weld on a pump discharge line (ref. 32705), failure of small diameter purge piping following successive vibrations (ref 32589), failure of a branch connection related to vibration – ref. 26516), slight cracking by fatigue at the border of a weld bead in an area with stress concentrations (notably presence of vibrations) – ref 7910;
- **Safety devices** (opening before reaching their pressure for opening bursting disks on reactors, no doubt because of their fatigue – ref 24122 and ref 21380; breakage of a safety pin on electrical power units - ref 17164.

ANNEX E

Presentation of the regulations and of the professional guides in France

1. POLICIES FOR MONITORING PRESSURE EQUIPMENT

This chapter presents the policies for the follow-up of pressure equipment in France. It comprises:

- a presentation of the principles of monitoring and follow-up during operation as imposed by regulations and proposed in different professional guides and standards;
- principles of the inspection plans;
- notions on life time;
- a reminder on the requirements relating to the qualifications of persons;
- a presentation of a few texts specific to LPG.

1.1 PRESENT REGULATIONS

1.1.1 DEFINITIONS RELATING TO PRESSURE EQUIPMENT

Pressure equipment not only include the apparatuses but also the pipings, the pressure accessories (valves and fittings.) and safety devices (pressure relief valves, low level alarms…). The thresholds for being subject to the different texts depend on the conditions $P_{service}$ – $P_s.V$ (variable depending on the type of equipment and on the nature of the substance).

The following definitions are given in the decree of December 13th 1999:

- **"Pressure equipment":** vessels, piping, safety accessories and pressure accessories.

  Where applicable, pressure equipment includes elements attached to pressurized parts, such as flanges, nozzles, couplings, supports, lifting lugs, etc...
- "**Vessel**": a housing designed and built to contain fluids under pressure, including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber
- "**Pipings**": piping components intended for the transport of fluids, when they are connected together for integration into a pressure system. Piping includes in particular a pipe or system of pipes, tubing, fittings, expansion joints, hoses, or other pressure-bearing components as appropriate. Heat exchangers consisting of pipes for the purpose of cooling or heating air shall be considered as piping;
- "**Safety accessories**": devices designed to protect pressure equipment against the allowable limits being exceeded. These devices comprise:
  - devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems (CSPRS), and,
  - limiting devices, which either activate the means for correction or provide for shutdown or shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and ‘safety related measurement control and regulation (SRMCR)’ devices
- "**Pressure accessories**": devices devices with an operational function and having pressure-bearing housings..

1.1.2 GROUPS OF SUBSTANCES

The recommendations relating to inspections of pressure equipment may depend on the nature of the substance which they contain.

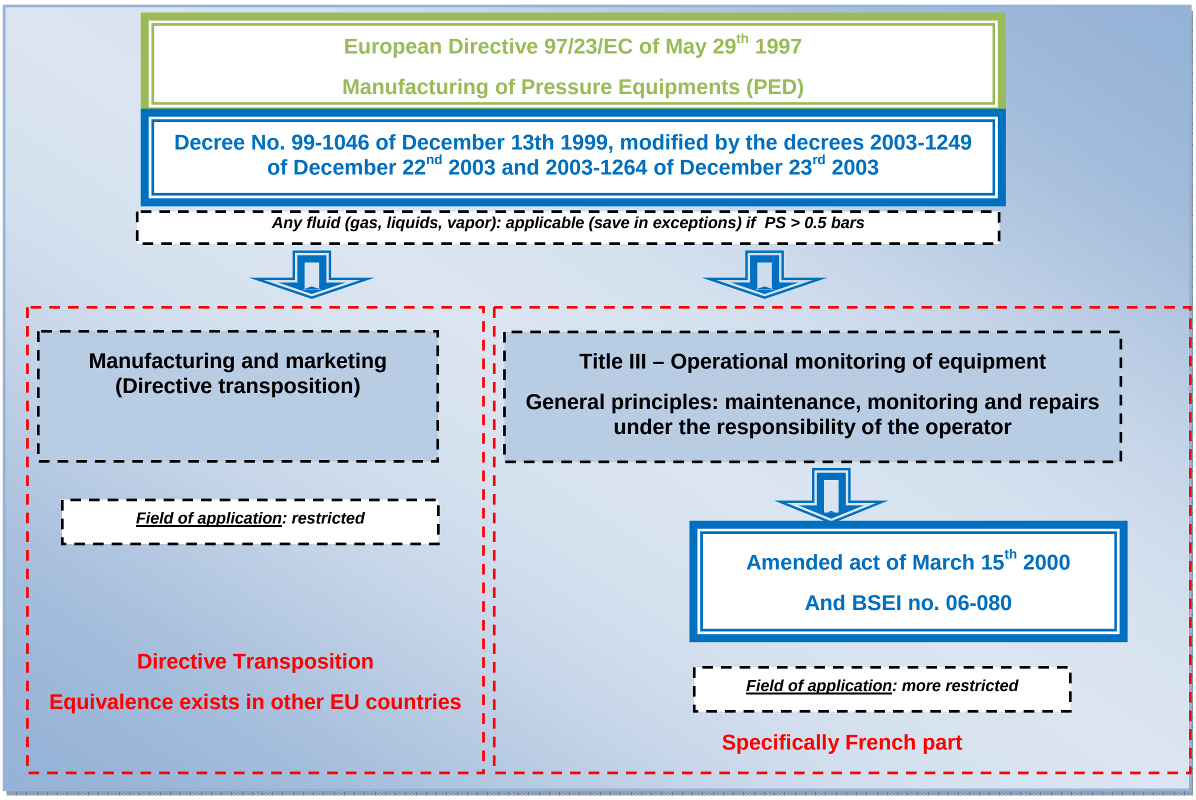
Thus two large classes are defined:

- **Group 1** comprises those of the fluids considered as hazardous in the sense of article R. 4411-6 of the work code belonging to the following categories:
    - explosives;
    - oxidizers;
    - extremely flammable substances;
    - easily flammable (very low flash point);
    - flammable (low flash point);
    - highly toxic;
    - toxic.
- **Group 2** comprises all the other fluids which are not mentioned above.

1.1.3 MAIN STATUTORY TEXTS IN FRANCE

On the European level, there exists a statutory framework defining requirements with regard to the design and manufacturing of pressure equipment (pressure equipment European Directive (PED)). But it does not deal with exploitation of PE. **To this day there is no equivalent concerning the in-service follow-up of equipment**[3].

The Directive is the subject of transpositions in the Member States of the EU and sometimes **requirements relating to the follow-up of equipment have been added into the national transpositions. This is notably the case of France**. In-service monitoring of pressure equipment is regulated in France by the decree of **December 13th 1999**[20] (transposition of the Pressure Equipment Directive including a chapter on in-service monitoring) and the act of **March 15th 2000**[19], the latter having a more restricted field of application but which is more prescriptive than the decree which only defines monitoring goals.



[3] *Discussions are in progress at the PWG (Pressure Working Group) for Europe in order to define a common European framework for exploiting PE.*

1.1.4 OLD AND NEW REGULATIONS

In France, the present regulations for pressure equipment are based on law **No.571 of October 28th 1943 relating to vapor pressure and gas pressure apparatuses.**

In 1943, the regulations made a distinction between vapor pressure apparatuses (**decree of April 2nd 1926**) and gas pressure apparatuses (**decree of January 18th 1943**)[19],. The statutory texts associated with the decrees showed three categories of equipment:

- Steam pressure vessels (and by extension over-heated water vessels);
- Gas pressure containers;
- Pipelines.

The field of application of the statutory texts was different from that of present regulations and was less restrictive. In a simplified way, it may be stated that a **minimum pressure of 0.5 bars was required for vapor equipment and 4 bars for other gases and liquids.**

When pieces of equipment did not enter the scope of the old regulations but today enter the scope of new regulations, one refers to **newly subject equipment**.

Old pressure equipment entering the scope of old regulations and which is still presently being exploited on industrial sites has therefore been manufactured and commissioned in accordance with these old regulations. However:

- Manufacturing conditions have been different from those of present equipment (selection of the materials, safety margins, gasket coefficient, corrosion overthickness, etc);
- Commissioning conditions may have been different;
- Present repairs may be conducted following the old regulations.

The **European Directive 97/23/EC of May 29th 1997**[1], mandatorily applied since May 29th 2002, applies to the design, manufacturing and compliance evaluation of pressure equipment and of assemblies for which the **maximum admissible pressure is above 0.5 bars[4] for gases, vapor, liquids[5].**

This directive is transposed in French regulations by the **decree No. 99-1046 of December 13th 1949**[20] subsequently amended by the **respective decrees 2003-1249 of December 22nd 2003 and 2003-1264 of December 23rd 2003** (articles 17, 18 and 19). The decree 99-1046 of December 13th 1999 goes beyond the European directive since it also includes provisions relating to in-service monitoring of pressure equipment[6] (French particularity). These provisions are of general nature and state the responsibility of the operator for maintenance, monitoring and repairs carried out on pressure equipment.

The act of March 15th 2000[19] modified on October 13th 2000 and on March 30th 2005, published in application of the decree of December 13th 1999, **includes complementary requirements relating to the operating of pressure equipment.** Its field of application is more restricted than that of the decree: it relates to equipment and **assemblies with gas pressure > 0.5 bars** (gas, vapor or liquid, the saturating vapor pressure at the maximum admissible temperature exceeds more than 0.5 bars at normal atmospheric pressure), with **additional conditions on the volumes or diameters** involved. The decree **BSEI No. 06-080 of March 6th 2006**[20] has specified the conditions for application of the act of March 15th 2000[19].

---

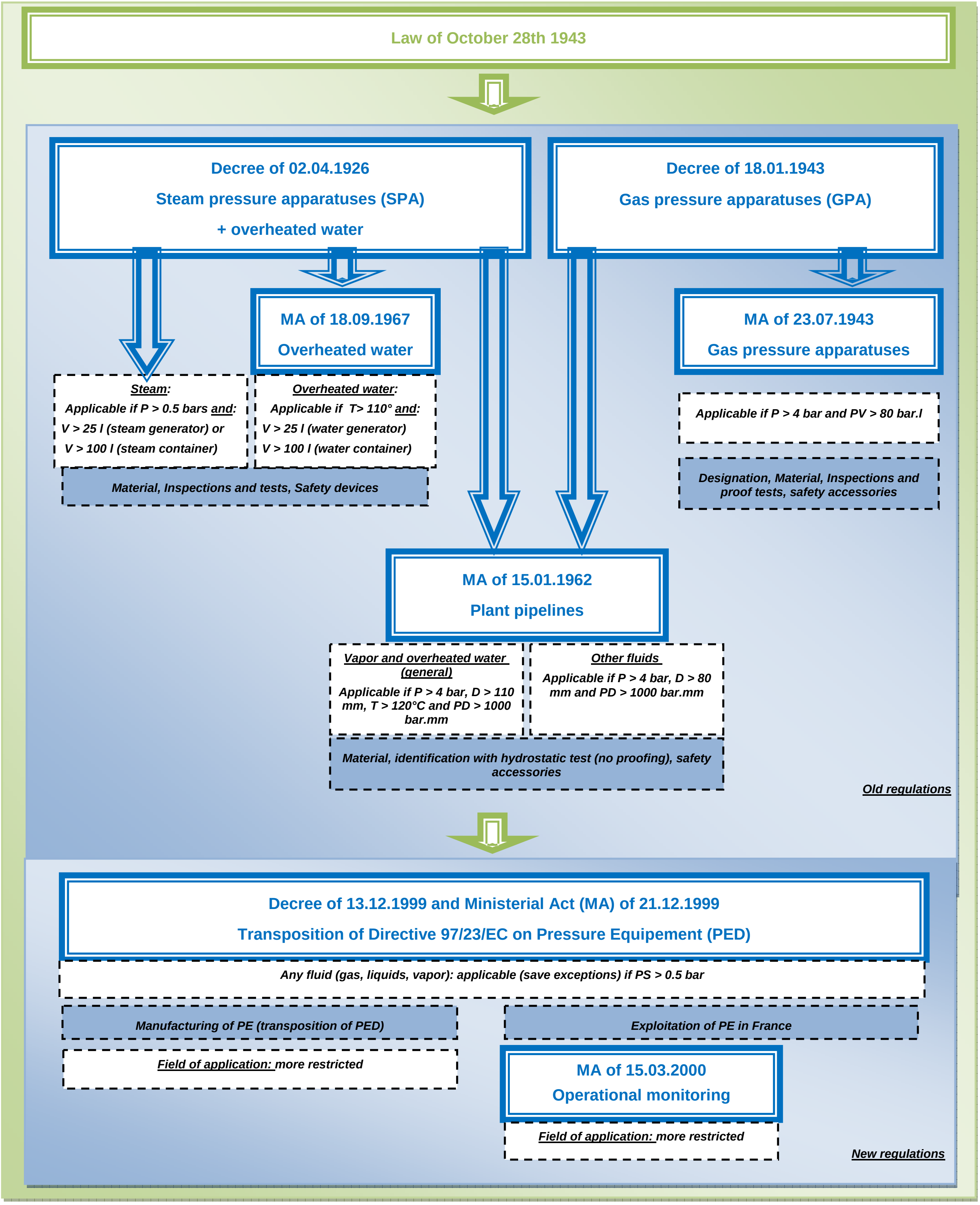
4 *This is the maximum pressure for which the piece of equipment is designed.*

5 *However, vessels which have to contain liquids for which the gas pressure above the liquid is less than or equal to 0.5 bar are excluded from the scope.*

6 *Transportation pipelines (and the last isolation device on site) are excluded from the scope of the decree. Other texts apply to transportation pipelines.*

For equipment which does not enter the scope of the decree but is subject to the decree of December 13th 1999[20], the **general operation conditions** defined in the decree (Title III) apply.

The following figure shows the panorama of old and present French regulations.



1.1.5 FIELD OF APPLICATION OF THE REGULATIONS

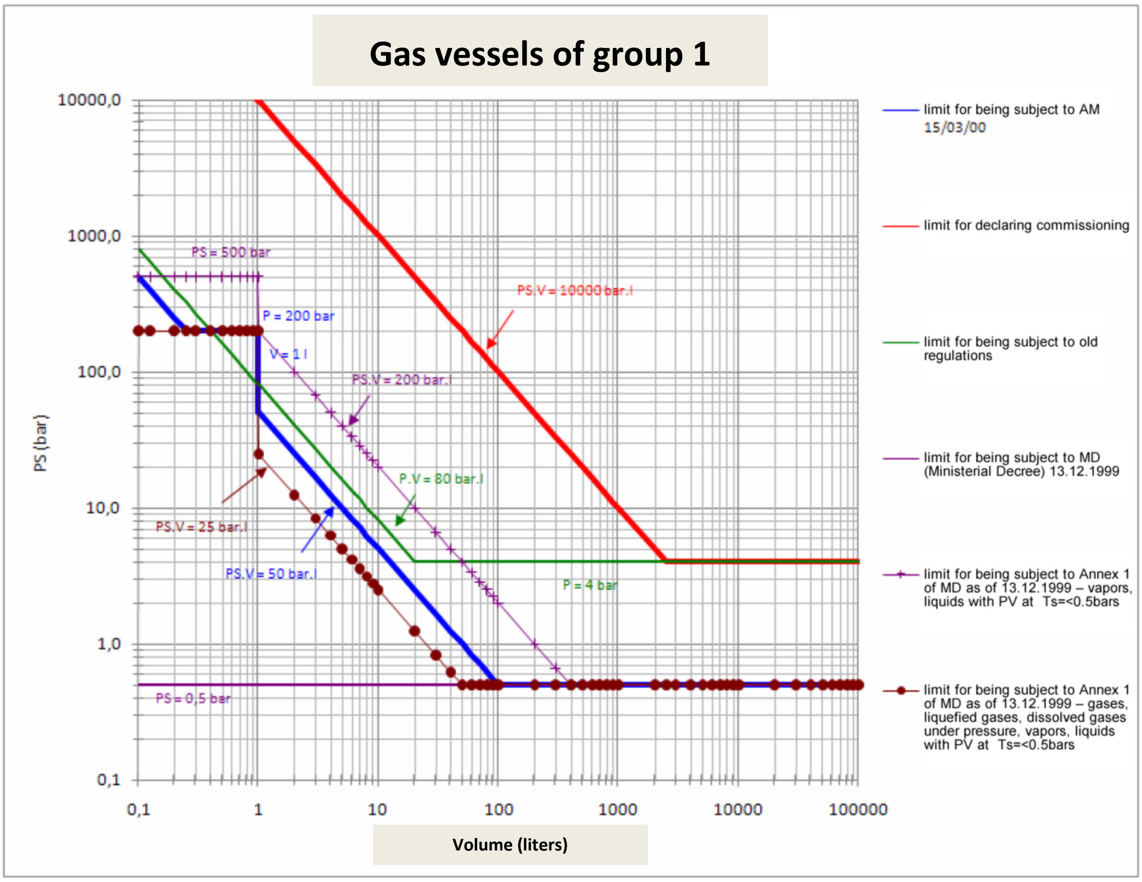
The fields of application appearing in the decree as of 13.12.99[20] and the decree of 15.03.2000[19] depend:

- On **the maximum allowable pressure (PS) ;**
- On the internal volume of the vessel or on the nominal size (Nominal Diameter) (DN) of the pipe;
- On **the group of the fluid**: if the fluid is from **group 1** (corresponding to the most hazardous substances: toxic, flammable, explosive, oxidizing substances, etc…), the applicability thresholds are generally lowered. The other substances are from **group 2**. It is noted that the submission threshold in terms of capacity of the vessels is low, so that the major part of the vessels enter the field of the PE regulations (from the moment that the gas pressure is above 0.5 bars). Very schematically, the vessels > 1 m^3 are subject to the regulations. For pipings, the nominal diameter threshold is DN25 (with minimum pressure conditions of 40 bars) and of DN100 (as soon as the pressure exceeds 1.5 bars).

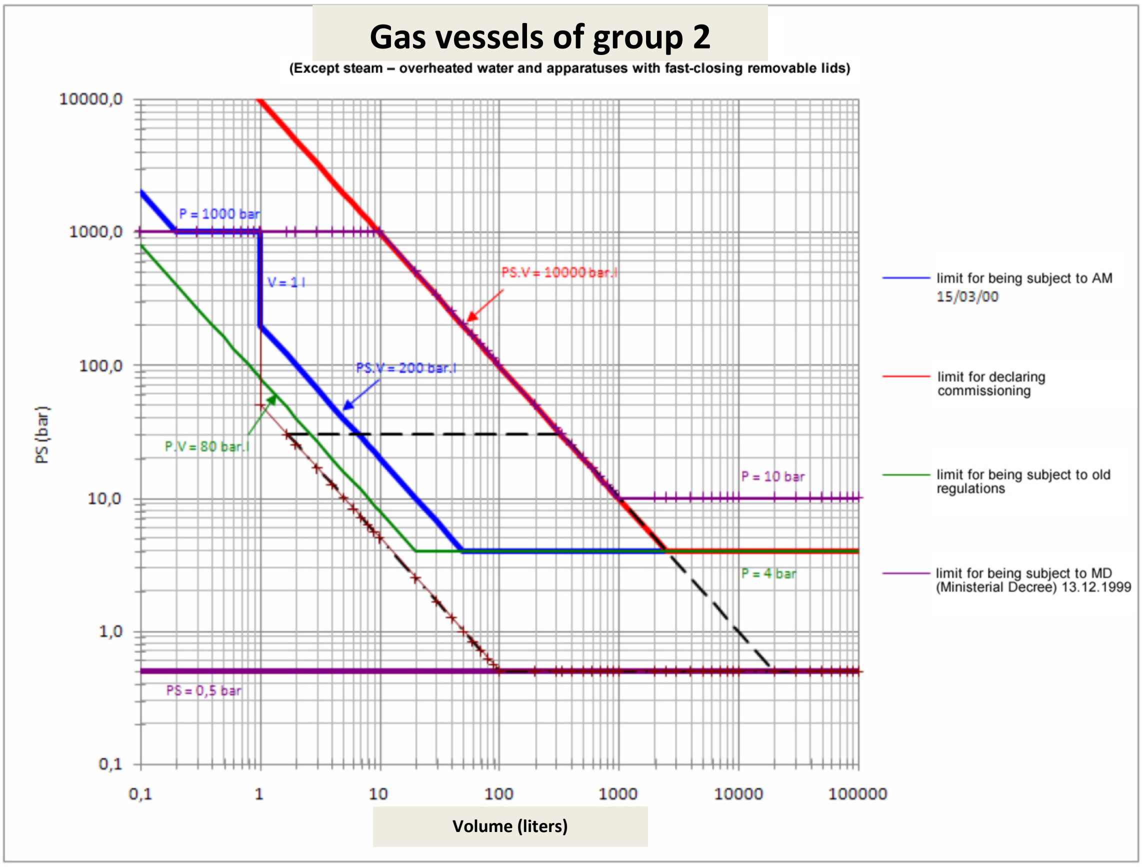
The figures on the following pages show the lower limits of the fields of application of the regulation. **The limits are not included in the field/scope.**

The following cases are shown:

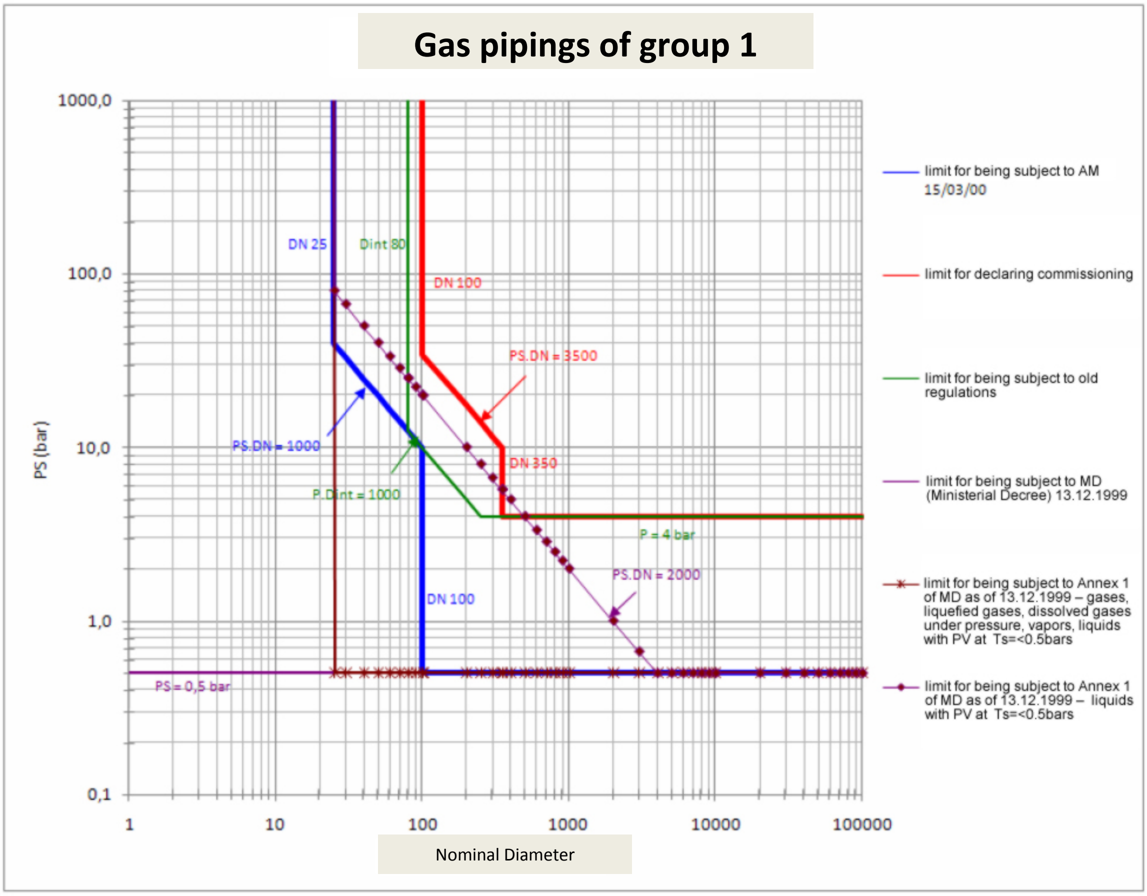
- Vessels (excluding apparatuses with a removable lid and excluding steam and overheated water apparatuses);
- Pipings (excluding vapor pipings).



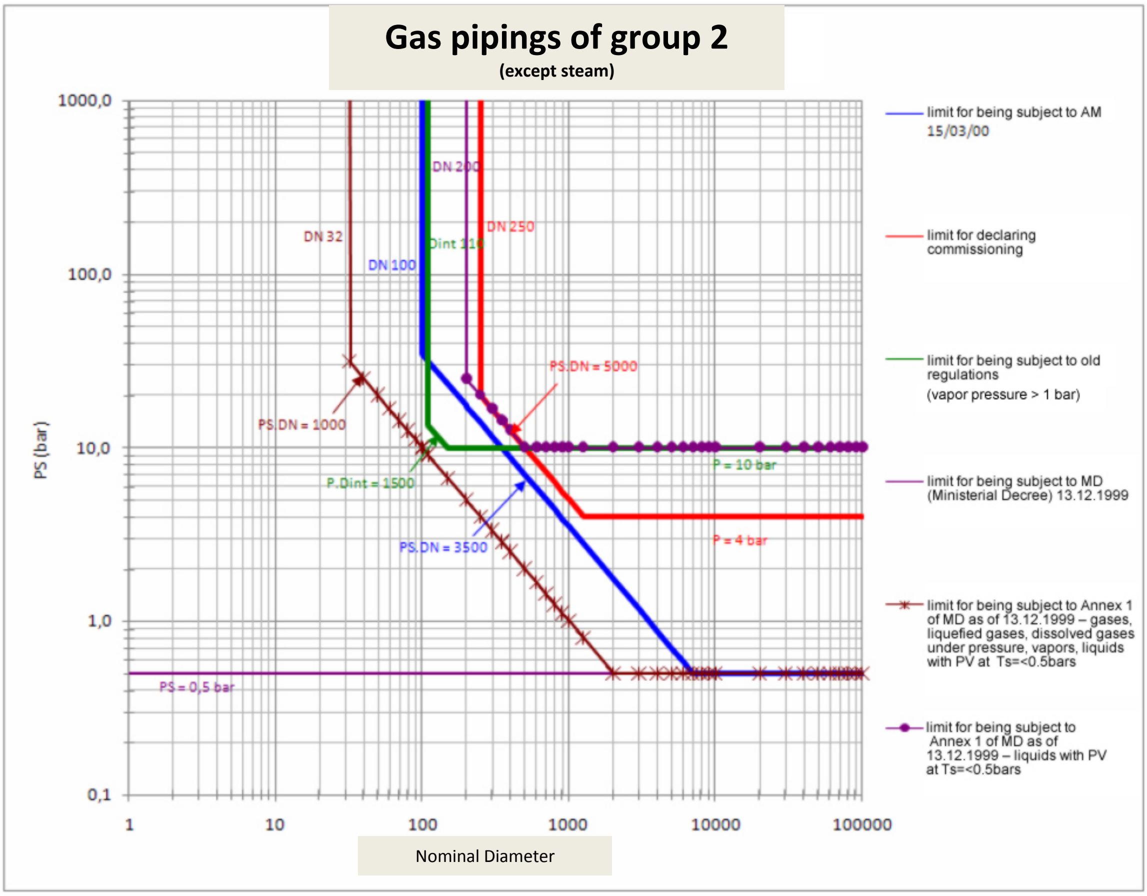
Gas vessels of group 1
PS (bar)
Volume (liters)
PS = 500 bar
P = 200 bar
V = 1 l
PS.V = 200 bar.l
PS.V = 10000 bar.l
P.V = 80 bar.l
PS.V = 25 bar.l
PS.V = 50 bar.l
P = 4 bar
PS = 0,5 bar
limit for being subject to AM 15/03/00
limit for declaring commissioning
limit for being subject to old regulations
limit for being subject to MD (Ministerial Decree) 13.12.1999
limit for being subject to Annex 1 of MD as of 13.12.1999 – vapors, liquids with PV at Ts=<0.5bars
limit for being subject to Annex 1 of MD as of 13.12.1999 – gases, liquefied gases, dissolved gases under pressure, vapors, liquids with PV at Ts=<0.5bars



Gas vessels of group 2
(Except steam – overheated water and apparatuses with fast-closing removable lids)
PS (bar)
Volume (liters)
P = 1000 bar
V = 1 l
PS.V = 10000 bar.l
PS.V = 200 bar.l
P.V = 80 bar.l
P = 10 bar
P = 4 bar
PS = 0,5 bar
limit for being subject to AM 15/03/00
limit for declaring commissioning
limit for being subject to old regulations
limit for being subject to MD (Ministerial Decree) 13.12.1999



Gas pipings of group 1
PS (bar)
1000,0
100,0
10,0
1,0
0,1
1
10
100
1000
10000
100000
Nominal Diameter
DN 25
Dint 80
DN 100
PS.DN = 3500
PS.DN = 1000
DN 350
P.Dint = 1000
P = 4 bar
PS.DN = 2000
DN 100
PS = 0,5 bar
limit for being subject to AM 15/03/00
limit for declaring commissioning
limit for being subject to old regulations
limit for being subject to MD (Ministerial Decree) 13.12.1999
limit for being subject to Annex 1 of MD as of 13.12.1999 – gases, liquefied gases, dissolved gases under pressure, vapors, liquids with PV at Ts=<0.5bars
limit for being subject to Annex 1 of MD as of 13.12.1999 – liquids with PV at Ts=<0.5bars



Gas pipings of group 2
(except steam)
PS (bar)
1000,0
100,0
10,0
1,0
0,1
1
10
100
1000
10000
100000
Nominal Diameter
DN 200
DN 250
DN 32
Dint 110
DN 100
PS.DN = 5000
PS.DN = 1000
P.Dint = 1500
P = 10 bar
PS.DN = 3500
P = 4 bar
PS = 0,5 bar
limit for being subject to AM 15/03/00
limit for declaring commissioning
limit for being subject to old regulations
(vapor pressure > 1 bar)
limit for being subject to MD (Ministerial Decree) 13.12.1999
limit for being subject to Annex 1 of MD as of 13.12.1999 – gases, liquefied gases, dissolved gases under pressure, vapors, liquids with PV at Ts=<0.5bars
limit for being subject to Annex 1 of MD as of 13.12.1999 – liquids with PV at Ts=<0.5bars

1.1.6 DECREE OF MARCH 15TH 2000[19]

The decree of March 15th 2000[19] relating to exploitation of fixed pressure equipment, in particular as regards requirements on the inspection and requalification operations of the submitted equipment as well as on the repairs and interventions on the equipment:

- **Periodic inspections** (Title III – articles 10-14): these operations have the goal of *« making sure that the condition of the equipment allows it to be maintained in operation with a safety level compatible with predictable exploitation conditions »*. This operation, performed by a competent person (from the site, from the SIR of the site, or from an external approved organization) under the responsibility of the operator, gives rise to a detailed and signed report. The inspection in all cases includes external verification (after execution of any operation for exposing or depositing removable portions[7]), an examination of the safety devices and, for the vessels (except for butane and propane) and the steam generators, an inner verification. Complementary investigations may be conducted if required. The inspections are conducted while taking into account:
    - Ascertained degradations;
    - Recommendations from the instruction sheet of the equipment.
    - Predictable exploitation conditions.

- **Periodic requalifications** (Title V – articles 20-27); Periodic requalification will complete the compulsory inspections for vessels, steam generators and pipings subject to declaration of commissioning. According to the decree of March 15th 2000, periodic requalification of a pressure equipment comprises the following operations:
    - **inspection** of the pressure equipment comprising:
        - an inner and outer verification with removal of the coatings (unless the procedure conducted by the authorized organization OH is approved by DRIRE);
        - an examination of the documents (descriptive files and the file formed during exploitation);
        - for pipings, verification of the identified areas in the inspection program defined by the operator and approved by OH.
    - **verification of the safety devices** associated with the relevant pressure equipment comprising a pressure relief valve recalibration if PSxV > 3000 bar.L.
    - **hydraulic test** of the pressure equipment. However, are exempted from a hydraulic test, the newly subject PE, the pipings and their safety devices and pressure accessories, vessels containing fluids other than steam or overheated water, the admissible maximum pressure of which is at most equal to 4 bars, as well as the pressure accessories of containers for which PSxV$\leq$1600 bar.L or PS$\leq$16 bars. The conditions for conducting the tests (imposed overload…) are specified in the decree.

    Requalification is generally carried out when the equipment is out of service.

    It is carried out by an expert from an approved organization or from a SIR if it is specially authorized for this purpose. Requalification gives rise to a certificate written and signed by the expert and transmitted to the operator. Success of requalification is materialized for vessels by the affixing of a « horsehead » and the date of the hydraulic test or of the periodic requalification inspection if the equipment is exempted from a hydraulic test and for pipings by a certificate.

    Requalification may be replaced with another method (after advice from the Central Commission for Pressure Apparatuses).

[7] *The exposure or the removal should allow the required verification to be achieved. For example, insulation, flame-retardant coating…*

- **Interventions** (Title VI – articles 28-31): two types of interventions are defined:
  - The modification corresponds to a change brought to the PE or to its operating conditions. If the modification is significant, a new evaluation of compliance by a notified organization will be required;
  - The other interventions are repairs.

    The interventions are carried out according to annex 1 of the decree of December 13th 1999 (PED) or, if the equipment is subject to the old regulations, by following the relevant old regulations. In the latter case, the QMOS (Qualification of Welding Operating Modes) and QS (Qualification of Welders and Operators) according to the **welding decree of 24.03.1978** are delivered by an authorized organization. Non-destructive tests (NDT) are conducted according to this same decree by examinators certified by an authorized organization.

    It is then established whether the intervention (repair or modification) is of the notable or non-notable type, following professional guides approved by the Ministry of Industry (**classification of the modifications or repairs of PE– AQUAP 99/13** and **factory pipings – AFIAP February 2004**).

    A compliance certificate is delivered by the operator or the person who acts as a substitute (repair man for example), the technical documentation is put together (on the intervention, the NDT, the inspections…).

    If the intervention is notable, it will further involve a **request for inspection by an expert from an** authorized organization (or from the SIR approved for this). Tests, evaluation of materials and requalifications will be carried out by the expert. The latter also proceeds with the **final verification** (an outer and inner visual inspection, examination of the safety devices) and the **hydraulic test**[8] (except for vessels which do not contain any steam or overheated water).

The decree defines the maximum time intervals between the inspections and the periodic requalifications **(except for pipings for which a monitoring plan, validated by an authorized organization, has to be proposed by the operator).**

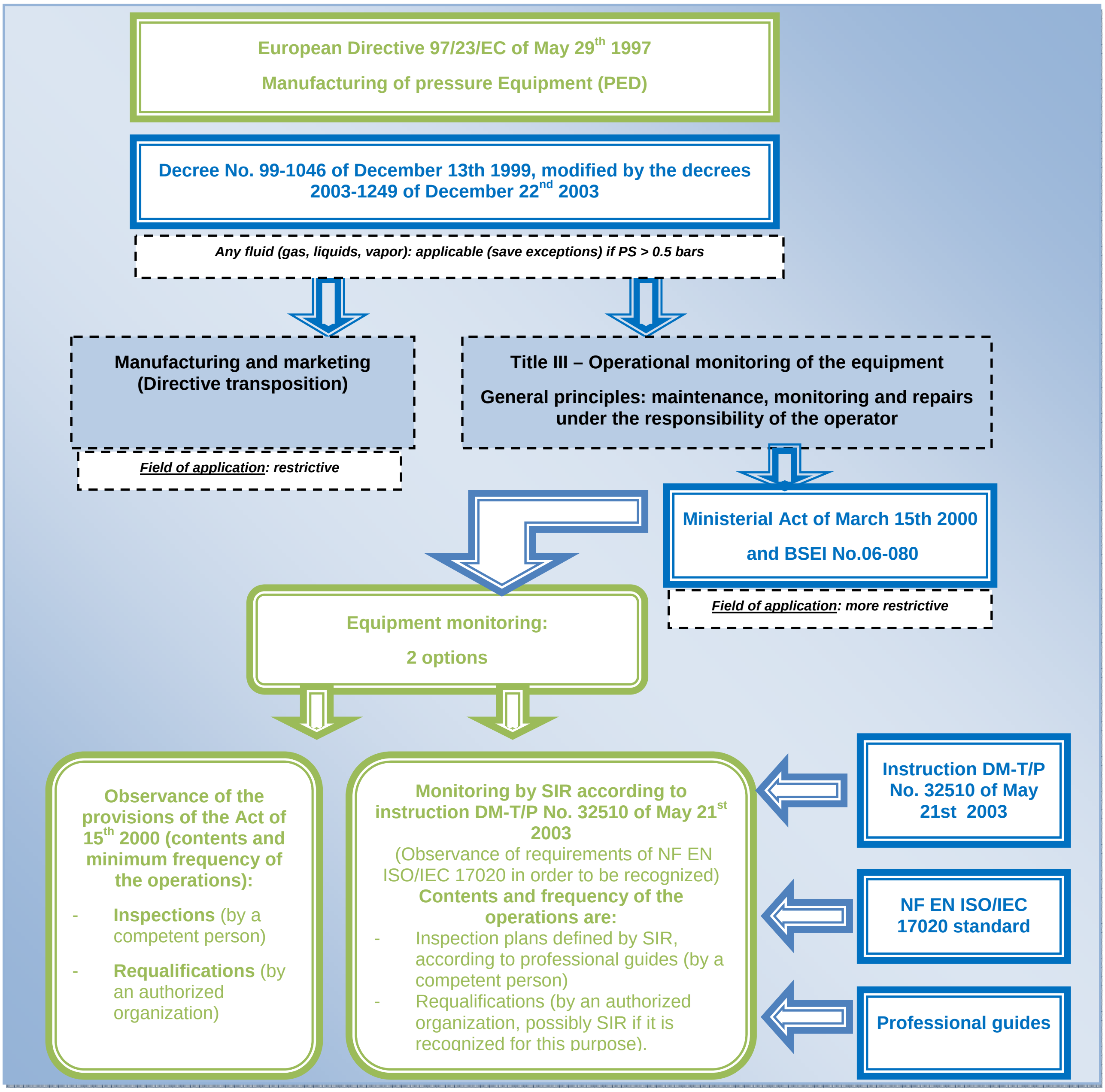
However, the regulations give the possibility of performing **risk-based studies**, subject to that the site has a **Recognized Inspection Service (SIR)**. The intervals between the inspections and the requalifiations may then be increased, with maximum values of 5/10 years or 6/12 years, depending on the professional guide used. The follow-up actions are carried out by the **recognized inspection service.** The decree then defines the conditions under which such an option is possible. The conditions for recognizing an inspection service are specified in the **instruction DM-T/P No. 32510 of May 21st 2003**[24] **relating to « recognition of an Inspection Service of an industrial establishment ».** It is required that:

- The inspection service observe the requirements of the **NF EN ISO/CEI 17020** standard « general criteria for operation of different types of organizations preceding the inspection » [10] of March 2005 (e.g. NF EN 45004); the DM/TP has adapted these criteria to SIRs.
- **Inspection plans** should be defined by the inspection services, setting the monitoring conditions of equipment (natures, localizations, extents and periodicities) and specifying the data for interpreting and exploiting the obtained results. These plans have to be carried out according to the prescriptions of professional **guides approved by the Ministry for Industry.** The guides in the chemical and petrochemical sector are:

[8] For pipings (non-longitudinal permanent assemblies), the hydraulic tests may be replaced by NDT, the tube having been tested in the workshop.

- **UIC/UFIP DT32[36] Guide: « Guide for establishment of inspection plans – Periodicity 5 year Periodic Inspection and 10 year Periodic Requalification » -** revision 2 of June 2008;
- **UIC/UFIP DT 84[37] Guide**: **« Guide for establishment of inspection plans – 6 year Periodic inspection and 12 year Periodic requalification »-** revision 1 of June 2006. The guide is only applicable to units having had an RIS for at least 5 years.

These guides set the general principles (taking into account the **criticality** of the equipment in the definition of the inspection plans) but require strong skills from the inspection services in order to be applied. The guides repeat the general requirements defined in the American guide API 580[72] (RBI for Risk Based Inspection) but do not propose formalized methods for evaluating criticality, nor the different parameters (probability, severity). Each site sets up its method while remaining compatible with the general requirements of the guides. The guides do not either propose any typical scheme for detailed inspection plans. The latter have to be carried out by each operator on the basis of his/her knowledge of the site (degradation modes, sensitive areas…).



Even if the principles of both guides remain the same, the guide DT84[37] details the elements required for evaluating the criticality of the equipment by integrating all the parameters in order to refine the evaluation thereof. Further, the guide integrates the **strong notion of feedback** as well as notions of **kinetics of damages and of sensitivity of the materials.** Reference will be made to the reports on the benchmarks in refineries.

The benefit of these methods based on criticality is that with them it is possible to target the monitoring actions on the most critical equipment and that they may give the possibility of attaining intervals between inspections and requalifications compatible with units operating continuously round the clock, with interruptions every 5 or 6 years. They determine extended inspection and requalification periods by taking into account the carrying out of non-destructive tests, when the equipment is operating between these statutory inspections.

The general prescriptions stemming from the Act of March 15th 2000[19] are the following:

Equipment[9]	Maximum interval between two inspections	Maximum interval between two requalifications
Pressure vessels[10]	40 months	3, 5 or 10 years[11]
Steam generators[12]	18 months	10 years
Pipings	Nothing imposed Program to be established by the operator in the year following the commissioning	3, 5 or 10 years[13] *(Only for pipings which have to be subject to a declaration of commissioning)*

The prescriptions relating to the maximum intervals for periodic inspections and periodic requalifications determined by the guides UIC/UFIP DT32[36] (UIC/UFIP DT84[37]) are the following:

Equipment	Maximum interval between two inspections	Maximum interval between two requalifications
Pressure vessels	5 years (6 years) Inspection plan established by the operator	10 years (12 years)
Steam generators	5 years (6 years) Inspection plan established by the operator	10 years (12 years)
Pipings	Inspection plan established by the operator	10 years (12 years) *(Only for pipings which have to be subject to a declaration of commissioning)*

---

[9] *Except for specific equipment such as respiratory cylinders for diving and mobile vessels in materials other than metal–cf. article 10 §3 of the decree of March 15th 2000.*

[10] *Mobile pressure equipment should be further checked on the outside before each filling.*

[11] *Depends on the corrosive or toxic nature of the substance. The duration is 3 years for equipment potentially containing corrosive impurities (fluorine, hydrogen chloride, hydrogen sulfide, etc.). Reference will be made to the Act of March 15th 2000 – article 22 §1. It is of 5 years for those containing a toxic or very toxic fluid, or a corrosive fluid towards the walls of the equipment.*

[12] *Valid for steam generators, apparatuses with a removable lid and with fast closure and the containers with pressurized steam or overheated water if the test overload has been reduced (otherwise, the interval is of 40 months)*

[13] *Idem previous note*

1.1.7 DECREE OF DECEMBER 13TH 1999[37]

The decree of December 13th 1999[20] is the transposition of the European Directive on Pressure Equipment.

The titles I, II, IV, V and the annex 1 set the conditions for the **design and manufacturing** of PE.

For equipment entering the scope of the requirements relating to the design and manufacturing, a **category** of equipment is defined (of category I for the less hazardous to IV for the most hazardous, including the safety devices). **The category conditions a severity level of the inspections**.

The design and manufacturing integrate the parameters intervening on the life-cycle of the equipment:

- Service life (a service life is a prescribed upon design);
- Predictable interventions (the interventions are prescribed upon design, in particular potential test exemptions);
- Loads (predictable process conditions, predictable degradations (corrosion, erosion, fatigue by vibrations for example…), loads of the wind, earthquake, type…);
- Adopted safety margins: these margins are in relationship with the codes used. But the use of codes such as CODAP is not imposed in the decree. On the other hand the use of CODAP is the guarantee of compliance with PED. If another code is applied (ASME), a verification of the admissible constraints should be carried out. The margins relate to different elements:
    - Retained admissible constraints;
    - Safety factors on the actual conditions of use (temperature, pressure…), constraints, calculation methods, properties and behavior of the materials;
    - Gasket coefficient;
    - Corrosion over-thickness
    - Etc…
- Design for possible fire resistance.

Manufacturing is carried out according to the prescriptions of the PED (adapted materials giving rise to a compliance certificate of the material – or a certificate with inspection, cutting and soldering according to prescriptions, adequate non-destructive tests, possible heat treatment…).

At the **end of the manufacturing**, the following operations are carried out:

- inspections (different inspections depending on the category of the equipment);
- hydrostatic pressure test;
- examination of safety devices;
- CE marking and labeling of the equipment;
- instruction sheet which notably specifies the use and the checking operations to be carried out by the user.

The procedures for evaluating compliance involve **authorized organizations which appear on the list of notified organizations.** The procedures for evaluating compliance depend on the category of the piece of equipment.

Title III relates to operational follow-up.

1.1.8 PROVISIONS OF THE DM-T/P NO. 32510[24] INSTRUCTION

The instruction DM-T/P No.32510[24] defines the criteria which an operator should observe in order that his/her inspection service be recognized.

With this recognition, industrialists are able to **define the nature and the periodicity** of the periodic inspections and requalifications, within the limit of the established relative professional guides. It is particularly useful for industrial units operating around the clock.

But the instruction DM-T/P No.32510[24] is not intended for authorizing recognized inspection services to carry out themselves the following inspection operations:

- Declaration;
- Controlling commissioning;
- Periodic requalification;
- Monitoring after repair or modification.

However, the inspection service will be led to carrying out permanent follow-up and inspection operations.

The recognition criteria defined in the instruction DM-T/P No.32510[24] are based on the principles of the NF EN ISO/IEC 17020[10] standard (ex NF EN 45004) from 2005. They concern:

- **The definition of recognition domain**, covering the scope of the equipment, the follow-up of which will be under the responsibility of the recognized inspection service; the recognition should specify its range (intervals of the inspections, requalifications, inspection of coated equipment…).
- **The recognition conditions** which include three strong points:
  - Strong commitment of management in the inspection and in setting up the inspection service;
  - Independence, competence and authority of the inspection service relatively to the other entities in the field of monitoring;
  - Knowledge on the manufacturing, exploitation and condition of the pressure equipment by the inspection service.

    Note: an inspection service may intervene on establishments on a neighboring site or on the actual site. In this case, the operators of the other establishments have to provide the inspection service with a written mandate allowing them to work under the same conditions as for their own establishment. They should also have the required competence (knowledge on the equipment of the other establishments, on the specific degradation modes…).

The inspection service then has the responsibility of elaborating and of applying **inspection plans**. These plans have to be compliant with the prescriptions of **professional guides** validated by the Ministry for Industry and notably follow the process for elaborating inspection plans as defined in these guides. If the guides do not specify the intervals between operations and/or the nature of the operations, the provisions of the decree of March 15th 2000 apply.

For **chemical and petroleum industries,** the reference guides (approved by BSEI) are the following:

- **UIC/UFIP DT32[36] Guide**; "Guide pour l'établissement des plans d'inspection (périodicités IP et RP 5 et 10 ans) - UIC/UFIP/CTNIIC document DT 32 révision 2 – juin 2008 » (Translation in English : **« Guide for establishing inspection plans –Periodicity 5 year periodic inspection and 10 year periodic requalification »**);
- **UIC/UFIP DT 84**[37] Guide: "Guide pour l'établissement des plans d'inspection permettant de définir la nature et les périodicités d'inspections périodiques et de requalifications périodiques pouvant être supérieures à cinq et –dix ans - UIC/UFIP document DT 84 - juin 2006 » **(** *Translation in English : Guide for establishing inspection plans for defining the type and frequency of periodic inspections and requalifications that may exceed five and ten year intervals)*. The guide may only be applied to units having had a SIR for at least 5 years.

The recognition **is established upon completion of a DRIRE audit**, providing evaluation of the compliance of the organizational provisions set into place as well as observance and application of the professional guides (or if the plans have not yet been established, the capability of the inspection service of establishing them and applying them is evaluated). The 1st recognition is established for a **maximum period of 3 years.** During this period, monitoring is established by DRIRE, in the form of extensive visits, including one for elaborating inspection plans.

Decisions for extension may then be made for maximum periods of 3 years, after a renewal audit. But the supervisions of DRIRE may then be reduced.

The field of scope may also be changed after an audit for extending the domain of recognition.

DRIRE carries out supervision on the inspection services, in the form of **extensive visits** and an **annual meeting**.

After a long standstill period, the inspection service should provide DRIRE with a full report on the follow-up operations carried out during this standstill.

1.1.9 PROFESSIONAL GUIDES IN THE CHEMICAL AND PETROLEUM INDUSTRY: GENERAL PRESENTATION

The UIC / UFIP guides were elaborated for the operators in order to provide them with guides for producing inspection plans.

The proposed method is based on an approach of the Criticality Based Inspection (IBC) or Risk-Based Inspection (RBI) type.

Note*: The method is established for monitoring pressure equipment, but it is specified that the method is applicable to any equipment containing a hazardous substance, the failure of which equipment may have significant consequences on the environment,…*

1.1.9.1 UFIP/UIC DT-32[36] GUIDE "GUIDE FOR ESTABLISHING INSPECTION PLANS – PERIODICITY 5 YEAR PERIODIC INSPECTION AND 10 YEAR PERIODIC REQUALIFICATION "

It gives the possibility of modulating the frequencies and methods of periodic inspection and periodic requalification (from MA 15.03.00) for evaluating the criticality of the equipment, for setting up suitable verifications during the inspections, setting up specific controls for monitoring and taking into account REX and limiting service conditions.

In this guide are found:

- Elements for evaluating criticality (analogous to the construction category of CODAP and CODETI);
- Elements of influence of frequency, quality and complete application of the verifications;
- Elements required in the inspection plan for:
    - The PE depending on their type (possible adjustment for specific pieces of PE);
    - Thermally insulated equipment (methods for removing insulation during inspection and requalification);
    - The pipework;
    - The accessories;
- Elements for selecting the checking operations depending on the degradation modes (presented succinctly);

- Sources of documentation and avenues for developing and improving plans;
- Provisions applicable to certain families of PE (having a coating or containing catalysts, absorbents or internal linings).

1.1.9.2 GUIDE DT-84[37] "GUIDE FOR ESTABLISHMENT OF INSPECTION PLANS – PERIODICITY 6 YEAR PERIODIC INSPECTION AND 12 YEAR PERIODIC REQUALIFICATION"

This guide is intended for the SIR, for which recognition dates from at least 5 years, in order to support the creation of the inspection plan of the PE on the basis of an RBI method.

The principle is to detail the elements required for evaluating criticality of the equipment by integrating all the parameters in order to refine the evaluation. Further, the guide integrates the **strong notion of feedback** as well as the notion of **kinetics of the damages and sensitivity of the materials**.

In addition to the elements of DT 32, in the guide, are found:

- Elements for detailed evaluation of criticality of the RBI type (failure probability * consequence);
- Elements to be taken into account for setting up monitoring methods;
- Detailed methods for periodic inspections and requalifications;
- Adjustments of verifications for series of vessels via a control of a sample equipment;
- Sources of documentation and methods for integrating and managing feedback;
- Methods for revising the inspection plan;
- Methods for revising the guide;
- Provisions applicable to equipment containing non-corrosive fluids;
- Provisions applicable to equipment which may not be subject to requalification;
- Information on taking into account Limiting Critical Operating Conditions (COCL).

1.1.10 STANDARD NF EN ISO/IEC 17020[37] OF MARCH 2005

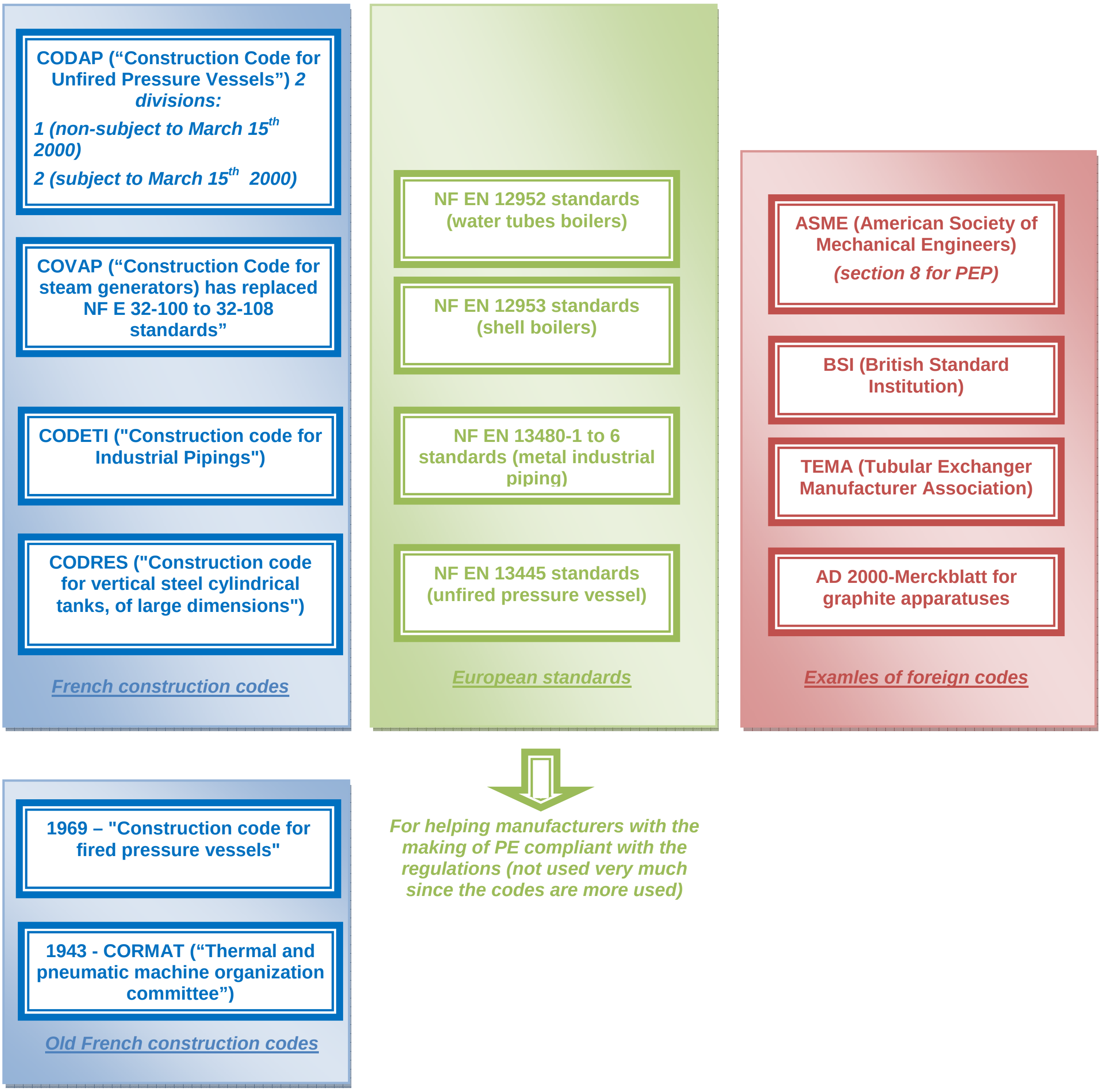
The **NF EN ISO/IEC 17020** standard of March 2005 relating to « General requirements for the competence of testing and calibration laboratories » repeats the text of the EN 45004 standard of 1995. It specifies the general criteria as regards the competence of organizations proceeding with inspection and also specifies the independence criteria.

The annex 1 to the decree DM/TP No.32510[24] of May 21st 2003 repeats the requirements of the standard while suppressing from the model retained as a quality baseline (based on the NF EN 45004 standard - 1995) the requirements which are not suitable for inspection services and while setting complementary requirements for the recognition of inspection services. Reference will be made to this annex for more details. The following page shows the great sections of the requirements.

- Administrative matters: the inspection organization or the entity to which it belongs should have a known legal structure. If it belongs to an entity exerting other activities, it should be identifiable in the organization. Documents should describe its activity and its field of competence.
- Independence with regard to organizations external to the inspection in order to guarantee impartiality and integrity requirements. Procedures should be applied for ensuring that results of the inspections cannot be influenced by other organizations.
- Confidentiality: the inspection organization should ensure confidentiality of the information collected during its inspection activities.
- Organization and management: the inspection organization should allow maintenance of the capability of fulfilling the function, should define and document the responsibilities and the structure of the organization responsible for issuing the reports. The person in charge should be a permanent employee. Effective supervision should be set into place. The function of each member should be described.
- Quality system: management should define and lay down in writing its policy, its objectives and its commitments and make sure that it is understood at all levels. A quality system should be set into place and regularly audited. Documented procedures should be drawn up for dealing with feedback and possible malfunctions.
- Personnel: the number of persons in the inspection organization should be sufficient and should have the required skills. Training sessions and accompanying actions are required;
- Installations and equipment: the properly identified pieces of equipment should be accessible for inspection; when computers are used, procedures are established for protecting the integrity of the data and their backup.
- Inspection methods and procedures: the inspection organization should use methods and procedures for inspections.
- Handling of the samples and objects presented to the inspection: Accurate identification of the pieces of equipment and safety devices which have to be inspected should be achieved by using reference marks used by the designer and by the operator on the plans. The preparation conditions should be defined (for example selection of the areas, the insulation of which has to be removed…).
- Records: The recording conditions are defined and documented as well as the conditions for archiving.
- Inspection reports: completed work should be the subject of inspection reports and/or of inspection certificates which should be signed. The latter contain the results of examinations and determination of compliance is made from these results, they should rule on whether the equipment should be kept in operation, etc…
- Complaint and appeal: in the case of an inspection service intervening in different establishments, a procedure dealing with complaints and appeals between the establishments should be defined.
- Subcontracting: normally the inspection organization should itself carry out the inspection tasks. If it resorts to subcontracting, it should make sure that the subcontracter is competent and follows work requirements specifying the required qualification/certification levels; the limits of monitoring or inspection, the inspection plan and the possible faults to be sought. The subcontractor should be assessed and the results of these assessments recorded.
- Cooperation: the inspection service should contribute to feedback of its group or of its professional union. It should benefit from and take into account the exchanges and feedback organized by professional unions (UFIP, UIC/CTNIIC…) or by other organizations (AFIAP, APITI…).

1.1.11 STANDARDS AND PROFESSIONAL GUIDES

The standards and guides associated with the construction codes are identified in the table below.



1.2 PRINCIPLES OF THE INSPECTION PLANS

The inspection plans are required by regulations in the case of sites having SIR. This is one of the required conditions in order to be recognized as an SIR.

The requirements of the inspection plans are globally the same for the usual guides (DT32[36], DT84[37]) but on the detail level are more or less extensive.

The inspection plans specify (cf. DT84):

- The **characteristics of the equipment**;
- The potential and proved **degradation modes,** the latter being described in the guides;

- The **categories of probability levels**[14]; this probability depends on the following factors:
    - Degradation modes and rates by integrating the different exploitation phases (normal phases, shutdown, startup…) and external conditions: weather, vibrations, boundary forces …;
    - Occasional presence in the product of elements likely to generate damages;
    - Feedback and history of the equipment;
        - ⇨ These parameters define a **damage factor**;
    - From the design and the building of the equipment by integrating observance of construction codes or standards, the geometrical complexity of the equipment, the relevance of the design selections…
        - ⇨ These parameters define a **manufacturing factor**;
    - Stability of the operating parameters by integrating the control of the Limiting Critical Operating Conditions (COCL), knowledge of the fluids…
        - ⇨ These parameters define a **method factor**;
    - The relevance of inspection actions (suitability of NDT, periodicities of the actions, representativity of the check points… suitability for quantifying damages);
        - ⇨ These parameters define an **inspection factor**;
    - The efficiency of the maintenance actions (technical maintainability) integrating achievement of recommendations issued by the SIR, the quality of the interventions, the damage level of the equipment.
        - ⇨ These parameters define a **condition factor.**

- **The classes of consequences or the severity of each failure.** The severity depends on:
    - the fluids present:
    - the hazards associated with the product (toxicity, flammability…);
    - their flash point;
    - the amount and on the flow which may be released in the case of loss of containment; on the phase of the substance in the case of discharge;
    - normal and transient operating conditions (temperature, pressure);
    - possibilities of isolation or fast emptying;
    - implantations, on « effects induced on their environment »[15];

---

[14] *__Note__: the terms used above correspond to those of DT84. DT32 involves the same types of parameters but in a less formulized way. In particular, the relevance factors of the inspection actions and the efficiency of the maintenance operations are additions of the new version of DT32 and are not necessarily integrated into the plans which comply with the old version.*

[15] *This designation used in both guides is not detailed in DT32. In DT84, these may be potential domino effects on other pieces of equipment or effects on persons located in the effect surface area.*

According to the methods, the severity may involve different factors:

- Impact on persons (internal to the site or outside the site);
- Cost related to loss of exploitation following unavailability of equipment and equipment which may be impacted;
- Cost of possible depollution.

<u>Note</u>: For certain methods (API 581-cf. annex K), the result is expressed by a surface area or a cost. It is important to know the parameter with which this factor is associated (risk on persons, environment or cost) in order to know the criterion which has led to hierarchization of the control actions in the criticality matrix.

<u>Note</u>: The methods for evaluating the intensity may be based on different assumptions (single breach size, weighting of several breach sizes, assumptions of set models, set class…). There again, in the case of the use of a software package, it is important to be aware of the assumptions used in the calculations.

- The **criticality of equipment**, defined as being as the product of the probability of occurrence and of the severity of consequences. Criticality integrates the maintenance and monitoring operations through the probability factor. Several criticality areas are proposed in the guides (4 in DT 84 and in API 581). If an equipment is in a high criticality area, actions will have to be conducted in order to reduce its criticality to a lower level. For equipment with intermediate criticality, verification of the suitability of the plan should be carried out. For equipment of low criticality, the methods are those provided in the plan and may possibly be reduced depending on the feedback. It is noted that the criticality matrices are not strictly the same in API 581 (cf. annex K) and in DT84[37]. DT32[36] does not show any example of criticality matrix.

  Producing the matrices remains the responsibility of industrialists, as well as the definition of the associated inspection plans.

- **Monitoring actions to be applied** on operating or out-service equipment, notably:
  - The natures and periodicities of the inspections and requalifications;
  - The types, localizations, extents… of non-destructive testings to be carried out and their periodicities;
  - Particular conditions for preparing equipment for the inspections and re-commissioning thereof;

  The periodicities of the inspections and requalifications are not directly provided in the guides according to criticality. Each site achieves the link between criticality and periods between inspections.

  *<u>Note</u>: certain methods applied on sites suggest including into the definition of inspection periodicities, the **remaining service life**, by imposing a period relative to the service life which is all the more restrictive since criticality is significant.*

- **Criteria and thresholds associated with the inspections and tests:**

- **Possible limiting critical operating conditions** (**COCL**) and associated thresholds, while also specifying the methods for monitoring the instruments associated with COCL and exploitation of the COCL.

The plans should integrate the particular areas which may be likely degradation sources (dead legs, areas under insulation, supports and abutments…).

Note: the guides DT32[36] and DT84[37] specify that for the fourth requalification, total removal of insulation should be carried out. Non-sensitive areas having been subject to insulation removal since or during the second requalification may not have their insulation removed if the good condition of the wall was then ascertained. Every two following requalifications, removal of insulation should be carried out under the same conditions. This requirement of total exposure does not affect pipework (DT32).

Procedures for **revising the plans** should be established, which integrate the time-dependent change of criticality evaluation factors and the consideration of feedback from the equipment and from equipment likely to be affected by the same degradation modes.

The DT84[37] guide specifies that the inspectors should take into account

- abnormalities detected by the operating personnel or maintenance personnel (damage coatings, vibrations);
- COCL being exceeded: feedback may be automatic towards the inspection service or be accomplished within the scope of reporting meetings with the operators.

1.3 NOTION OF SERVICE LIFE – MAINTAINING OPERATION

1.3.1 A FEW PRINCIPLES

Service life defined upon design: limits

Upon designing equipment, parameters are involved which have an influence on the service life.

For pressure equipment, the decree of December 19th 1999[20], transposition of the European Directive on Pressure Equipment sets in its titles I, II, IV, V and annex 1 the conditions for **designing and manufacturing** PE.

For equipment entering the field of requirements relating to the design and manufacturing, a **category** of equipment is defined (from category I for the less hazardous to IV for the most hazardous, including safety devices). **The category conditions a severity level of the inspections.**

The design and the manufacturing integrate the **parameters involved in the life cycle and in the service life of the equipment** (cf. § 1.1.7.).

However, the actual conditions of the equipment may be more or less restrictive, **so that the service life is rarely defined in an overall way** with replacement of the equipment at the end of the initially provided service life.

The operating conditions (starting or stopping cycles, pressure/temperature conditions, nature of the substance, external loads (vibration, winds…), environmental conditions…) have an influence on the service life of the piece of equipment.

In practice, pieces of equipment nevertheless rarely have a predefined service life. Pipings do not have any service life (no guarantee from the manufacturers).

Only certain pieces of equipment (in a limited number) may be considered as « consumable ». This is determined by feedback and is related to particular conditions of temperature, of fluid, of material (for example: a steel/carbon exchanger with a corrosive fluid). These pieces of equipments are subject to frequent inspections and/or systematic replacements. Certain pieces of equipment in chlorochemistry for example, are installed for a predefined duration of X years because of their known accelerated ageing.

Correlation between the age of the equipment and inspection frequencies

Within the framework of the WGs, ASN specifies that, in the nuclear sector, the frequency of the inspections increases with the age of the installations, notably because the age of the equipment is involved in certain degradation modes (occurrence of certain modes or acceleration of the latter).

The correlation between frequency of the inspection operations and remaining service life of the installation is not a statutory obligation, even if indirectly for certain degradation modes, links may exist in certain guides.

1.3.2 ACCEPTABILITY CRITERIA

Beyond the application of monitoring operations, **the question** is posed of **the acceptability of the obtained results**. The goal of the monitoring operations applied on the equipment is to "check that the condition of the equipment allows it to be maintained in operation with a safety level compatible with predictable exploitation conditions”.

The basis should be the experience, the results of previous NDT tests, but one should be watchful on the fact that the rate of time-dependent changes of the flaws may be modified.

There no specific **regulations on the acceptability thresholds for the obtained results.**

Acceptability criteria are defined in order to determine whether the equipment may be maintained in operation over a determined period (for example until the next shutdown or the following one). Depending on the nature of the reported and/or predictable degradation, use may be made (experience of the sites) of:

- The calculation codes (CODAP, CODETI…) which for general losses of thickness allow determination of a minimum thickness compatible with the maximum exerted pressure; industrialists then define acceptability rules depending on the codes used, on the service conditions and on the relevant areas; the thicknesses are calculated by taking into account degradation rates evaluated from prior measurements (i.e. the last two measurements, or the last and the first measurements, or those leading to a more significant thickness loss rate). The measurements are conducted at the same points (marked on the equipment) in order to allow the measurements to be monitored over time and an analysis of the time-dependent changes.
- Decisions may be made as to the presence of cracks: in the case of cracks, compulsory repair of the equipment for example;
- Decisions may be made as to the presence of blistering: the latter may be tolerated but monitoring is performed in order to make sure that there is no time-dependent development.

When degradations are noted on a piece of equipment and these degradations potentially compromise its maintaining in operation, several options are possible:

- **Make the equipment inoperative**, with or without replacement;
- **If possible suppress the damage,** with or without repairs;
- **Repair the component**, permanently or temporarily by either suppressing the degradation mode or not;
- **Change the operating conditions**, possibly by degrading the operating conditions (reduction of the operating pressure, etc…);

  More extensive monitoring may be applied in order to make sure that the extent and the time-dependent change in the degradation rate do not jeopardize the safety conditions;
- Analyze the margin between the present conditions of the equipment and the minimum defined ones in the construction codes and **apply a method of the Fitness-For-Service type** and/or evaluate the remaining service life (if information exists on the size of the flaws); these complex methods are described in the following paragraph. Professional guides such as API 579 (Fitness-For-Service) or BS 7910, with specialized skills, may be used for determining whether a piece of equipment may be maintained in operation safely until the next shutdown.

Several actions are possible simultaneously. The decisions are then based on economical considerations.

1.3.3 REPAIRS AND MODIFICATIONS

If repairs or modifications are carried out on a piece of equipment, **it is necessary to ask oneself whether the repair is satisfactory and to evaluate its service life.**

Repairs on pressure equipment should follow the recommendations of the regulations in effect (guides on repairs of PE). If consequent work is carried out, the competent person or another independent consultant will have to be **consulted before carrying out the repair.** The repair may be made by following the associated statutory requirements (on PE for example). These impositions are valid in France but also in the U.K. (cf. HSE report – Plant ageing[63] – 2006). It is recommended by HSE to resort to an opinion from a professional in order **to validate the repair**. The repair has to be made according to the initial design code, or a new one if it no longer exists.

If it is considered that the repair introduces a higher risk, mitigation steps may be applied.

The repair specification should be careful with regard to maintaining the operation of safety equipment and to maintaining the possibility of inspection on the equipment.

The possibility of damaging the equipment will also have to be considered (presence of contaminants, stresses due to subsequent heat treatments, poor alignment after repairs, access constraints…).

1.3.4 REDUCTION OF THE CONSTRAINTS ON THE OPERATING MODE

If simple criteria are not met for normal operating conditions and/or if a FFS method has shown that the service life of the equipment is not sufficient with normal operating conditions, it may be decided to **"declassify"** the equipment, by modifying the operating conditions (reducing pressure, temperature, applied loads, number of cycles ….).

If such decisions are made, **an overall analysis of the modification** should be carried out, in order to make sure that there are no new constraints on these associated pieces of equipment.

1.3.5 EVALUATION OF FITNESS FOR SERVICE AND OF REMAINING SERVICE LIFE

Preliminary note: The information contained in this chapter 1.3.5 stems from the document "Plant Ageing" [63] of HSE and from the CETIM article on procedures for evaluating the remaining service life of structures [15].

The principle of the Fitness For Service (FFS) method is to evaluate the integrity of the structure of a piece of equipment for subsequent operation (often until a next shutdown or a next inspection), taking into account degradations and deviations relative to the design conditions.

The FFS may be applied at any moment during the service life of a piece of equipment:

- At the moment of its design (design phase);
- During its operation before occurrence of a flaw;
- Once a flaw has occurred.

In the first two cases, assumptions are made on the occurrence and on the nature of degradations. In the third case, the basis is on actual degradations.

For industrial plants, there are **two main guides** used for evaluating whether the equipment may be maintained in operation. These two guides[16] used in Europe[17], are the following:

- The API Recommended Practice 579 (2000): Fitness-For-Service[77], updated in 2007 under the name of API RP 579-1/ASME FFS -1 (2007);
- The BS 7910 – (2005) - Guide to methods for assessing the acceptability of flaws in metallic structures[61] .

Both of these guides are recognized as being the most secure and represent good practices, although they do not always give strictly the same results.

But there would exist other guides giving rules for evaluating harmfulness of flaws: references will be found in the document HSE "Plant Ageing" [63 or in the document ¯« CETIM - Evaluation of harmfulness of cracks – comparison with the procedures BS7910, API 579-1/ASME FFS-1, RSE-M et FITNET » [16]

Application of the guides is carried out when doubts occur on maintaining the equipment until a given deadline, for example because considering the corrosion rate, it is assessed that the required minimum thickness (no corrosion over-thickness) has been reached. Tolerance is then taken on the minimum value in order to take into account margins taken upon designing the equipment. **The accepted tolerance then theoretically depends on the margins taken upon design and on the construction codes used**. Also for cracks, safety coefficients are taken upon design on the loading or the size of the cracks, which justifies the application of FFS methods.

BS 7910[61]

BS 7910 is applicable to **metal structures** in **many industries, without being specifically dedicated to pressure equipment.** It is very focused on flaws inside welds and around welds. **The specifically covered flaws are essentially cracks.**

---

[16] In France, the RSE-M code applicable to pressurized water nuclear reactors was updated in 2005.

[17] The European network FITNET attempted to make a European standard from BS 7910, but certain countries (including France) were opposed to this. The guide is therefore not recognized today as a standard.

API 579-1 / ASME FFS-1 [77]

API 579 is focused on the evaluation of equipment in **refineries and petrochemistry. It is highly directed toward pieces of pressure equipment and notably to those built according to the ASME codes** (Boilers and Pressure Vessel Code) **and pipings (B 31) and by API for storage tanks.** Evaluations of FFS are consistent with the tolerances given in these codes. In particular, 1st level analyses are based on formulae from these codes. If other codes are used, application of FFS requires an interpretation on behalf of the user.

The use of API 579 is designed for **three types of users**:

- **Level 1 corresponds to factory inspectors** with minimum knowledge on inspection and on components.
- **Levels 2 and 3 may only be used by expert engineers.** They require that a lot of information be collected on the equipment, the possible encountered degradation mode… Consequently, studies are conducted by a set of competent persons (process engineer, NDT examinator, corrosion specialist…). Level 3 applies more extensive calculation methods of the finite element type and require more consequent computer means than level 2 and therefore specific qualifications of the persons. Generally, if level 2 already gives satisfaction, level 3 is not undertaken.

  In the USA, as a result of abusive uses of the FFS method, the US administration has set into place a license for organizations which may conduct FFS studies on level 3.

The use of BS7910 also includes three levels for analyses of fractures and fatigue. For BS 7910, level 1 already requires extensive skills.

Reference may be made to annex H for more details on these two guides.

It is noted that the use of these methods requires specific skills from the users. The data required for applying the methods may be difficult to obtain. It is difficult to know the reliability thereof.

1.4 REQUIREMENTS RELATING TO THE SKILLS OF THE PERSONS

The operations for monitoring equipment are performed **under the responsibility of the operator** by a person considered as competent. This person may be a person from the site, from the SIR of the site or from an external authorized organization.

Authorized organizations

Authorized organizations are necessarily involved at different moments of the process:

- Validation of the inspection plans for pipings, elaborated by the operator;
- Carrying out periodic requalification (or by the SIR, if it was recognized for this purpose, which is rarely the case).
- In the case of notable involvement, control by an expert from an authorized organization (or by the SIR if it was recognized for this purpose).

Sometimes the authorized body may be led to carrying out the inspection operations themselves, on demand from the operator.

The authorized organizations appear on an official list (decree of June 22nd 2005[25]). They comprise the APAVE, BUREAU VERITAS, ASAP (Association for the safety of pressure apparatuses) which includes the Institut de Soudure (Welding Institute), SGS, SOCOTEC and NORISKO.

Qualifications of the inspectors of the SIR

The recognition criteria defined in the instruction DM-T/P No.32510[24] are based on the principles of the NF EN ISO/CEI 17020[10] standard (ex NF EN 45004) of 2005. Beyond the requirements defined in DM/TP No. 32510[37] of May 21st 2003, there are no particular requirements as to the qualification of the inspectors of an SIR, except for an internal authorization delivered by the site. However in practice, **training sessions with qualification are organized by the CTNIIC (National Technical Committee for inspection in the chemical industry) which delivers UIC certifications** (UIC level 1 and UIC level 2). These UIC levels are correlated with the responsibilities of the inspectors on the sites: level 1 is generally associated with operations for setting into place an inspection plan, for carrying out monitoring operations, for proposing actions. But level 2 is required for validation operations. The DRIRE generally require these qualification levels.

Qualifications of the other actors in monitoring operations

In the case of **welding operations**, the qualifications QMOS (Qualification for Operating Welding Methods) and QS (Qualification of Welders and Operators) according to the decree on welding as of 24.03.1978 will be checked.

In the case of **NDT operations**, there exist **COFREND accreditations** with different levels for the majority of the **NDTs**. Level 1 is easy to obtain and is far from guaranteeing actual experience of the person. The required level also depends on expectations (a level 2 accredited person is able to make interpretations as to the acceptability of the results). The NDT operations are generally sub-contracted to specialized companies and the qualifications applied to a given type of NDT. By checking accreditations, it should be possible to check the competence of the intervening persons. For ultrasonics (US) with view to thickness measurements, there are no COFREND requirements and these operations are often, in the case of an establishment with an SIR, performed by inspectors of the SIR.

1.5 A FEW PARTICULAR TEXTS

Specific regulations for certain types of installations have completed the statutory field:

- **Guide of Good Practices for monitoring by Acoustic Emission pressure Equipment** (guide AFIAP[26]): the guide proposes the replacement of the hydraulic test (periodic requalification) with a gas pressure test, with acoustic emission monitoring for certain pieces of equipment: this is notably the case of spheres, cylindrical LPG tanks. Normally the guide does not exempt from visiting the interior, but most often exemption is obtained upon justification at the DRIRE, so that it is possible to do without the emptying of the tank.

- **Statutory inspection of pressure equipment with <u>outer</u> or <u>inner</u> coatings** (Guide AQUAP[27])**:** this guide intended for the inspectors provides details for establishing the examinations to be conducted within the scope of inspections on thermally insulated PE. These recommendations are given depending on the hazard level of the equipment.

  First of all it should be emphasized that are excluded from the field of application of the present procedure:

  - pipework;
  - equipment covered by a statutory text, a DM-T/P decision, a BSEI decision, or a professional technical handbook (CTP) approved by the Ministry for Industry, which specifies for the methods of in-service inspection, the provisions to be taken within the scope of coatings, insulation devices or linings;

- pressure equipment monitored by a Recognized Inspection Service within the perimeter of its recognition.

  <u>Note</u>: for the conditions of insulation removal of establishments with SIR, reference may be made to DT84 and/or DT32, which provide in an annex details on the areas which have to be subject to partial or total insulation removal (cf. report on the refinery storage benchmark).

The basic principle to be retained is that for operating equipment, the insulation in place is deemed to be innocuous with regard to the wall from the moment that no degradation of the wall is observed on areas for which insulation has been partly removed or which have been examined and considered suspect.

Sealed thermally insulated devices (a protective casing welded to the wall or the like) are deemed to have retained their innocuousness and waterproofness in the absence of any noted suspicion during the visual examination.

Paints with small thicknesses and galvanization are not considered as coatings capable of interfering with inspection, the good condition of the wall may be evaluated from the condition of the actual coating. This is notably corroborated by the questions & answers sheet DGAP5/3 of DMTP 32140.

Thus, depending on the inspection to be carried out, the guide proposes four levels of insulation removal from the simplest to the most complete.

- **Standard specific to LPG: as stated in the standards, «these European standards are based on legislations and regulations used in Europe but also on rules and customary practices of industrialists».**
  - **<u>European standard NF EN 12817[34:</u> Inspection and requalification of aboveground LPG tanks with a capacity of less than or equal to 13 m^3 for liquefied petroleum gases – December 2002, amended in June 2006.** This is a standard dealing with methods and with the background required for inspecting aboveground LPG tanks. It introduces three types of checking operations:
    - **<u>Routine inspection</u>**: external visual inspection of the visible portions of the tank (with view to detecting external corrosion) and of its pieces of equipment, it includes checking the safety units (condition of the drainages of valves, grounding connections, level gauges);
    - **<u>Periodic inspection</u>**: external visual inspection of the visible portions of the tank and of its pieces of equipment, but at a lower frequency than that of routine inspections; it comprises in addition to routine inspections verifications of the vents of valves, of pressure gauges, stop valves, absence of corrosion on pins, nuts …;
    - **<u>Periodic requalification</u>**: the latter comprises at least **<u>one</u> of the following elements**:

      a/ Individual requalification of each tank, including external visual inspection and at least one of the following elements;

      - Internal visual inspection;
      - Hydraulic test;
      - Checking with acoustic emission;
      - Thickness checking with ultrasonics method;
      - Another equivalent method.

b/ requalification by sampling a production batch.

It should be noted that an inspection of the site should also be provided, including a **check on the condition of the supports and foundations** in order to ensure that « they are sound, without any visible damage or differential settlement ».

The standard does not specify any interval between the different checking operations.

- **European standard NF EN 12819 (standard being amended[35]), Inspection and requalification of aboveground tanks with a capacity greater than 13 m^3 for liquefied petroleum gases. Like the preceding one, it describes three types of verifications to be carried out:**
    - **Routine inspection**: external visual inspection of the visible portion of the tank (with view to detecting external corrosion) and of its pieces of equipment, in addition to routine inspection of the tanks $\leq$ 13 m^3, it includes verification of the condition of the vent tubes of the safety relief valves, verification of the responses of the remote-controlled valves and inspection of the site (including the absence of deterioration of the optional protection systems against impacts, verification of the sound condition without any damage of the supports and foundations, without any differential settlement and with anchorage bolts in good condition;
    - **Periodic inspection**: external visual inspection of the visible portions of the tank and of its pieces of equipment, but at a lower frequency than the routine inspections; in addition to the routine inspections, it comprises checking operations for maneuvering mechanisms of collectors, valves, pressure gauges, optional pressure switches, temperature measurement apparatuses, stop valves…;
    - **Periodic requalification**: the latter comprises verification of the valve loading or its modification, verification of absence of corrosion on pins, nuts… maneuverability of the flow rate limiters and anti-return valves **and** at least **one of the following elements**:
        - Internal visual inspection;
        - Hydraulic test;
        - Inspection by acoustic emission;
        - Thickness check;
        - Another equivalent method.

    The standard specifies that the interval between two requalifications should not exceed 12 years but does not give any more information on the intervals between the different checking operations.

There exist **requirement specifications for the construction of particular equipment** with which it is possible to benefit from adjustments to statutory provisions subject to compensatory measures. This is for example the case of the requirement specifications relating to **buried tanks intended for storage of liquefied flammable gases** – Guide AFIAP – Specific provisions applicable to buried tanks intended for storage of liquefied flammable gases – June 2004 (guide recognized by DM/TP 33105); the guide specifies the required conditions for exemptions of external verifications of the wall and of the supports upon periodic inspections and for exemptions of exposing the outer wall of the tank during periodic requalification.

2. POLICIES FOR MONITORING STORAGE TANKS OTHER THAN THOSE UNDER PRESSURE

This chapter includes two aspects:

- A presentation of the principles for in-service checking and monitoring as imposed by regulations and proposed in different professional guides and standards;
- Notions on service life.

2.1 THEORETICAL ASPECT: APPLICABLE REGULATIONS, STANDARDS AND GUIDES

2.1.1 REGULATIONS

Atmospheric storage tanks are subject to regulations depending on nature of the substances:

- **For tanks containing lightweight liquid hydrocarbons:**

  French regulations on atmospheric tanks containing hydrocarbons are based on the texts: "Ministerial acts of November 9th 1972 and November 19th 1975 – Aménagement et exploitation des dépôts d'hydrocarbures liquides[42: ("Layout and exploitation of liquid hydrocarbon depots") and "Ministerial act of September 4th 1967: Aménagement et exploitation des usines de traitement de pétrole brut, de ses dérivés et résidus[43] ("Layout and exploitation of plants for processing crude oil, its derivatives and residues".)

  These texts formalize the prescriptions in terms of installation, exploitation, protection and inspection rules for tanks of flammable liquid.

  These rules are imposed to the whole of the hydrocarbon tanks present in depots. However, the Prefect keeps the right of modifying statutory prescriptions for specific equipment.

  These texts do not bring many statutory parameters taking into account ageing during design, manufacturing, commissioning or modifications.

  However, the **statutory obligation of carrying out an internal seal inspection of the tanks every ten years** is found. This inspection may be replaced with an external seal inspection.

  This prescription is shown in article 504.5 of the decree of November 9th 1972 and November 19th 1975[39]:

  "The tanks containing liquid hydrocarbons with the exception of heavy fuel oils, bitumens and fats should be subject to a visit of the interior every ten years in order to check their seal. This prescription is not applicable when technical arrangements have been taken for detecting any leak in the bottoms of the tanks."

  Heavy hydrocarbons (heavy fuel and bitumen) are not subject to this compulsory seal inspection.

- **For tanks containing heated products:**

  Heated tanks containing coils of tubing are not subject to the statutory seal inspection since heated products are heavy products (heavy fuel-oil, bitumen…).

  Nevertheless, the tubing coils are subject to the pressurization regulations and therefore to periodic requalification. This requalification is carried out upon emptying the container.

  Particular provisions on the inspection interval are given by BSEI No.07-206 recommending the use of the Professional Technical booklet (CTP)« **Specific provisions applicable to heaters of storage tanks** »:

  Thus, periodic requalification may be carried out with an interval ranging up to 20 years, this is possible provided that the CTP conditions are met:

« 1-. The product contained in the tank upon contact with water does not give any chemical reaction likely to compromise either immediately or in the future, the mechanical strength or the integrity of the tank.

The following substances are deemed to meet this condition when all the resistant portions of the tank are in non-austenitic steel:

- *Hydrocarbons originating from refining operations*
- *Sulfonated hydrocarbons*
- *Fluorinated or chlorinated hydrocarbons*

2- The tank is suitably protected against overpressure risks consecutive to clean breakage of an element of the heater.

3- The last test of the heater was carried out at a pressure meeting one of the following conditions:

- *for heaters made under the provisions of the amended decree of April 2nd 1926, it is equal to:*
  - *three times the working pressure if the latter does not exceed 6 bars,*
  - *the working pressure increased by 12 bars if the latter is greater than 6 bars without exceeding 12 bars,*
  - *twice the working pressure if the latter is greater than 12 bars.*
- *For heaters made under the provisions of title 2 of the aforementioned decree of December 13th 1999, it is at least equal to the largest of the following two values:*
  - *2 x PS*
  - *4/3 x PS x 1.25 (ambient f / Ts f) »*

CTP recommends checking the safety devices related to these equipments every 18 months.

Periodic requalification consists of a visual external inspection and of a hydraulic test. The accessories are also checked at the same time.

These heated tanks are therefore opened at most every 20 years. This opening is the opportunity for carrying out an internal inspection of the container.

- **For tanks containing other substances (toxic agents, acids…)**: there is no general regulation applicable to these tanks, at the very least per large type of substances. However prefectural decrees may impose monitoring of these pieces of equipment to the operators. Within the scope of this study, no specific regulation related to a given substance was sought.

2.1.2 PROFESSIONAL GUIDES

Beyond general guides defining the principles of the methods based on criticality and which are detailed in the chapter on pressure equipment (API 580[72], API 581[73]; DT32[36] and DT84[37]), there exist specific professional guides for flammable liquids and they are used in France:

- The **UFIP- 2000**[42] **guide:**"Guide for inspection and maintenance of vertical cylindrical aboveground steel metal tanks of liquid hydrocarbon in a refinery"[42]; This guide is intended for the inspection service (not necessarily recognized) for them to carry out the essential prescriptions relating to the inspection and maintenance of aboveground storage tanks **containing liquid hydrocarbons**. The guide is very different from the Pressure Equipment (PE) guides since it is built on much more practical bases. It is based on the two guides described below (EEUMA 159 and API 653).
- The **EEUMA 159:** "Users guide to the maintenance and inspection of above ground vertical cylindrical steel storage tanks » (1994)"[53]; This guide aims at providing essential prescriptions relating to the inspection and maintenance of aboveground vertical cylindrical storage tanks. The guide is built on practical bases and it may be used without any other reference.
- **API 653** [37]: "Tank inspection, repair, alteration and reconstruction""[76]: This guide is intended for the **specified** inspection service**, authorized** to carry out the essential prescriptions relating to inspection and maintenance of the tanks **built from the API 650 code**. However, it is specified that it may be used for the whole of the construction code. The guide is different from the PE guides (API) since it is built on much more practical bases, in the same vein as the guide UFIP – 2000 presented above.
- **EEUMA 183 guide**: "Guide for the prevention of bottom leakage from vertical cylindrical, steel storage tanks"[54]. This guide deals with the main degradation mode of atmospheric tanks, leaks at the bottom of the container. It is a collection of information and recommendations aiming at improving the integrity of the bottoms of storage containers. This guide is not detailed in the present report.

Reference will be made to the benchmark "refinery storage" for more details on the contents of these texts.

The guides include checklists of check points (both external and internal).

These guides define types of checking operations on these equipemnt:

- **Regular routine inspections** carried out during a round:

	Intervals between the routine inspections
UFIP	**Regularly**
API 653	**1 month**
EEUMA 159	**3 months**

- **Periodic inspections** aiming at monitoring **external effects of corrosion**:

	External monitoring	Thickness checking by ultrasonics (US)
UFIP	**1 to 3 years** (paint condition and foundations of the tank) **2 to 5 years** depending on the history and the nature of the storage (external corrosion condition) – either heated or at room temperature. Comprises monitoring of internal corrosion of visible areas.	Possible checks of roof and shell thickness by the ultrasonic method
API 653	At most every **5 years** if the corrosion rate is unknown. If the corrosion rate is known, this value is modified	Checking thicknesses by ultrasonics may be carried out (optional) If the latter is accomplished, at most every 5 years if the corrosion rate is unknown. If the corrosion rate is known, this value is modified. Max 15 years
EEUMA 159	**3 to 8 years** depending on the nature of the storage (heated storage, crude oil, etc.) Also depends on the climate	Checking thicknesses by ultrasonics may be carried out (optional) May be replaced by an electromagnetic method which is less accurate but covers a larger surface area

- A **check by acoustic emission** allowing determination of the general corrosion condition on the one hand and localization and evaluation of the probability of the presence of leaks on the other hand;

	Intervals between checks
UFIP	Bottom metal sheet check every 0 to 10 years (depending on the earlier stage of active and cracked corrosion)
API 653	No information
EEUMA 159	No information

- An **inside inspection,** its frequency is dependent of the results of the previous steps:

	Intervals between, inspections
UFIP	**A maximum of 20 years** when in presence of tubing coils (depending on the stored product, inspection history, acoustic emission results)
API 653	The frequency depends on the corrosion rate and the thickness of the bottom which have been determined during the last visit of the interior. In the case when the corrosion rate is unknown, the interval between two visits should not exceed **10 years**. The interval should never exceed **20 years** except in the case when a RBI [18] method is set into place
EEUMA 159	The frequency depends on statutory conditions, on the experience of the industrialist, on this type of tank, on operating conditions (product, temperature, climate…) and results of inspection carried out during the last visit of the interior. Guide values: **6 years to 16 years** depending on the nature of the storage (heated storage, crude oil, etc.)

2.2 NOTION OF SERVICE LIFE – MAINTAINING OPERATION

<u>Service life defined upon design: limits</u>

When designing equipment, parameters are involved which have an influence on the service life.

For storage containers, there exist in CODRES or other construction codes, parameters which have a direct influence on the service life of the piece of equipment. The design of the containers is based on different parameters depending on the prime contractor, which influence ageing:

- Construction category: it may be over-estimated in order to increase safety.
- Selections of design loads: predictable operating load, conventional loads (wind) and exceptional loads (earthquake, fire)…
- Safety margins in the calculation: safety factor, material selection, corrosion over-thickness…
- Manufacturing parameters: assembly quality, welding quality, materials, coatings, accepted tolerances…

The version of the code used is also of importance, the codes changing over time with feedback and development of technology.

However, the actual conditions of the equipment may be more or less restrictive, so that the **service life is rarely defined globally** with replacement of the equipment at the end of the initially provided service life.

The operating conditions (start-up or shut-down cycles, pressure/temperature conditions, nature of the substance, external loads (vibrations, winds…), environmental conditions …) have an influence on the service life of the equipment.

[18] *Reference is clearly made in 'API 653 to the RBI and Fitness- For- Service methods (API 580, 581 and 579). The guide prefers these methods for defining the checking operations.*

Checking operations carried out on the storages should allow determination of whether the storage may be maintained in operation or requires repairs.

There are no specific statutory criteria on these aspects except for the global notion of maintaining the mechanical integrity of the tank.

The repairs related to the results of inspections allow the service life of a piece of equipment to be extended. These operations range from simple refilling (an operation consisting of adding metal in the localized corrosion area) in the case of a very localized corrosion point up to complete renewal of a portion of the equipment (i.e. floating roof, lining of the bottom of the container…). However, for the most common degradations, changing the metal sheet represents the most used solution.

Guides may be used for describing the repairs (essentially API 653[76] and EEMUA 159[53]

Methods of Fitness-For-Service may be used for calculating remaining service life and for acting accordingly. The guide mainly used for this purpose is API 579[77].

The whole of these elements justify the use of the notion of remaining service life. The latter represents the duration during which it is possible to maintain the equipment in its entirety. The estimation of the remaining service life should take into account the initial design of the equipment, the conditions of use of the equipment, all the results of the inspections conducted on the equipment and the modifications/repairs made on the equipment.

Correlation between the age of the equipment and the inspection frequencies

Certain of the guides used (API 653[76], EEMUA 159[53]…) establish a link between the intervals between inspections and the remaining service life of the equipment, itself evaluated relatively to the results of previous inspections.

3. EQUIPMENT (PLANT PIPINGS AND TANKS) OTHER THAN PRESSURE EQUIPMENT

3.1 THEORETICAL ASPECTS: APPLICABLE REGULATIONS, STANDARDS AND GUIDES

The equipment (plant tanks and pipings) which does not enter the scope of the decree of December 19th 1999[20] is not subject to monitoring requirements within the scope of the pressure equipment regulation. Those excluded from the scope of the decree of March 15th 2000[19] should be the subject of monitoring but without any specific prescription on the monitoring.

However, the development of risk-based methods leads industrialists applying these methods to setting into place a plan for monitoring equipment, which is then voluntarily subject to monitoring. This equipment is called **equipment subject to voluntary monitoring (ESSV or ESV).** For these pieces of equipment, the operator (the inspection service) defines inspection plans which are then different from the statutory inspection plans. In this case one no longer refers to periodic inspections and/or periodic requalifications but simply to inspection or monitoring plans. The contents are of the responsibility of the operator. No imposition is set as regards the intervals between inspections.

For the sites which do not apply this type of method, these pieces of equipment are not subject to any obligation of monitoring (see note below).

Today there are no set conditions for defining whether a piece of equipment enters or not the field of ESSV.

Note: there does not seem to exist any specific regulation relating to the monitoring of equipment other than pressure equipment, in any case generally, without reference to any given substance. However, industrialists are often confronted with obligations defined in prefectural exploitation decrees (for toxic, corrosive substances.). l

4. ELECTRIC EQUIPEMENT AND SAFETY INSTRUMENTATION

❖ **General case**

There are no statutory requirements for monitoring systems with safety instruments (SIS). However, functional safety standards to be voluntarily applied in France (IEC 61511[8] and IEC 61508[7]) set however good practices for managing them and controlling them.

❖ **Particular case of safety devices mounted on PE**

Within the scope of the PE regulations, the examination and the verification of the safety devices (including pressure switches, associated instrumented systems…) are provided at the same time as periodic inspections and requalifications, at set intervals for the equipment which they protect. The nature of the checking operations to be performed are determined more specifically in the decree BSEI No.06-080 as of – March 2006[20].

There exists a European standard (the standard NF EN 764-7[44]) which gives elements on monitoring safety devices mounted on PE.

In the particular case of LPG, the European standards NF EN 12817[34] and 12819[35] set verifications on certain safety devices for each type of contemplated checking operation (routine inspection, periodic inspection, periodic requalification) but without setting the periodicity thereof. Reference will be made to the benchmark on refinery storages for the list of the operations to be accomplished on the various safety units.

5. SAFETY DEVICES OTHER THAN ELECTRIC ACCESSORIES

Within the scope of PE regulations, the examination and verification of safety devices (including valves, rupture disks) are provided, at the same time as periodic inspections and requalifications, at set intervals for equipment which they protect. The decree BSEI 06-080[20] allows a distinction to be made between the notions of examination and verification required within the scope of periodic inspections and periodic requalifications.

There exists a European standard (the standard NF EN 764-7[44]) which gives elements on the monitoring of safety devices mounted on PE.

For storage containers, there is no regulation but checking the vents belongs to the checklist of inspections to be carried out on containers and is defined in professional guides.

6. CIVIL WORKS

6.1 OVERVIEW OF THE REQUIREMENTS

The retained field of study relates to the 4 following elements:

- containment dikes,
- container foundations,
- pipeline supports (pipe racks);
- liquid networks under foundations: gutters, humid ditches, buried pipes conveying effluents

which are potentially polluted in the manufacturing units (including dry ditches)

Selecting the first 3 is motivated by accidentology. Selecting the last is related to the study of foundations since an uncontrolled leak on one of the networks may cause significant degradation of the foundation.

Covered subjects

- **Equipment monitoring**: no document was identified on any monitoring of civil engineering elements.
- **service life**: no document on any service life of civil engineering elements was identified. The only known duration is the **ten year guarantee** at the moment of building.

  In order to give elements of response, a few pieces of information should be provided on the degradation modes and the techniques for detecting ageing of civil engineering elements.

  - **Retention ponds**:
    - Degradation modes:
      - Cracking (which affects the waterproofness);
      - Erosion of tank dikes (which affects the safety volume);
      - Corrosion of frameworks (in the case of reinforced concrete structures. May affect the mechanical strength).
    - Monitoring technique: essentially visual. There are no criteria on the size of admissible cracks on containment dikes. Nevertheless, work carried out within the scope of monitoring nuclear plants and engineering structures should result in relevant criteria.
    - Monitoring technique: filling closed containment dikes and level monitoring (calculation of the penetration rate). No threshold found.
    - Vulnerable elements for seal inspections: connections between pieces of equipment: shell-disk, pond-disk, pond-drains, pond-bases, pond-pipings.

  - **container foundations**:
    - degradation modes: differential settlement and collapse.
    - Monitoring technique: essentially visual. Differential settlements most of the time induce perturbations at the actual containers. The following should then be verified:
      - the settlement between the centre of the bottom and the shell edges (uniform differential settlement). UFIP criterion. 30%;
      - the differential settlement between two points distant from each other by 10 m. UFIP criterion. 100 mm;
      - the maximum value of the inclination. UFIP criterion: 1/100 of the height.

  - **pipeline supports (pipe racks)**:
    - degradation mode: corrosion. No threshold or technique is indicated in this part. Nevertheless managing corrosion is widely dealt with for all equipment except for civil works. It is possible to considerably build on this.

- **liquid networks under foundations**: this part is not dealt with;

- **other information**: the guide "technical booklet on buried tanks" edited by AFIAP gives elements on the inspection of the civil engineering portions of a tank under slopes: *"The positioning of the tank (..) should be checked by qualified personnel, as often as necessary, without the interval between two successive verifications being longer than 12 months. These verifications give rise to a record".*

  Checks on the positioning of the tanks during periodic inspections and requalifications (and particularly the one carried out during the first inspection) should provide determination of the deformation of the characteristic elements (for example and depending on the case: upper generatrix, meridian, head of the supporting legs, etc..)"

  Comment: these examples are indicative; a priori the operator may freely decide what is to be studied in order to characterize its differential settlement.

  "From these elements, the effective differential settlements have to be established and compared with maximum accepted values during initial stability calculations. During periodic requalification tests, the checking operation should be accomplished before filling with water and then after setting up hydraulic pressure, the tank being full of water."

- **repairs and modifications**: no document was identified on the management of repairs and of modifications of the civil engineering elements.

6.2 REMARKS

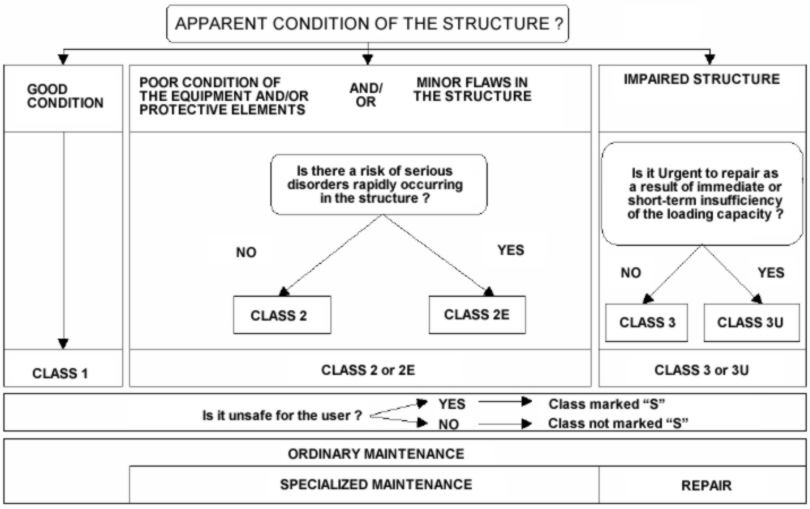
This paragraph groups remarks, notably from experts and/or industrialists encountered during visits on site, or made in the course of the civil engineering WG.

- **An example: the firewalls;**

The firewall, which is a civil engineering unit which is predominant for the safety of warehouses, is subject to extremely clear and circumscribed standards and certifications. On the other hand as regards service life, inspection and maintenance, there is a normative gap. The reports simply indicate that the wall should not undergo modifications.

- **Interesting aspects on monitoring silos, engineering structures (SETRA) and nuclear plants;**

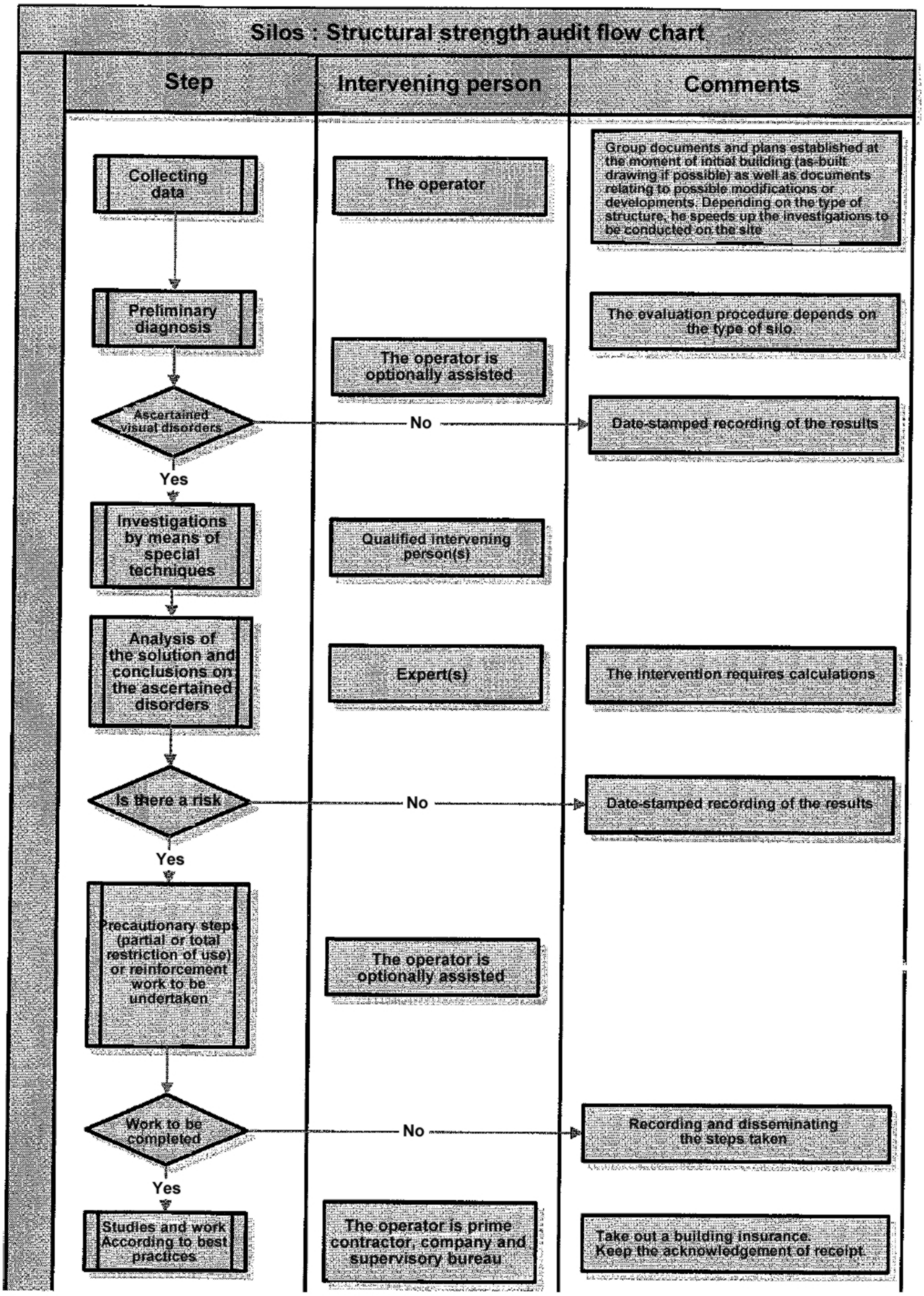
The following summary gives the most interesting elements of three fields, from which a guide on the ageing of civil engineering installations may take inspiration. All the methods retain the principle of classifying structures so as to determine a criticality of the ageing. A classification example adopted by SETRA is shown in the table below:



Moreover, a table of the common points adopted by each of the methods is shown below:

	Storage silos	Civil works (bridges)	Nuclear
Actors	Operators/services HSE	DDE for inspections of first and second levels . Specialized services at the third level	Operator/ASN (who sub-contracts technical parts of the inspection to IRSN)
Periodicity	Yearly visual inspection	Routine yearly visual inspection (first level) Extensive visual inspection every 3 years (second level)	Re-examination of safety requested by ASN every 10 years (with shut-down of the units for 3-4 months). More frequent inspections by EDF
Service life	No « a priori » service life	idem	40 years on basic nuclear plants. 60 years on EPRs.
Training	Two day cycle for the actors	Training for several days for IQOA	No information on operator practices.
REX	Set into place. Accidents referenced by BARPI.	Set into place	Set into place. GP REX / 3 year data collection by IRSN. And REX independently accomplished by EDF. Accidents analyzed by ASN and IRSN

An inspection flow chart for storage silos is shown on the next page.


Silos : Structural strength audit flow chart
Step
Intervening person
Comments
Collecting data
The operator
Group documents and plans established at the moment of initial building (as-built drawing if possible) as well as documents relating to possible modifications or developments. Depending on the type of structure, he speeds up the investigations to be conducted on the site
Preliminary diagnosis
The evaluation procedure depends on the type of silo.
The operator is optionally assisted
Ascertained visual disorders
No
Date-stamped recording of the results
Yes
Investigations by means of special techniques
Qualified intervening person(s)
Analysis of the solution and conclusions on the ascertained disorders
Expert(s)
The intervention requires calculations
Is there a risk
No
Date-stamped recording of the results
Yes
Precautionary steps (partial or total restriction of use) or reinforcement work to be undertaken
The operator is optionally assisted
Work to be completed
No
Recording and disseminating the steps taken
Yes
Studies and work According to best practices
The operator is prime contractor, company and supervisory bureau
Take out a building insurance. Keep the acknowledgement of receipt

ANNEX F

Presentation of practices for controlling ageing in France

7. INTRODUCTION

INERIS conducted during the 1st half of 2009, visits on industrial sites with the purpose of better apprehending good practices and/or difficulties in applying the monitoring of equipment on site.

Fourteen visits were conducted:

- 6 in refineries;
- 2 in a LPG depot;
- 4 on chemical sites (1 site without any SIR[19] and 3 sites with SIR);
- 2 in depots of flammable liquids.

The practices encountered on site are of two types, depending on the nature of the site and on the organization set into place:

- **Establishments with Recognized Inspection Services (SIR)** (such as certain large chemical sites and refineries) apply for the majority of the pieces of equipment, **methods based on criticality** relying on professional guides and different tools (DT 32 and DT84 or RIMAP or relying on API 581);
- **Establishments without any SIR** conduct operations for monitoring the equipment according to regulations in effect. There may either exist an inspection service or not.

This annex presents the practices encountered in the field. For practices relating to refineries (not dealt with in this report), reference will be made to the two reports on refineries.

- DRA-09-102957-08289B - DRA71 – operation A1.2 / DRA73 – operation C2.1: Control of ageing of industrial plants – refinery storage benchmark. The analysis is targeted on two types of storages: LPG storages and atmospheric tanks of flammable substances.
- DVM-09-102957-08343B - DRA71 – operation A1.2 / DRA73 – operation C2.1: Control of ageing of industrial plants – Refinery pipework benchmark.

8. REFINERIES

The reader will refer to both reports on refineries.

9. LPG STORAGE UNITS

❖ **Introduction**

Two visits of sites were conducted within the scope of this study. Both sites are installations having existed for less than 20 years.

The centre head is responsible for monitoring the equipment. **Monitoring of the equipment is carried out according to the regulations with an authorized organization.** The latter at least carries out the statutory checking operations.

REX on both sites does not show any corrosion problems, or any particular concern related to fatigue of the equipment (vibrations of compressors absorbed by flexible hoses) except for possible loosening of flanges resulting from vibrations. No cracking phenomenon was observed.

[19] *RIS = Recognized Inspection Service*

❖ **Monitoring of pipings**

According to the organization of the site, OH draws up the inspection plans for the pipings and determines the check points or is only involved in validating the plans. In the latter case, the plan is defined by the operator and is then validated by OH. Technical services from the registered office then provide support for elaborating these plans. On both of the visit sites, the piping inspection plan specifies the identification of the sensitive points (flanges, valves, rack supports) and monitoring of the valves. It is elaborated on the basis of the experience of persons or according to a method for evaluating failure factors and consequences of a possible failure of the piping, based on the criteria of CODETI. The check points are determined on piping isometric drawings and are then localized on site in order to make sure that the check points are always the same and allow a comparison of the results of successive checking operations.

The whole of the pipings with a diameter above ½'', for which monitoring would not be compulsory, are in the course of being integrated into the inspection plan.

Monitoring of the pipings to this day includes on both sites:

- External visual examination;
- Thickness measurement by ultrasonic techniques;
- Examination of the supports; on one of the sites, it is specified that examination of the concrete supports has not been carried to this day but that visual verification of the concrete and metal portion will be integrated into the revision of the plans.
- Monitoring of the accessories on the line (notably thermal expansion valves; on one of the two sites, the valves are inspected by OH visually every 40 months and are systematically changed every 10 years. They are tested every year by a mechanical lifting test and it is checked that the valves are properly placed);

On at least one of the sites, a round is conducted **every day by an operator for visual inspection** (not formalized) of the visible pipings, for example so as to make sure that the expansion valves are not opened. Painting campaigns take place regularly (the painting of the pipings is redone roughly every 7 to 8 years).

On one of the sites with 6 '' pipings for which ten year requalification is compulsory; the pipings are disassembled for internal inspection.

❖ **Monitoring of the tanks**

The tanks on both sites are of different design (aboveground cylinder, sphere under texsol or tanks under slopes).

Monitoring is provided by the authorized organization, according to the regulations:

- **<u>Periodic inspection</u>**, every 40 months, with **external** visual examination (except for the RST apart from the low portion which is visible after possible removal of sand from the access area) with checking for the absence of impacts or deformation, on-file verification of the safety devices (recording the loading); **the visual internal inspection is not carried out** on the LPG spheres and cylinders for which exemptions are provided, according to regulations. Complementary measurements may be carried out (**thickness measurements** for example);

- **<u>Periodic requalifications,</u>** every 10 years differ depending on the site:
    - o **On one site,**
        - ▪ <u>internal monitoring</u> is not systematically carried out; according to regulations (AFIAP Guide), the hydraulic test is always replaced by <u>acoustic emissions</u> which give the possibility of keeping the sphere full and of detecting possible flaws. Thickness measurements are also carried out. The measurement points

are located on areas which are estimated to be critical, i.e. the bottoms of tanks, the welds, the tappings.

  - external monitoring is only carried out on the visible portions;

- **On the other one,**
  - the tanks undergo a hydraulic test and internal monitoring consisting of visual observations and of thickness measurements by ultrasonics (meshing every meter of the wall of the tank and 10% of the welds, tappings, stiffeners, nodes,…) and magnetoscopic inspection of certain welds.
  - sand removal is carried out in order to visually check the aspect of the passive coating. Peeling tests and thickness measurements have already been carried out.

The requalifications also include the verification of the safety devices, which is generally expressed by changing the valves for the small tanks and reloading for the large tanks; also the safety equipment such as bottom valves are systematically replaced on requalifications conducted on both visited sites. On one of the sites it is also proceeded with systematic replacement of pressure switches, thermostats….mounted on the tanks at the periodic requalification.

- **Monitoring of the safety systems and service life**

Monitoring of the safety systems mounted on the tanks is partly related to that of the pressurized tanks: as seen earlier, examinations of the valves, replacement of bottom valves of tanks… are in-line with the periodic inspections and requalifications. However operating tests take place at frequent periods with view to checking proper operation of these safety systems (for the tanks and the other portions of the installations).

Systems with safety instruments are thus the regular subject of operation tests from the sensor up to the actuator. These tests are conducted either by the site personnel (gaugers once a year, gas detectors operate every 3 or 6 months) or by the suppliers (gas and flame detections – every 6 months or once a year for recalibration). On one site, the retained approach is to entirely test the first detector (including its servo-control); the following detectors are tested by disabling the servo-control. The last detector is tested with the re-enabled servo-control. Motorized valves are themselves tested every 6 months to 1 year. The waiting periods between tests come from recommendations of the operator, moreover consistent with the instructions of the manufacturers. However, it is noted that the tests for which the processing operations are redundant (relaying and automation) do not systematically give the possibility of being sure that both chains are operating. On one of the sites, all the chains are not tested (for example the servo-controls of pressure switches and of thermostats are not tested).

The tanks under slopes are equipped with cathodic protection, by an imposed current, dimensioned for more than 30 years. **Cathodic protection is checked every month** by the operator. The data are reported and accessible in premises adjacent to the offices. The result of the check is sent to the specialized company which will also itself provide **yearly checking** of cathodic protection by means of a reference electrode.

The transfer arms are subject to yearly inspection (rotating joint, grounding connections, flip-flap with systematic replacement of the pins). On one site, the valve is disassembled by the supplier once a year.

The automaton (Siemens) is managed by an external company; yearly checking operations are performed. In the case of modifications of the logic, a complete test is carried out by the site personnel.

The fire-pump units are subject to starting-up tests weekly or every fortnight; every 6 months for two days, the manufacturer ensures maintenance and carries out a set of tests in order to make sure that the unit remains within its operating parameters. Every month, the fire network is tested (for example through POI exercises). On one site, it is checked that a yearly check of non-plugging of the nozzles is carried out.

For safety equipment, global **service lifes** are retained on one site for the DG (5 years, according to the recommendation of the manufacturer). For equipment (pressure switch, thermostat, valves, check valves…) with which the tanks are equipped, changing or revising is carried out at each requalification, thereby limiting their service life to 10 years. For the other pieces of equipment, there is no defined service life. The equipment is regularly changed preventively. The question of obsolescence is therefore not posed.

❖ Monitoring of civil works and structures

Settlement of the tanks is monitored (surveys are carried out annually by a surveyor in different reference points of the spheres under Texsol, which allow verification of the stability relatively to the ground and relatively to the bearing concrete structure; or on the other site followed by a mark welded on the tank and jutting out from the slope).

Monitoring of the foundations supporting the pipings is carried out visually on one site. On the other one, provision is made for integrating the monitoring on the concrete supports of the racks and the metal portion into the future inspection plans.

❖ Service life – Acceptability conditions for maintaining operation

After the inspections, the **question is posed on the acceptability of the measurements and under which conditions a piece of equipment may be maintained operating safely or requires repairs.**

On both sites, the organization carrying out the inspections draws up inspection reports on which appear the measured thickness values (comparison with setback thicknesses), the condition evaluated after visual examination (welds and pipings), the condition of the supports and accessories. They finally conclude on the acceptability of the piece of equipment and possibly give recommendations (repainting of corroded portions.).

The acceptability rules relate to **thickness measurements**. There are not any other identified degradation modes justifying other criteria.

The criteria on thickness are the following:

- **For pipings**, a minimum thickness is required (setback thickness), according to the position (tubes, Ts, reduction of bends) and the piping diameter. When the measurement reaches this value, either complementary checking operations are carried out, or replacement of the piping is decided; in practice, this value has never been reached and the conducted thickness measurements are very stable. The minimum required thickness is above the critical design value in order to be sure that no failure will occur. An alert thickness is already defined above the setback value in one of the visited sites but is being investigated on the other sites. As the thickness measurements are very stable, no calculation of corrosion rates has been carried out for the time being. The time until the next shut-down (requalification) is therefore not explicitly taken into account. The thickness is defined on the basis of calculation codes (CODETI), with possible adaptation to the site (guide tables with more penalties established by the group).
- **For the tanks**, the notion of limiting thickness is identical. However, the site is not aware of the limiting value. It is a datum known to the OH, stemming from calculation notes of the manufacturers: if this value is reached, action is performed.

It is specified on one site that the possible presence of **pits** gives rise to a complementary investigation on behalf of the authorized organization. However the presence is not estimated to be critical. Piercing will actually lead to a leak of very small diameter, easily identifiable (noise) and having a low aggression potential.

❖ **REX**

For one of the sites, organizing the feedback from the group is managed through a tool called « RAMSES », shared with the whole of the sites of the group. The gas sector is the first investigator of the tool for the group.

On the other one, there is no computer tool but life sheets with which it is possible to go back to possible faults. There is centralization for the centers of the group (at least for the safety systems).

❖ **Traceability of the information**

The results of the statutory inspections are recorded in files.

Further on one site there are «computerized» life sheets on the pieces of equipment on which appear the whole of the operations which have been carried out (repairs, tests, maintenance, replacement…). On the other site, these sheets do not exist.

❖ **Link between EDD and inspection plans**

There is no strong link between the persons carrying out EDD and those carrying out the inspection plans.

❖ **Follow-up of the actions**

After the checking operations carried out by OH, the center head or deputy head assesses the recommendations which thereby define a **Plan of corrective actions**. This plan of corrective actions is the subject of internal audits between sites and with the management of the operations.

The produced action tables are then dispatched:

- to the companies for work;
- to the painting companies for « painting » actions.

When the action has been performed, there is closure of the associated action sheet by the centre head.

A computer system « GMAO » allows the operator on the site to view the whole of the work to be done.

4. CHEMICAL SITES WITHOUT ANY RIS

❖ **Introduction**

The visited site is a chemical site with less than 100 persons, with an HSE service, a maintenance service, the responsible person of which is in charge of monitoring the equipment and is well acquainted with the site (more than 10 years of experience on the site). This is not a site with a recognized inspection service (RIS). A QEHS manager is present on the site and works in collaboration with maintenance. **The site is responsible for controlling the equipment.** Upon reception, the site performs a visual examination and makes sure by consulting the **manufacturer file** that the hydraulic tests have been carried out at the manufacturer. A guarantor for the monitoring is present on the site (head of maintenance).

Corrosion is not a problem on the site, insofar that the products do not have any corrosiveness. Corrosion only comes from ambient air and no concern has been encountered up to this day.

Accidentology is indeed linked with **fatigue phenomena**. Leak problems have been encountered (pits on welds and poorly tightened flanges) originating from a poor initial weld or poor supporting of the pipings. In this case, maintenance operations are conducted.

- **Monitoring of the pipings (not subject to the pressure regulations) and of pressure equipment**

The inspections of the equipment and their periodicity are defined by the **guarantor of the follow-up** and essentially on **the basis of the regulations** (national regulation and prefectural decrees) and of the **Return of Experience (feedback)** (REX) of the site. The elements taken into account in establishing the inspection plans are:

- The REX (results of the inspections) which allows the periodicity of the tests and of the inspections to be adapted;
- Production necessities (for example the equipment inspections on the single gas boiler are carried out yearly in order to guarantee continuous and reliable operation over the year)

The inspection and maintenance actions are subject to a **consensus between production, safety and maintenance**. Audits of the group (corporate audit) are carried out every three years. They are sometimes more demanding than French regulations.

The inspections for a great part are **sub-contracted to an authorized organization.** The latter **defines the preferential degradation areas** on which the inspections will be made as well as the nature and the periodicity of the inspections.

The group is studying the **application of a software package RBMI**[20][21] (risk-based maintenance and inspection) for the inspection plans. The software will soon be imposed to the sites. It will define:

- The critical products and pieces of equipment;
- The inspections and maintenance operations which will have to be carried out on these pieces of equipment.

- **Monitoring the systems equipped with safety instruments**

For SISes, a functional test of the complete chain (sensor, automaton, actuator) is carried out every year by the personnel of the site.

Corrective maintenance of the automaton dedicated to safety is carried out by an automation specialist of the site with a supply of spare parts (I/O cards, Profibus communications card).

In the case of modifications in the process, the repercussions also concern the possible update of the software of the automata dedicated to safety.

The diesel engines of the fire network are tested every week, by the personnel of the site.

The rupture disks of the reactors are also sensitive pieces of equipment, they tend to open at an untimely moment in the case of **ageing**. Preventive inspections of their degradation are carried out every year (visual examination and electric resistance test). Depending on the results, the inspections may be spaced out, while being aware that corporate audits recommend inspections at least every 3 years.

- **Monitoring of civil works and of structures**

The **containment dikes** are checked by the EHS service once a year (absence of cracks at the bottom and on the walls) by checking that there is no loss of level in the case of partial filling. **The other civil engineering elements (concrete foundation supporting the structure of the racks, the racks…) are not inspected.** It should be noted that the nature of the rack (hot galvanized rack) limits possible degradations.

[20] HSE: Hygiene, Safety, Environment

[21] *RBMI = Risk Based Maintenance and Inspection*

❖ Service life – Acceptability conditions for maintaining operation

After the inspection, the **question is posed of the acceptability of the measurements and under which conditions a piece of equipment may be maintained operating safely or requires repairs.**

The site does not have internal means today for deciding on the maintaining of a piece of equipment in operation. **It relies on the recommendations of the authorized organization,** but the information provided by OH has potential risks, but, according to the opinion of the site, however remains rather vague; OH is not committed to maintaining the piece of equipment; the decision lies within the responsibility of the sites. In particular, in the absence of regulations, OH does not provide any technical support.

There is no predefined service life. The service lifes in certain cases depend on the equipment and it is the quality of the equipment which conditions a « potentially » long service life or not. For example, the valves are selected to be in stainless steel so as not to be subject to ageing. The service life of the gasket was extended to using graphite gaskets (5 years).

For the pieces of equipment, as seen earlier, the results of the inspections lead to decisions as to maintaining some pieces of equipment operational and they are not guided by the use of guides.

❖ REX

The REX is a primordial element in revising inspection plans. **But the traceability of the results does not always provide satisfaction,** insofar that the information reported in the SAP tool most often is lacking in specifications as to the condition of the equipment and the inspections carried out. The return is more verbal than written, which is detrimental to proper taking into account of REX.

But the REX extends beyond the site: exchanges take place between the sites of the group. Sometimes, the manufacturers also provide a REX. When maintenance contracts exist with the suppliers, it is easier to have a REX on the equipment via the manufacturer.

❖ Follow-up of the actions

Maintenance is managed by SAP: the maintenance head defines the interventions (SAP generates intervention slips and the results of the inspections are then archived on a specific document and traced).

❖ The link between EDD and inspection plans – Links between services – management of change

The actions of inspections and maintenance are subject to a **consensus between production, safety and maintenance**. The interests of the various intervening persons are not always the same, but a consensus is found: maintenance tends to increase the period for inspections, but the production prefers for questions of reliability of production that the preventive checking operations remain frequent.

Regular exchanges take place between production maintenance and logistics.

Safety reviews are organized in the case of a change in the process and/or the equipment. A check-list of the points to be studied exists depending on the intended changes. Various aspects are analyzed (ATEX, ergonomics, regulations…). The repercussions also concern possible update of the software of the automata dedicated to safety.

❖ Competence of the persons – Sub-contracting

There is no «formalized» competence level according to any reference system, but the persons of the site which are involved (in maintenance for example) are deemed to be competent because of their experience. The maintenance service consists of 5 persons each having a specialization (instrumentation, boiler work.).

When maintenance and monitoring operations are sub-contracted, **the sub-contracting person is systematically followed** (at the beginning of the operations at the very least) by a person of the site. The sub-contractors are known to the site but there is no sharing among the different sites, because the sub-contractors are generally local.

Non-destructive tests are conducted by the OH. For metrology, a COFRAC certificate is required. For welds, the site examines the authorizations of the welders and whether they are specifically qualified for welds on steel and/or stainless steel (authorizations delivered by APAVE and the "Institute de Soudure").

5. CHEMICAL SITES WITH SIR

❖ **REX**

« Process » safety

Real approaches for managing REX are beginning to be set into place but they remain still more or less well formalized. These approaches assume strong involvement of the personnel in order to get back to the information which may be exploited for REX. The teachings are transmitted in the internal « group » but they are also shared externally, for example with professional federations or the administration. Beyond the collecting of information, the main difficulty nevertheless lies in setting up and efficiently tracking the preventive/corrective actions which result therefrom.

« Equipment » safety

The events are declared to the « pressure » DRIRE with observance of the reference classification (A, B, C, D1, D2). The sheets are filled in both for regulated equipment (PE) and those « voluntarily subjected » (ESSV). The declared events are generally classified as D1.

Exchanges also take place at UIC and UFIP notably via the National Technical Committee of Chemical Industries. Less formal exchanges also take place with authorized organizations (mainly APAVE but also IS and BV).

The GEMER Base managed by IFP is also a source of REX. A day for exchanges is organized once every 2 years. The base presents case studies. To this day, about a hundred sheets have been entered into the base. Filters on the title give the possibility of accessing accidents/incidence concerning the site.

❖ **Equipment monitored by the RIS**

The pieces of equipment targeted by the inspection plans are:

- PE pipings and tanks;
- ESSV pipings and tanks.

There is no plan for monitoring all the pipework. The PE and ESSV are monitored in the same way by the RIS. Monitoring includes that of all the safety devices (valves, rupture disks, instrumentation). The definition criteria of the ESSV are internal to the groups, or even to the sites. They are generally based on

- High seriousness or criticality;
- Production availability;
- A particular regulation (for example prefectural decrees impose monitoring of storages of flammable materials);
- Image of the company in the case of a loss of containment (for example, loss of containment on piping crossing the channel);
- Equipment specificities (plastic equipment, heated equipment, etc.).

As regards civil works, the foundations are not always monitored formally and systematically. The same applies to supports of pipings and anchorings. The checking operations very often consist in visual surveys (index, displacement of skids).

❖ **Inspection plans**

The inspection plans are established on the basis of a 5/10 year periodicity. There is no intention to switch to 6/12 years which requires more cumbersome analysis. The inspection plans are generally managed in SAP.

Definition of the inspection plan (IP)

The inspection plans are defined on the basis of a methodology for determining criticality. Criticality is calculated by producing the sum or the product of a seriousness factor and of a failure probability factor. The criteria are generally established according to DT 32 with adaptations:

- Seriousness criteria: fluids and products which are present, possibilities of isolation and rapid emptying, implantation, effects induced on the environment.
- Probability criteria: degradation modes and rate, external conditions, occasional presence in the product, design & construction, stability of the operating parameters, relevance of the inspection actions, efficiency of the maintenance operation, mechanical stresses, period of use…

The results of the « EDD » risk analyses are not always taken into account but in any case this is being considered.

The inspection plans are either defined or not by an iso-degradation loop. Each plan generally comprises:

- The reminder of the characteristics of the functional location (fluid group, equipment reference, criticality, material, design and construction parameters, etc.);
- The nature and the periodicity of the inspections (inspections during operation, IP, RP);
- The possible LCOC for specific pieces of equipment, for which the influence of the process parameters on the degradation mechanisms are well-known;
- The REX (history of the observations, modifications and interventions).

The periodicities of the inspections are determined on the basis of risk and of REX. The nature and the extent of the inspections are defined from identified degradation modes, which notably depend on the materials, the process/installation parameters and on the applied fluids. The check points are identified on equipment diagrams showing the rated minimum thicknesses and calculated thicknesses for each sub-assembly as well as sometimes directly on the equipment. These points are established by expertise and REX.

The IP and the RP are carried out during the scheduled shut-downs of the units. The periodicities of the shut-downs depend on the exploitation constraints and are therefore very variable considering the multiplicity of encountered situations.

Revision

The inspection plans will generally be revised on the occasion of methodological developments or a modification of equipment and/or processes. Modifications of equipment and of processes before implementation are subject to an approach of systematic analysis and preliminary approval in order to study its impact on safety, environment and hygiene. A specific procedure exists for managing changes.

Applying the periodic inspections (PIs)

Inspections during operation (NDT + visual examination) and periodic inspections may be carried out by the RIS or by the EE. The periodic requalifications (visit + test) are carried out by an Authorized Organization.

The Fitness-For-Service methods are only very rarely used. Even if they give the possibility of avoiding hydraulic tests, acoustic emissions are not used much since their application is expensive.

The LCOC (Limiting Critical Operating Conditions) are monitored by the operator. If defined thresholds are exceeded (normally not attained, since alarms are emitted before reaching the critical threshold for acting and preventing the critical threshold from being attained), the operator should warn the RIS about this.

The minimum thicknesses are determined from calculation notes (CODAP, CODETI) and the degradation rates are determined from the results of NDT. The measured thickness is compared with calculated thicknesses, by assuming the rate with the highest penalty. Residual service lifes are generally not calculated. In the case of time-dependent changes in the degradation rate, a link is made with the operator in order to search for the causes and to carry out the required corrections.

Corrective maintenance actions

Corrective actions may be requested by:

- Technical inspections;
- DRIRE inspections;
- External and internal audits.

Generally, the actions are generally requested as a result of a visual observation during operation. The orders for having the maintenance services intervene are classified by priority. Priority is given to the HSE constraints.

Sometimes, if the inspections reveal faults, continuation of the operation may be decided, without any immediate action, if this has no risk. One then switches to degraded operation subject to most particular monitoring by the operator and the RIS.

❖ **Managing competences**

The RISes are generally under the responsibility of an experienced person from manufacturing and/or maintenance. The inspectors are generally approved UIC level 2.

All the Non-Destructive Testing (NDT) procedures are entrusted to authorized COFREND personnel (level 2 is generally required). The same applies to maintenance actions (qualification of the welders, etc.).

External providers and inspection organizations are regularly assessed, or even audited.

Highly applied research is carried out within « corrosion » laboratories on the degradation mechanisms and persons (technical experts) are appointed for contributing and organizing networks (technical inspection, materials-corrosion, etc.).

- **Systems with safety instruments**

The MMRI or IIPS most often form a small part of safety loops of defined installations. The reliability levels (NC or SIL) do not generally exceed level 2. The SIL approach tends to be generalized but all the industrialists have not engaged it.

The tests for periodic verification of the MMR safety loops are generally planned and achieved by qualified personnel from « method/electricity/instrumentation » services. The periodicity is rather variable depending on the activities. On continuous processes, the deadlines are conditioned with unit shut-downs.

The tests for operating the loops are generally incomplete tests in the sense that they do not allow detection of all the possible hazardous faults. All the functionalities are not tested (alarms, response time, behaviors upon failure, etc.) and the tests often exclude the « detection » part because of the impossibility of being actuated by the process. The detectors are nevertheless periodically tested in the workshop.

If the tests concern accessories which are important for safety, associated with PE, the test reports are then transmitted to the RIS (if necessary).

The « Fire&Gas » systems are most of the time under a « supplier » care and maintenance contract.

Under certain circumstances limited to a bare minimum, for purposes of exploitation or maintenance, a safety device has to be disabled. Setting up a shunt generally requires a stamp from the operator and from the intervening person upon launching the operation and then when acknowledging return to the normal situation.

In order to optimize the reliability of the electronics and to increase the service life, the automata and the electronic portions of the SIS are grouped in buildings with controlled temperature (heating & air-conditioning). The replacement of a safety automaton is most often dictated by the impossibility of finding parts for ensuring maintenance (no longer produced by the manufacturer). Ordinary spare parts are generally available in the store (sensors, power supplies, I/O cards, etc.). The selection of replacement components deals with « SIL » equipment and equipment « tested by use » defined on the basis of feedback which is often informal.

Not many industrialists have engaged a real approach to feedback. The large industrial groups nevertheless generally have an internal database partly fed with data up-flows from their different sites.

Rotating equipment is generally monitored by the maintenance service within the scope of a preventive maintenance plan (greasing, sealant liquid level of mechanical fittings, etc.). Vibratory verification tests are carried out on the most hazardous equipment (high power pumps, alternating compressors, etc.). Many pumps are centrifugal pumps and therefore do not generate significant vibrations.

If rotating equipment (motors, pumps, compressors, fans, etc.) has to be reconditioned or repaired, the pieces of equipment are removed and sent to the workshop. External companies and/or their operators have an ISMATEX and/or SAQRATEX certificate. Otherwise, the fire-pump units are subject to many operating tests.

6. DEPOTS OF FLAMMABLE LIQUID

- **Introduction**

The sites visited by INERIS are of two types:

- a small size hydrocarbon depot, administering about thirty containers, employing about thirty persons;
- a consequent hydrocarbon depot, managing more than about a hundred containers, receiving more than two hundred employees.

The main difference between the sites is organizational.

The number of employees and the extent of most consequent monitoring on the site promotes the setting into place of high internal skills related to inspection and maintenance. The « Equipment » service carries out inspections, maintenance as well as management and follow-up of changes. However there is no dedicated « inspection » service.

On the contrary, the management of the site where the number of employees is restricted is logically oriented towards outsourcing of competences.

❖ **Rex - accidentology**

- Accidentology

No major incident/accident has been reported on any of the two sites since their creation.

- Internal REX (upward communication)

With the internal organization, it is possible to go back to all the striking facts and to problems having occurred in the depot via the following means:

- Reports on non-compliance, requests for preventive and/or corrective actions,
- Weakly meetings gathering the manager of the depot, the different managers and group leaders
- Freedom of expression given to the whole of the personnel during the days of yearly HSSQE training
- CHSCT
- Local dialog is particularly important in the life of the depot

The reported incidents/quasi-accidents are analyzed and the preventive and/or corrected actions to be applied are followed. The whole of the follow-up of the incidents is subject to a procedure.

Each site establishes a quarterly report to its group. Moreover, « safety alerts » may also be transmitted up to the « Group » QHSE manager.

- External REX (downward communication)

The external REX is fed by:

- The ARIA base of BARPI
- Data from the group (quarterly report summarizing the internal REX to the sites and the external REX)
- The « on line » base of the group which gathers the notable accidents and incidents of the group
- A participation in certain work groups;
- Returns from clients

The transmission of the REX is accomplished by posting, training, via the HSSQE days and the meetings of the CHSCT.

The yearly HSSQE training is training distributed over 3 daily sessions with the purpose of exploring the important themes of the year (ADR, ATEX, POI, EPI, Environment, SGS, etc.). This day of training also allows exchanges between the personnel and the management on all the subjects which are dealt with (freedom of expression). A written answer to the comments made is provided.

- **Management of the competences and of the intervening persons**

External companies attend yearly training on safety and are regularly informed on modifications carried out on the site (direction of traffic, extension, etc.). The training program integrates personnel from external companies and temporary personnel (interim period, fixed-term contracts, traineeships). Moreover guild periods are set into place.

Depending on the group, a critical list of sub-contractors may be defined by the type of activities.

MASE certification is imposed to external companies. These companies are in the process of changing their baseline system (UIC to MASE). Competence certificates of the intervening persons are also required depending on the nature of the interventions (UIC, GIES, ISMATEX, SAQRATEX, etc.).

- **Monitoring the equipment**

All the pieces of equipment are monitored by specialists* via a Computer-aided Maintenance Management Software Package(GMAO) (tanks, pipings, mechanical & electrical apparatuses, EIPS). The GMAO is used for:

- Planning and following-up inspection and maintenance actions
- Managing inventories and supplies

Designated specialists (vehicle maintenance, fire, plumbing equipment, etc.) ensure monitoring of the pool of equipment in their field of specialization (programming & carrying out checking operations, recordings, etc.). This specialist function is described in the job description sheet of the relevant personnel.

A weekly team meeting discusses all the incidents of the week. The abnormalities detected during daily interventions are reported by the operators in a logbook.

Compliance-bringing actions are regularly transmitted to the DRIRE by the head of operations.

  - **ATEX equipment**

A register is held for the pool of electric pieces of equipment. The list is used by inspection organizations which ensure monitoring by contract.

For mechanical equipment and in particular pumps, the list does not exist. Their revision is entrusted to specialized corporations (KSB, etc.) which are certified ISMATEX/SAQRATEX. Certain interventions may be accomplished by the workshop of the site (for example changing of linings) but they remain limited.

Mechanical equipment is the subject of preventive maintenance (all valve types, pumps, valves, container bottom flap-valves, etc). Vibratory testing operations are not or not very used since the equipment does operate continuously.

  - **Systems with safety instruments**

New safety reports integrate the definition of MMR. The EIPS have been redefined in order to have them coincide with MMR (a procedure for managing MMR). All in all, there are about ten EIPS or MMRs which have been defined. Among these EIPS, functions are found with the following NC1 or NC2 safety instruments:

- **High level detection function** accomplished by VEGA radar level measurements, a safety automaton and valves at the container bottom: the calibrations of the radar levels are carried out annually by means of a measuring rod. The safety chain is tested every month, except for the detector which is forced. The radar level measurement instruments are also used for evaluating the loading rates (WHESSOE level measurement instruments are normally used for the control but this is not always the case). The separation principle of control/safety is therefore not always observed.

- **Gas detection function** accomplished by IR optical detectors (DRAGER). The detectors are subject to internal verifications and to several calibrations per year (supplier maintenance contract).

  - **Storage containers**

The containers are of the type with a fixed roof, a floating roof or further with a fixed roof with an internal floating screen. They are made in carbon steel or stainless steel. Some of the containers may be equipped with an inerting kit or further be thermally insulated and heated.

Each site has a procedure for inspecting the containers. Monitoring of the condition of the containers is of the responsibility of the head of operations. The inspections are carried out according to a monthly, yearly or ten-year periodicity.

<u>Monthly inspections</u> are visual and are focused on the outside of the container. They have the purpose of checking the general good condition (foundation, shell, roof, railing) as well as that of associated accessories (valves, pipings, pumps, vents, instrumentation, etc.). These inspections are carried out by experienced operators.

<u>Yearly inspections</u> are carried out by qualified (external or internal) inspectors and consist in a complete verification of the outside of the containers. On the small size site, inspection of corrosion by the head of operations and/or the maintenance manager accompanied by a painting company is also conducted yearly. This inspection gives the possibility of scheduling paint work for the following year (pipings, racks, tanks, etc.).

<u>Ten year inspections</u> consist in a detailed examination (hydraulic test, checking the welds of the bottom marginal metal sheet, magnetoscopic scan of the bottom metal sheets, thickness measurements by ultrasonics, screen gaskets, rod tubes, etc.) of the outside and inside of the containers having been emptied, cleaned and degassed beforehand. These inspections are carried out by the manufacturer of the container or by an external corporation. On the large size site, a member of the equipment service leads the operations. On this occasion, the accessories (foot valves, pumps, valves, etc.) may be subject to revision.

<u>An inside and outside visual inspection</u> is also systematically carried out upon changing the allotment of the containers.

Generally, the discovery of an abnormality causes scheduling of the repair. In certain cases, on the most consequent site, the inspector may resort to the company having designed the containers in order to specify a diagnosis. In this case, advanced calculations may be applied for maintaining the container in operation under controlled safety conditions (Fitness For Service).

No testing by acoustic emission is made for postponing the ten year visit on the sites of visited depots.

  - **Pipelines**

All the pipings are listed and characterized.

Monitoring of the pipelines is subject to a specific procedure. A distinction is made between:

- multi-purpose pipings being subject to particular care as regards traceability of the conveyed products,
- dedicated and scraped pipings conveying sensitive products (acetic acid and vinyl acetate)
- dedicated pipings without any specificity

The pipings are subject to the following periodic inspections:

- Visual examination
- Hydraulic test
- Thickness measurements.

The periodicity of these inspections depends on the type of piping (factory, transport, PE).

Visual inspections aim at detecting the degradation mechanisms (corrosion, deformation, cracking, etc.). These inspections deal with:

- Bolted assemblies
- Connected accessories (valves, flap-valves, instrumentation, etc.), flap-valves being subject to specific monitoring
- Thermally insulated portions
- Supports

With hydraulic tests a test of the waterproofness may be conducted.

The thickness measurements are carried out by ultrasonics according to diagrams identifying the check points (straight portion, bend, reduction, « T-shaped » parts).

Additional inspections « on demand » may also be carried out (NDT, visual examinations or specific seal inspections).

The interventions (repairs – modifications) on pipings not subject to the PE regulations have to be performed with observance of the CODETI requirements with an intervention file being provided. In the case of a change in the exploitation conditions, the procedure for managing SGS modifications is applied.

The interventions on the subjected pipings are subject to a checking operation after their carrying out by the authorized organization on the basis of an intervention file (description of the intervention, calculation results, test reports, welding booklet, material certificates).

On the large size site, the inspections are given priority by a risk analysis (frequency and seriousness) related to environmental impacts. The most sensitive pipings are subject to yearly inspection while the whole of the pipings is inspected with a maximum frequency of 10 years.

Generally, the depots do not have any or only very few PE pipelines subject to the decree of March 15th 2000.

❖ Management of change

A procedure for managing changes in the installations or processes was set into place. Any modification is the subject of detailed analysis before it is carried out. In the case of a change in allotment of a container, the administrative authorities are informed about this (DRIRE, prefecture).

❖ Civil works

The waterproofness of the pans was brought back to compliance. The pans and the racks are systematically checked during visits of tanks and of pipings but this is not necessarily specified in the corresponding procedures.

❖ Conclusion

The absence of a dedicated inspection service on the petroleum depot sites generates strict observance of the regulations without any particular « exemption » (ten year opening).

If the setting up into place of well defined inspection procedures is recent, the main problem remains the lack of competent personnel, notably on small size sites. The time dedicated to monitoring assumes an increasingly large share in maintenance and management services. Outsourcing of the monitoring actions requires a cumbersome approach in terms of validation of the competences.

There is no RBI approach set into place. The largest sites however introduce simple risk analyses with which the monitoring actions may be prioritized.

As regards monitoring of atmospheric containers, it is noted that generally the quality requested by the client and the rotation of the products generate several positive effects on the depots:

- Frequent opening of atmospheric containers;
- Tracking down corrosion for economical reasons;
- Frequent emptying involving a reduction in the amount of stagnant waters.

ANNEX G

Presentation of the regulations and of the professional guides in the United Kingdom

1. GENERAL REGULATIONS

The basic document governing the regulations on Health and Safety is the Health and Safety at Work Act 1974 (HSAWA[45]). It is applicable to any type of installations.

This document establishes the responsibility of the employer towards his employees and towards the general public, but also the responsibility of the employees towards themselves. The regulations are established as goals. It introduces the concept of « so far as reasonably practicable ». **Among the obligations of the employer, is found the one relating to maintenance of the installations in order to guarantee the upkeep of safe installations.**

In the case of developments (changes in technologies, accidentology, European Directives) requiring adaptations in the requirements, the Health and Safety Executive (HSE) (in collaboration with the Health and Safety Commission- HSC) has three tools available:

- **<u>The regulations</u>** (« Regulations »): these are laws voted by Parliament. They generally follow from the Health and Safety at Work etc Act 1974, on proposal from the Health and Safety Commission. They are often the transposition of European Directives. They are most often drawn up in the form of goals.
- **<u>The « Approved Code of Practice »</u>**: also published by the HSE, they provide practical examples providing explanation of the terms used in the regulations. These codes have a legal status;
- **<u>The guides (« guidances »)</u>**: published by the HSE, they have authority to interpret the laws by integrating examples of application and by giving technical advice. Following them is not compulsory, but observing these guides is a guarantee for compliance with the law. These guides are updated if need be.

Generally, with each « Regulation » is attached an « Approved Code of Practice » including a « Guidance » section.

Thus there exist various regulations, of a general nature, originating from European Directives but which are also attached to the Health and Safety at Work Act 1974. These regulations include requirements relating to the monitoring of equipment but these requirements remain very general (need to carry out inspections, by competent personnel (with a meaning given to « competent » which is variable depending on the regulations), at frequencies often related to the criticality of the equipment.

The general texts are the following:

- Control of Major Accident Hazards Regulations 1999[46] (COMAH): this text, subsequently amended in 2005, implement the Seveso Directive 96/82/EC. It is therefore only applicable to Seveso installations, but does not include any specificity per type of equipment. Their aim is to prevent major accidents involving dangerous substances and limit the consequences to people and the environment of any accidents which do occur.For plants handling or storing dangerous substances, they are required to inform the competent authorities, as well as draw up safety reports and emergency plans. Requirements are also established in terms of informing the general public. The COMAH imposes that the operators take all required measures for preventing any major accident and to limit the consequences thereof. The competent authorities with regard to this regulation are the Health and Safety Executive (HSE) and the Environment Agency (EA); they regularly carry out visits (inspections) in order to make sure that the provided measures are applied. **The COMAH includes a few requirements as to maintaining the integrity and monitoring of the installations**:

- The safety management system (SMS) should specify in procedures the organization in place and who are the persons responsible on the site for monitoring the equipment (inspection, maintenance), and their competence…The operator should provide training of the personnel allowing them to keep their skills (article 439 of L111).
- The safety report should take into consideration the physical integrity of the equipment at all stages of the life of the installation, which includes the justification of maintenance programs (frequency and nature) and of provisions taken for «periodic examinations » and the evaluation of the critical systems and the competence of the personnel (article 467 of L111).

- **Management of Health and Safety at Work Regulations 1999 (MHSWR[47])**: this text follows from the European Directive 89/391/EC. It requires that the employers conduct an evaluation or risks and employ competent persons, benefiting from suitable training. It does not include any section relating to following up the maintenance of integrity of the installations.
- **Provision and Use of Work Equipment Regulations 1998 (PUWER[49])[22]**: this text requires that **any piece of equipment** used at work, **be secured, maintained and inspected in order to make sure that it keeps operating safely.** The person defining and/or carrying out inspections should be **competent** (this may be an employee with the required competence) and should thereby have sufficient knowledge and experience. A distinction is made between the required competence for elaborating the inspection program and that for carrying out the inspections (lesser requirements in this case). The recording of the inspection should be kept until the next inspection. For equipment potentially subject to degradations which may cause hazardous situations, the employer should ensure **inspections at suitable intervals (dependent on the risk**) and set into place possible corrective measures (Regulation 6). The ACOP specifies that the extent of the inspection depends on potential risks. The inspection may include visual examinations, functional tests and tests. If necessary it may lead to partial disassemblies. It is noted that the goal of the inspection is to find out whether a piece of equipment may be maintained in safe operation and whether all the degradations may be detected and dealt with (article 57). Specific regulations may complete the requirements (for example the regulation of pressure equipment). This text is applicable to any type of equipment (storage containers…).
- **Pressure Systems Safety – Regulations 2000 (PSSR 2000[51])[23]**: this text notably regulates the monitoring of pressure equipment (PE). It is completed by the « Approved Code of Practice and Guidance »: L122[52]. It presents requirements relating to monitoring of PE.
- **DSEAR[24] – Dangerous Substances and Explosive Atmospheres Regulations** are the transposition of the ATEX Directive. This text, relating to the risk of explosion, does not include any specific section relating to follow-up of the integrity of the equipment except that the installations have to be maintained in good condition.
- **Petroleum regulations (Petroleum Act of 1928)** impose possession of a license for possessing petroleum products and observance of the associated conditions. A booklet published by HSE (HSG 176[60]) is available. For the petroleum regulations, only this last booklet is studied in this annex.

The texts containing information on the monitoring of equipment are studied subsequently in this annex.

---

[22] *The code of practice and associated guide is L22. It was taken into account in the analysis in a succinct way, only containing very general information on the monitoring during operation.*

[23] *The PER (Pressure Equipment Regs) concern the design, manufacturing and commissioning of pressure equipment. Its field of application is slightly different from that of PSSR 2000.*

[24] *The regulation of 1972 relating to highly flammable liquids and to LPG (HFL 1972) is no longer applicable.*

2. PSSR 2000 REGULATIONS AND ASSOCIATED TEXTS

2.1 GENERAL PRESENTATION

In the United Kingdom, the regulations for pressure equipment are defined by **goals**, through the Pressure Systems Safety – Regulations 2000 (noted as PSSR 2000[51] subsequently in the report). It is completed by the Safety of Pressure Systems – Pressure Systems Safety Regulations 2000 – Approved Code of Practice – L122[52] (noted as ACOP subsequently in the report) drawn up by the Health and Safety Commission (HSC) which includes a section of Approved Code Of Practice which has a legal status (which gives advice on how to follow the regulations) and a Guidance and Guide (which is not compulsory but the following of which is considered as a good practice).

PSSR 2000 defines the responsibilities of the different intervening persons (manufacturers, operators, competent persons, etc) and sets **general principles** as to monitoring pressure equipment.

Reference is explicitly made to the risk related to the pressure of the equipment, without **referring to the risk related to the nature of the substance**.

The regulations apply:

- to fixed pressure vessels ("installed systems") including its associated pipework and protective devices ;
- pipework with its protective devices including the associated accessories such as valves, flexible hoses, bends, pumps, compressors ;
- to pipelines including the protective devices.

It relates to equipment containing the following fluids:

- steam;
- fluids which have a pressure greater than 0.5 bar above atmospheric, including:
    - gases;
    - liquids with a vapor pressure of the gas phase in equilibrium with the liquid at 17.5°C, above 0.5 bars absolute;
    - gases dissolved under pressure in a solvent such that the gas may be released into the atmosphere at room temperature conditions without heating.

The regulations include a section relating to the installation and to the requirement that the operator[25] define secure operating conditions for the equipment. We shall not develop these aspects in this report.

As regards monitoring during operation of the equipment, the regulation imposes that the user of an installed system writes a scheme of examination including all the components of the pieces of equipment for which a failure may lead to a hazardous situation and in particular the protective devices (rupture disks, pressure relief valves…). This plan should be established by a **competent person**. A competent person refers to the service or organization which carries out the inspection; this is not an individual, unless this person is his/her own employer. The competent person may be a service provider of the operator, an external third party organization or an intervening person as his/her own employer.

ACOP specifies in its ACOP part (legal obligation) the notion of **competent person** defined in PSSR 2000.

[25] *The employer is the owner of the installation.*

The person is associated with two types of functions, both of these functions may be provided by the same persons:

1- Elaborate or validate inspection plans;

2- Carry out the inspection operations according to the plan.

Generally and for both functions, the competence corresponds to a level **of knowledge, expertise and experience. The required competence depends on the complexity of the system** and the competent person may not be alone for complex systems. A team grouping experts, persons with good knowledge of the installations, specialists, should be available for exploring the extent of required skills. Further the organization should have a quality system (« proper standards of professional probity »).

Thus, an (approximate) breakdown into three types of systems (except for transportation pipelines, not dealt with in this report) is proposed in the ACOP:

- **Minor systems** correspond to systems containing steam, pressurised hot water, compressed air, inner gases… which are small systems not posing any problems. In a simplified way, the pressure-temperature conditions are not critical (pressure < 20 bars, temperature between -20°C and 250°C, pressure-volume condition < 2x105 bars.liters);
- **Intermediate systems** include the majority of storage systems and process systems;
- **Major systems** are those which because of their size, complexity or hazardous contents require the highest level of expertise in determining their condition.. These systems comprise pressure storage systems for which the product of pressure by volume is greater than 106 bar.liters and any manufacturing or chemical reaction system for which the product of pressure by volume is greater than 105 bar.liters.

For each type of systems, the requirements relating to the staff, to the specialist services, to the organisation, are specified (§ 105).

The competent person should have a degree of **independence** relatively to the operator, in particular when the inspection service is a unit internal to the site.

The competent person remains **responsible for the totality of the inspections**, including the results of tests and/or non-destructive testing operations carried out by possible third parties.

The ACOP in its <u>Guidance part (not mandatory)</u> specifies that certification according to "BS EN 45004 – 1995 General Criteria for operation of various type bodies performing inspection", is an indication of the competence level. But **accreditation** (recognized by the Government via the United Kingdom Accreditation Service – UKAS) according to this standard remains a voluntary act. **This is recommended for organizations intervening in the elaboration or validation of inspection plans and for those who carry out inspection operations on major systems.**

It is the responsibility of the operator to verify that **such a plan or its certification** is carried out by a competent person.

The plan should be **regularly revised at suitable intervals,** in order to take into account recommendations from the competent person and in order to ensure that it remains compatible with present operating conditions.

The plan should specify:

- The nature of the examinations; the ACOP (legal part) specifies the elements contained in the plan (identification of the equipment and of the items subject to an examination, the nature of the examinations (out-of service or in-service examinations) including inspections and testing of the protective devices, the critical parts having to be examined by a competent person after repair or modification, the name of the person certifying the written scheme and the date of certification);
- The intervals between inspections; the ACOP (legal part) specifies that the protective devices should at least be examined at the same time as the plant to which they are fitted;
- The required preparations in order to be able to carry out examination of the equipment.

The plan may specify that it is necessary to carry out an inspection before first use.

The **carrying out of the inspection by a competent person** should then be performed while following the prescriptions of the inspection plan (extent of the checking operations and observance of the prescribed intervals).

The **competent person** having carried out the inspections should draw up an **inspection report**, sign it, date it, and send it to the operator (or draw it up if the competent person belongs to the company of the operator) as soon as possible, without exceeding a period of 28 days.

This report includes the following information:

- The parts having been subject to an inspection with the condition of the parts and the results of the examinations;
- The specifications of repairs or changes in the operating conditions, if required, by specifying a deadline for accomplishing the work or the modifications of the operating conditions; operating the plant is forbidden as long as the requests from the report have not been satisfied;
- The date of the next examination. In certain circumstances, and provided that there is an agreement with a competent person outside the site, a postponement may be accepted. The authorities ("enforcing authorities") should then be warned about this.
- The opinion of the competent person on the relevance of the plan and whether it has to be possibly modified while specifying the reasons for this.

If during the inspection, the competent person sees a situation of imminent danger, he/she should immediately inform the user and make sure that system is not operated until repairs or modifications of the operating conditions. The competent person should further inform the enforcing authorities within a period of 14 days.

In the case of modifications or repairs, the person carrying out the work should make sure that the operations carried out do not generate any danger and do not prevent operation of the pieces of safety equipment.

A follow-up file should be established including the last inspection report, possible previous reports if they provide information on the condition of the system.

It should be noted that for equipment with permanent contact with the atmosphere, in order to keep them at atmospheric pressure, the operator should make sure that the venting system is not blocked.

2.2 NOTION OF COMPETENCE – ACCREDITATIONS – RECOGNITION

2.2.1 COMPETENCE OF THE INSPECTION PERSONNEL

As seen earlier, **PSSR 2000 does not impose any certification** according to BS EN 45004 which would allow validation of the competence of organizations intervening in the inspections even if it is recalled in ACOP in its part Guidance (not compulsory) that certification according to "BS EN 45004 – 1995 General Criteria for operation of various type bodies performing inspection" is an indication of the level of competence.

The inspections and the NDT should be carried out by companies having a recognized quality system and the organization should be adapted to the risk of the installation.

Accreditation from UKAS may be required, according to BS EN ISO/IEC 17025 Testing or EN 45004 – Inspection:

- NF EN ISO/IEC 17025[9]: General requirements concerning the competence of the calibration and test laboratories;
- NF EN ISO/IEC 17020[10]: General criteria for the operation of different types of organizations proceeding with inspection

But the **accreditation** (recognized by the Government via the United Kingdom Accreditation Service – UKAS) according to this standard remains a voluntary act. **This is recommended for the organizations intervening in the elaboration or validation of the inspection plans and for those who carry out checking operations on major systems**.

The document RG2 (Draft version as of February 2009[62]) « Accreditation for In-service inspection of pressure systems / Equipment », drawn up by UKAS, provides a guide on transcriptions of the requirements of the ISO/IEC 17020 standards for inspection operations. It proposes that the development and certification of inspection plans be included within the scope of the accreditation, the inspection including analysis of the faults and the decision as to maintaining them in operation, the transfer of the results of the inspections with possible recommendations, the possible modification of the inspection plan or of limiting operating conditions. Reference will be made to this document for more information on the requirements in terms of personnel, organization, training, procedures, sub-contracting.

It also proposes 5 competence categories (depending on the experience, qualification, duration on site). Depending on the complexity of the system to be studied, suitable competence categories are proposed (see annex 1 of RG2).

2.2.2 EUROPEAN COMMITTEE OF USER INSPECTORATES (ECUI)

This commission, created in 1992, on the initiative of APITI (France), WEID (Netherlands) and EEMUA (United Kingdom), groups inspectors belonging to operators. The EEUMA provides secretarial functions. This instance participates in the discussions within the European instances. Upon issue of the PE directive, the Working Group on Pressure (WGP) was created in order to relay and provide answers to manufacturers and users of PE. The ECUI contributed to elaboration of many guides (approximately 200). The EEMUA contributed to recognizing inspectors of the operator (2nd-party User Inspectorates as opposed to 1st party which is the manufacturer and to the 3rd party which is an external organization) and allowed this recognition to be safeguarded.

Within the scope of work with CEN, promotion of risk-based inspection methods is sought.

2.2.3 COMPETENCE OF THE PERSONNEL CARRYING OUT NDT

Competence requirements are defined according to a central scheme for certification (« Central Certification Scheme ») (PCN for Personnel Certification in Non-Destructive Testing which is the international scheme for certification on the basis of the standards EN 473 Non-destructive testing and ISO 9712 Non-destructive testings -- Qualification and certification of the personnel) or on the basis of a scheme of the company.

The requirements in terms of competence of the persons carrying out NDT are specified in the standard BS EN 473-2000:. Qualification and certification of NDT personnel. General principles. Three levels (levels 1, 2 and 3) are given corresponding to feasible tasks (from level 1 able to carry out NDT to level 3 authorized for supervising them).

When the result of the NDT plays a major role in maintaining safety, additional steps are taken such as:

- Auditing NDT with independent operators carrying out sampling of the NDT already accomplished;
- Repeating NDT with different persons and/or techniques;
- Have an independent third party follow the operations.

2.3 PRESENTATION OF ASSOCIATED PROFESSIONAL GUIDE (GENERAL – NON-RELATED TO A SUBSTANCE)

PSSR 2000[51] regulations define the general principles (notion of competence, inspection reports, inspection plans, modification of the plans).

They do not provide specific information on the frequency of the inspections, on their nature.

However there exist different guides which may be used by industrialists and which provide more specific elements on the natures of the inspections:

- a guide (SAFed[55] guidelines on periodicity of examinations) gives general recommendations on the typical intervals between inspections and gives elements on the possibility of extending the periods between inspections.
- another guide SAFed[56]- “Guidelines for Competent person – In-service examination of pressure systems pipework relates to pipings”, excluding so-called complex pipings such as those of refineries; these guides are detailed in the following chapters.
- Risk-based Methods (RBI) are also used (API 580[72], API 581[73]).

  _Note_*: A feedback for the use of such methods is presented in chapter 3.*
- The guides API on inspections (API 510[74] and 570[75].

Other guides, non-specific to the United Kingdom[26], elaborated by the Institute of Petroleum, exist. They aim at providing a collection of good practices for inspections during operation and pressure tests for the equipment used in chemical and petroleum industries. These guides belong to a series of guides forming the IP Model Code of Safe Practice. These guides are to be seen as a complement to existing regulations and are not a substitute for local regulations.

[26] Even if the document has an international nature, it was drawn up with a concern for adjusting to the regulations of the United Kingdom (Pressure System and Transportable Gas Containers Regulations 1989 (noted as PSR) and for pipings the HSWA, the CIMAH).

- Institute of Petroleum – model code of safe practice. Pressure piping systems examination, part 13 (1993) [58];
- Institute of Petroleum – model code of safe practice. Pressure vessels examination, part 12 (March 1993) [57].

2.3.1 GUIDE SAFED - GUIDELINES ON PERIODICITY OF EXAMINATIONS[55]

The guide provides recommended intervals between successive examinations of pressure systems. It provides information about the factors to be considered when assessing whether it is appropriate for an existing interval between successive examinations to be extended.

It specifies that the intervals between inspections are conditioned by different parameters:

- design details ;
- method of construction ;
- conditions of use ;
- standards of maintenance ;
- the safety record of the system ;
- its current condition ;
- an evaluation of the conditions of operation of the system.

A **first in-service inspection should be provided within 24 months following commissioning** and its initial examination**.** It is intended for detecting deficiencies in the design, manufacturing and/or installation of the equipment. The period of 24 months may be extended subject to the justified opinion of the competent person. The guide does not specify the contents and the techniques to be used but the scheme of examination should specify this.

The following inspections during operation will be determined depending on the results of this first in-service examination and on the possible recorded defects or deterioration.

The recommendations on the checking for correct operation of the safety devices are included in the document.

The need of revision of the plans has to be considered by the competent person at each significant change.

The pipeworks are in majority excluded from the inspection plan (according to article 8 of PSSR 2000) and its associated Approved Code of Practice. However, if the pipeworks are included in the scheme of examination, the latter should take into account the following factors:

- Corrosion;
- Erosion;
- Creep;
- Fatigue.

The guide then provides recommendations concerning the maximum intervals between inspections, depending on the equipment. It makes a distinction between boilers (not dealt with in this report) and other systems.

Intervals are suggested in the guide, depending on the type of vessels and of pipings.

The vessel of class A corresponds to a piece of equipment when deterioration is possible or where there is little evidence on which to predict their behaviour in service. Vessels subjected to a daily pressure cycle should normally be allocated to this class unless a full fatigue assessment has been undertaken.

The vessel of class B is the one which is not subject to significant deterioration; it may be classified in class C if it is shown that it is not subject to degradation. On the other hand, if inspections show that degradations occur, it should be classified in class A.

The vessel of class C corresponds to those for which examination intervals up to a maximum of 12 years is permitted. In order to be classified as C, a full fatigue assessment has to be undertaken and it is required that

- Equipment has been examined on successive occasions and no deterioration have been found after a total of at least 72 months. The following inspection will have to take place before the assumed end of the life cycle of the equipment;
- Or for a new piece of equipment, it has the same characteristics in terms of material of construction, design details, pressure, temperature and nature of contents as an item already classified as C.

An **interval from 12 to 14 months** is required for equipment subject to a potentially corrosive fluid and for vessels with little or no corrosion allowance. Generally if the process vessels have exceeded 80% of their design life, examination interval not greater than 14 months is required. However, if the manufacturer specifies 12 month intervals, they will have to be referred to.

An **interval from 24 to 26 months** is recommended by the guide for:

- **Pressure vessels subject to rapid detrioration (class A) that have** some or all of the following conditions**:**
    - Contents which cause rapid corrosion/erosion ;
    - Potentially corrosive external environment ;
    - Vessel subject to significant vibration ;
    - Vessel subject to significant cyclic pressures ;
    - Vessel subject to significant cyclic temperatures and/or thermal shock ;
    - Safety valves or other protective devices susceptible to blockage ;
    - Rivetted seams ;
    - Inwardly dished ends ;
    - No reinforcement of mounting plates ;
    - Removable covers for charging purposes.
- And **pipings potentially subject to rapid deterioration**[27] (some or all of the 5 first previous conditions);

An **interval from 36 to 48 months** is recommended for vessels of class B (for which none of the conditions stated above are verified).

Intervals from 60 to 72 months are suggested:

- for **vessels which are a priori susceptible to deterioration.** For example this is the case of liquefied gas vessels of class A and B, of CO_2, chlorine and ammonia vessels (if absence of SCC), of buried LPG vessels or tanks under slopes and of aboveground LPG vessels.
- For **pipings which are not susceptible to rapid deterioration** (not meeting the criteria established above for inspections every 24 to 36 months).

---

[27] For pipings operating under conditions favorable to creep or fatigue phenomena, the remaining service life should be taken into account. Reference will be made to the guide for more details.

Finally, **intervals from 120 to 144 months** are suggested for equipment for which sufficient evidence of non-deterioration is available. This is for example the case of liquefied gas fluid vessels of class C, of aboveground LPG vessels (with internal access subject to an external visual examination every 60 months), the large stainless steel brewing vessels.

Note: in the particular case of equipment for which the service life is clearly defined upon design depending on critical operating conditions[28], up to 80% of the service life, the intervals will be based on 20% of the service life calculated with maximum values of 26 months (class A), 48 months (class B) or 96 months (class C). Beyond 80% of the remaining service life, the intervals will be defined on 10% of the service life calculated with a maximum of 14 months for classes A;

Note: ***the guide gives indications concerning the required information with which the intervals between inspections may be extended beyond recommendations.*** *The factors are the usual encountered factors such as documentation and traceability on the results of the examinations and documentation on the equipment, knowledge on the degradation modes, maintenance and operating conditions, etc.*

2.3.2 SAFED- GUIDELINES FOR COMPETENT PERSON – IN-SERVICE EXAMINATION OF PRESSURE SYSTEMS PIPEWORK[56]

The guide SAFed- "Guidelines for Competent person – In-service examination of pressure systems pipework" is specific to the inspections on pipings and provides more specific elements than the previous guide. **However, the guide is not applicable to large-scale and complex pipework systems (refineries for example). For these installations, please refer back to API 570.**

The guide is intended to complete the statutory requirements of PSSR 2000 but it may be **applied to pipings transporting hazardous fluids, for which the hazard is related to the nature of the fluid and not to its pressure.** The guide includes in the terms of "pipework" pipings and associated components such as hoses,flanges,valves, supports and anchorages. It is not applicable to pipelines.

Insofar that the pipings with a diameter $\leq$DN25 for pressures of less than 40 bars do not represent a major risk (low flow rate in the case of a leak and probability reduced by the comparatively greater thickness of these pipings), it is not required to perform conformity assessment by a notified body, for sizes up to DN25 and for sizes between DN25 and DN100 up to PS[29].DN = 1,000.

In the particular case of steam pipework and for which the risks of water hammer are significant, particular attention should be spent during examinations on the steam traps and draining systems in order to avoid accumulation of liquids in the pipings, notably in transient phases (start-up, shut-down).

[28] The temperature and pressure conditions are specified in the document

[29] PS is the design pressure (maximum allowable pressure)

The guide recalls that PSSR 2000 and its associated approved code of practice[30] tends to exclude in majority the pipings from the examination schemes, from the moment that they have been subject to initial examinations. It is therefore essentially the principle of determination of criticality which allows a decision to be made on whether a piping should be part of an examination scheme. The nature of the fluid is involved (for its possible consequences in the case of loss of containment) and the fact that pipings may be subject to deterioration. It is suggested in the guide to select pipings with a diameter > DN150 with PS.DN > 1,000 bar.mm (fluids other than steam and toxic and/or flammable fluids) in the inspection plans but to consider in any case the proximity with persons as an additional selection parameter: in the absence of a significant impact on persons, the piping will not be selected in the examination scheme. For hazardous fluids (toxic and/or flammable fluids…); it is recommended to conduct the same type of risk-based analysis.

Note: the piping is considered to be between two pieces of equipment if isolation valves exist between the pieces of equipment and the piping. Otherwise, the piping is considered as being in the equipment.

In the case of large pipings, it is recommended to consider several sections in order to target the monitoring actions to the specificity of the studied section. It is advised to reason on the basis of piping isometric drawings.

The guide recalls that the degradations on pipings often relate to faults under lagging but that other mechanisms may occur.

Nature of the checking operations

The guide provides for the selected pipings that an inspection plan be carried out including:

- **External examination of the pipings**: except if this is impossible (buried pipings not dealt with in this report), external examination is carried out by walking along the piping in order to evaluate the deteriorations; if required, additional access means will be set into place. By visual examination it is thereby possible to already localize flaws of linings, gasket leaks, excessive vibrations… Preferably, the inspection will be carried out during the normal operation of the installation but the inspection may be carried out at another moment (for example during hydraulic tests) at the discretion of the competent person.
- **Possible thorough examinations** will then be conducted at suitable locations. The latter should correspond to areas estimated as being the most critical and representative of the whole of the piping.
    - For external corrosion, the thickness measurement points will be limited if the external lagging is in good condition. In this case, the measurements will be limited to the most critical points (with partial removal of laggings if required). These areas estimated to be critical are for example low points, bends, supports and Tees. If laggings degradation areas are identified, the measurement area will have to be extended in order to ensure the measurement of minimum thickness.
    - For internal corrosion, the process remains the same: identification of potentially critical areas and measurements of potential flaws by different techniques (long range ultrasonic testings, profile radiography, flash radiography, thermography, remote cameras, pressure testing, use of intelligent “pigs”…). The guide recommends in the case of the possibility of lamination or accumulation of corrosive substances in low portions to carry out measurements on the circumference of the piping rather than a single measurement.
    - For possible cracking phenomena (by fatigue or another cause), other more suitable techniques will be used (ultrasonic, magnetic particle testing, dye penetrant examination, eddy current testing, radiography, metallurgical examination and replication…).

[30] *This is the code “The Pressure Systems Safety regulations 2000 – Approved Code of practice”*

Note: the guide issues a warning against excessive inspection of old pipings for which the welds may have flaws that would not pass modern non-destructive testing procedures and acceptance criteria in current standards. However, with the low stresses involved and large factors of safety such welds may be suitable for many more years of safe operation.. The inspection should actually only be limited to the areas for which a risk exists (feedback of faults, significant risk in the case of a leak).

Frequency of the inspections

A typical table is proposed for pressure pipings.

Conditions	**External inspection**	**Complementary examinations**
Non-corrosive	36/38 months	Not applicable [a]
Corrosive environment	24/26 months	24/26 months [b]
Corrosive or erosive contents	24/26 months	24/26 months [b]
Steam	24/26 months	24/26 months [c]
Fatigue	As above but subject to remnant life assessment	As above but subject to remnant life assessment
Creep	As above but subject to remnant life assessment	As above but subject to remnant life assessment

Notes

(a) The external examination can be supplemented by additional tests or examinations to confirm integrity where the consequences of failure are high;

(b) The period may be extended up to 72 months depending on the rate of corrosion and the condition of the pipework;

(c) The period may be extended to 48/50 months if the piping is in good condition and is not in a corrosive environment.

Examination of the protective devices

The examination is a priori dissociated from that of the piping. Reference will be made to the guide SAFed – “Guidelines on periodicity of Examinations” for inspections of the units on the pipings. Reference will be made to chapter 1.2.

However, where liquid can be trapped between closed valves in pipework, the liquid relief valves need to be removed and tested periodically, normally 5 or 10 years depending on duty.

Examination of the other components

The components such as flexible hoses or bellows should be checked by the operators before each use. Checking of proper alignment, of the absence of torsions will also be carried out at each inspection plan, with feedback to the manufacturer for re-certification.

Repairs and modifications

The guide includes a section of repairs and modifications on the pipings. Without developing the contents, these operations should be performed according to recognized standards and if the modification is substantial it should be validated by a notified body. For more details please refer to the guide.

2.3.3 INSTITUTE OF PETROLEUM[31] – PRESSURE VESSEL EXAMINATION[57] – MODEL CODE OF SAFE PRACTICES – PART 12

The guide relates to pressurized tanks and excludes pieces of equipment with mobile portions (compressors, pumps…), as well as transportable tanks. It also deals with the safety devices associated with the tank.

It provides a procedure for identifying, classifying and following up pieces of equipment in order to guarantee maintenance of operating conditions (« fitness for purpose »).

For the U.K., it is an aid for operators for following the PSR regulations and for carrying out inspection plans (« scheme of examination »).

The guide deals with different aspects, notably:

- The necessity of identifying and recording each piece of pressure equipment in a unique way and of having specific documentation available (location number, plans, specifications, certificates… and limiting safe operating conditions (« safe operating limits »)) (Chapter 2).
- The necessity of classifying every piece of equipment according to regulations:
    - Class A:
    - Class B: these are pieces of equipment which will not be subject to compulsory periodic inspections. The tanks containing toxic or flammable substances which would not be subject to pressure, therefore theoretically not being subject to compulsory periodic inspections, will in any case be subject to periodic examinations.

It then presents the **principle for determining inspection periods** after having allocated to the tank a grade (« Grading allocation »). This step should be carried out by personnel well acquainted with the equipment and its operation and should be validated by the **competent person**[32] (« competent person »). The periods between inspections finally depend on the retained grade and on the existence of sampling inspection procedures (« sampling examination procedures »).

- **Determination of a grade (0 to 3)**: Grade 0 corresponds to equipment for which the periodicity between inspections will be the lowest. In a simplified way, equipments of grade 0 correspond to **pieces of equipment which are not very well known and for which time-dependent changes are difficult to predict** (for example having been subject to only one inspection after commissioning). When knowledge on the equipment is increased and when following previous inspections, the observations allow the conclusion to be drawn that the degradations vary little over time, it is possible to increase the grade of the piece of equipment from 1 to 3. However, the period may be lowered when the tank approaches the predicted or design service life.
- **Determination of the periods**: the table below, from the guide, establishes the link between the period and the grade of the equipment. The indicated values are maxima and lesser values may be proposed. It is specified that the **analysis of the consequences in the case of a failure may suitably modify the retained period between inspections**. Many other parameters are indicated (potential degradation modes, maintenance policy, presence of linings, presence of insulation or fire-retardant, etc…) (see chapter 5.3 of the guide).

---

[31] the Institute of Petroleum and the 'Institute of Energy merged in 2003 in order to give rise to the Energy Institute. This is a professional association grouping more than 30 companies throughout 100 countries working in the energy sector. It has the goal of promoting supply and secure use of energy in all its forms. .It provides standards, guides of good practices and contributes to the awareness of industrialists of the energy sector by organizing conferences and discussions, editing publications, training sessions

[32] This is the person or the organization (internal to the site or external organization) authorized by the operator for carrying out or approving inspection plans and for examining the pressurized pieces of (cf. PSR regulations)

	Recommended maximum period inspections (months)			
Equipment	**Grade 0**	**Grade 1**	**Grade 2**	**Grade 3**
Pressurized tanks[33]	60	72	108	144
Safety devices	24	36	72	-

In the case of similar tanks, a rotation in the inspections may be carried out, consequently extending the period between the inspections of a given tank. This sampling rule cannot not be applied to safety devices.

In the case of the installation of a new tank similar to other ones, its grade may as soon as it is commissioned be aligned with the grade of similar equipment and which is well known.

The finally retained deadlines should be observed. Otherwise, the signed agreement should be established beforehand between the operator and the competent person and the authorities which should be informed about this.

Revision of the grades may be carried out as soon as an incident occurs or if changes in the operating conditions occur or if the tank approaches (or exceeds) its design service life.

For **safety devices** (and the possible safety systems having the function of preventing an excessive rise in temperature or pressure), the maximum inspection periods are shorter than those of the tanks. The principle for assigning the grades is the same as for the tanks. An increase in grade is only justified by a solid feedback of good operation, both traced and documented.

The contents of inspections to be carried out for the pre-commissioning inspections, the first inspection and follow-up inspections during operation are mentioned in a not very detailed way. By monitoring during operation and from measurements and analysis of the tank, it is possible to determine the time-dependent change in degradations and to predict the remaining service life of the equipment. The inspection includes an external, internal checking operation.

The preparation conditions are discussed (removals of internal linings, access means, cleaning of the parts to be inspected…). It is recalled that the preparation of the operations is part of the statutory inspection plan («scheme of examination»). Possible tracking of the operating parameters (tanks operating) does not generally replace internal visual inspection.

Monitoring of the safety devices should not be limited to the actual accessories but should include the associated piping from the moment that blockings may occur.

- **For pressure relief devices**: the maximum period is 72 months. The valve has to be disassembled and then tested on a bench in order to check the opening pressure. The results are recorded. Next, the valve is disassembled, cleaned, repaired, modified in order to ensure opening at the required pressure. A particular attention is paid to devices which may isolate the valves from the tank.
- **For controlled valves:** disassembly is difficult and only the control valve is tested.
- **For the rupture disks**: they have to be changed regularly in order to avoid failure due to fatigue or corrosion. By conducting opening tests after the disassembly it was possible to check whether the disk had kept or not its capability of opening at the required pressure.
- **Other accessories**: the instrumentation involved in the safety chains should be tested regularly.

The **principles of the applicable test methods** are described for:

- Force tests (« strength testing ») including hydraulic or pneumatic tests;

[33] *Except for process reservoirs or exchangers*

- Leak tests (« leak testing »);
- Non-destructive testing;
- Destructive testing;
- Analysis of materials.

2.3.4 INSTITUTE OF PETROLEUM – PRESSURE PIPING SYSTEMS EXAMINATION58– MODEL CODE OF SAFE PRACTICES – PART 13

The guide relates to pressurized pipings[34] and excludes transportation pipelines for which a specific guide exists. It also deals with safety devices associated with the pipings.

It provides a procedure for identifying, selecting the pieces of equipment to be monitored, classifying and monitoring pipings in order to guarantee that the operating conditions are maintained (« fitness for purpose »).

It forms an aid to the operators for following the PSR regulations and for carrying out inspection plans (« scheme of examination »).

The guide deals with different aspects, notably:

- The necessity of **identifying** each pressurized piping (without necessarily having an identification in the form of a number on the site);
- The necessity of **selecting** which pipings will be subject to monitoring (by a competent person). The selection relies:
    - on possible statutory requirements,
    - on knowing or assuming strong probabilities of potential degradation related to a difficult environment (fatigue, erosion, corrosion),
    - on the evaluation of the consequences in the case of loss of containment. The consequences are evaluated in terms of impact on the persons, (either off-site or on-site) and in terms of impact on the environment.

  However, **maintaining safe operation of the non-selected pipings remains under the responsibility of the operator.** The latter should provide checking procedures which will not be necessarily carried out by a competent person (in the sense of the regulations).
- The necessity of **recording** available information on the piping (reference, certifications, certificates, etc…);

The guide then presents the **principle for determining periods for inspections** after having allocated to the piping a grade (« Grading allocation »). This step should be carried out by the personnel well acquainted with the piping, its operation and its environment. The periods between inspection finally depend on the retained grade.

[34] *Cryogenic pipings in operation are an exception and certain deviations relatively to the guides are authorized. For more details refer to the guide..*

- **Determination of a grade (0 to 3)**: grade 0 corresponds to pipings for which the periodicity between inspections will be the lowest. In a simplified way, the pieces of equipment of grade 0 correspond to not very known pipings and for which the time-dependent changes are difficult to predict (for example having been subject to only one inspection after commissioning). When knowledge on the piping increases and when, following previous inspections, the observations allow the conclusion to be drawn that the degradations do not change very much, it is possible to increase the grade of the equipment from 1 to 3. However, the period may be lowered when the tank approaches the predicted or design service life.
- **Determination of the periods**: the table below, from the guide, establishes the link between the period and the grade of the equipment. The indicated values are maxima and lesser values may be proposed. It is specified that the analysis of the consequences in the case of a failure may suitably modify the retained period between inspections. Many other parameters are indicated (located degradation modes, presence of small sections with DN < 50 mm, expansion bellows, vibrations, etc…) (see annex A of the guide).

	Recommended maximal period between inspections (months)			
Equipment	**Grade 0**	**Grade 1**	**Grade 2**	**Grade 3**
Pipings	36	48	84	144

The finally retained deadlines should be observed. Otherwise, a signed agreement has to be found beforehand between the operator and the competent person and the authorities have to be informed about this.

In the case of the installation of new tubing similar to other ones, its grade may be aligned from the moment of its commissioning with the grade of similar pipings which are well known.

A revision of the grades may be carried out as soon as an incident occurs or if changes in the operating conditions occur or if the piping approaches (or exceeds) its design service life.

A **competent person**[35] makes sure:

- That the selected components are monitored according to the inspection plans and that the results are exploited in order to check whether the equipment may be maintained operating, under safe conditions;
- That possible repairs, modifications, replacements are carried out according to the requirements of the code.

Internal testing of pipings is very generally not possible. Non-destructive testing (NDT) gives the possibility of having an evaluation of the interior condition of the pipings. A particular attention should be paid to external examination of the pipings and to examination of the supports.

The importance of the preparation conditions is emphasized (reference to the IP model of Safe Practice, part 3 « Refining Safety Code ». Monitoring the loaded piping (touching, use of specific NDT, partial removal of thermal installations. …-cf. annex B of the guide) may prove to be satisfactory. It should be noted that this code of practice is obsolete from now on.

The **competent person then draws up an inspection report** including recording of the results, the possible revision of the plan, the specification of possible modifications, the determination of the date of the next inspection.

[35] The competent person is the person or the organization designated by the operator for carrying out or approving the inspection plans for pipings. In the United Kingdom, this may be a person from a site or from an external organization. For the definition, reference will be made to the PE regulations.

The elaboration of the inspection plan should take into account the following specific points:

- The existence of an internal lining and the possibility of its deterioration;*
- The presence of insulation and of fire-retardant lining, which may generate corrosion phenomena under the insulation, under temperature conditions from -5 to 140°C. In this case, partial removal of the insulation is required in order to evaluate the extent of the external corrosion. Austenitic steel pipings are particular vulnerable (Stress Corrosion Cracking phenomenon – SCC);
- The valves and tappings which may be a preferential source of fatigue;
- The buried pipings, which although protected from corrosion by a lining and cathode protection, remain brittle. Monitoring of the cathodic protection should be carried out. A smart scraper (« intelligent pig ») may also be used;
- The bellows which have to be checked in order to make sure that relative movement is absorbed by the expansion gaskets. The absence of leaks, of deformation should be checked periodically.
- The occurrence of extreme operating conditions or of abnormal exterior conditions (fire for example) which may lead to premature degradations.

The conditions for monitoring the safety devices are similar to those for the accessories mounted on the pressurized tanks.

The **applicable principles of the test methods** are described for:

- Force tests (« strength testing ») including hydraulic or pneumatic tests;
- Leak tests (« leak testing »);
- Non-destructive tests;
- Destructive tests;
- Analysis of the materials.

2.3.5 SUMMARY OF THE REQUIREMENTS OF THE PROFESSIONAL GUIDES

The tables on the following pages summarize the requirements depending on the professional guides.

Pressurized tanks

	SAFed – Periodicity of examination	IP – part 12 – Pressure Vessels	API 570 – Pressure Vessel inspection code
Field of application	*PE and others*	*Tanks in the chemical and oil industry*	*Tanks in the chemical and oil industry*
Interval between inspections	According to the class of the equipment (knowledge on the equipment and on potential degradations) Class A: 24 to 26 months Class B: 36 to 48 months Class C: 60 to 72 months Up to 120-144 months if REX of non-degradation (Includes internal inspection LPG)	According to the grade 0-3 (knowledge on the equipment and on potential degradations, but also according to possible consequences + other criteria) Tanks: 60 to 144 months Accessories: 24 to 72 months	External: 60 months Internal: 120 months maxi Pressure test: no prescription on the interval (may be replaced with NDT)
Particular case	If close to the service life defined upon design, reduced interval If traceability, documentation…, extended interval	If close to the service life defined upon design, reduced interval	Possible Influence of service life If RBI, no max. interval
Nature of the inspections	Not explicit	External and internal inspection Preparation conditions	External and internal inspection Pressure test: only after repairs or modifications
Examination of safety devices	Yes, at least as often as the equipment Max. 26 months	Yes, with details on the nature of the monitoring operations	Valves: max. 5 years

Pressurized pipework

	SAFed – Periodicity of examination	SAFed Pipework	IP – part 13 – Pressure Piping	API 510 – Piping Inspection code
Field of application	*PE and others*	*Except for complex pipework (refinery)* *PE and hazardous substances*	*Pipework in the chemical and oil industry*	*Pipework in the chemical and oil industry*
Interval between inspections	According to the class of the equipment (knowledge on the equipment and possibility of degradations) <u>Class A</u>: 24 to 26 months <u>Class B</u>: 36 to 48 months <u>Class C</u>: 60 to 72 months Up to 120-144 months if REX of non-degradation (Includes LPG)	According to criticality (pressure and hazardousness of the substance, impact on persons, possibility of degradation). For pressurized pipework If corrosion, erosion: 24/26 months (External + NDT) Otherwise: 36/38 months (External + NDT if need be)	Selection of the pipings to be monitored in the plan, according to consequences on humans and on environment and according to probability of failure + other criteria) Pipework: 36 to 144 months	According to the class and the nature of the monitoring operations: Pipework: 60 months to 120 months
Particular case	If close to the service life defined upon design, reduced interval If traceability, documentation…, extended interval	If creep, fatigue: see remaining service life If good condition in spite of corrosion: NDT at 72 months Care of bellows, flexible hoses	Pay attention to specific points (bellows, linings…) and to supports	Buried pipework Injection points
Nature of the inspections		External inspection (walk along the pipework) Complementary measurements (NDT) on targeted areas	External inspection Complementary measurements	External inspection and thickness measurements, including inspection under the insulation Pressure test: only after repairs or modifications
Examination of safety devices	Yes, at least as often as the equipment	Refer to the guide SAFed Interval of examination	Yes, with details on the nature of the monitoring operations	

2.4 PRESENTATION OF THE PROFESSIONAL GUIDES AND STANDARDS SPECIFIC TO SUBSTANCES

2.4.1 LPG (ABOVEGROUND PRESSURIZED TANKS).

This chapter presents guides of good practices used in the United Kingdom, issued by associations of professionals, for installations handling and storing LPG.

- Code of Practice 1 – Part 3 (2006), UKLPG.
- The EEMUA 190 guide - Guide for the Design, Construction and Use of Mounded Horizontal Cylindrical Steel Vessels for Pressurized Storage of LPG at Ambient Temperatures => this guide was not studied in the present report.
- The (European) standard NF EN 12819 (a standard being modified) inspection and requalification of aboveground tanks with a capacity greater than 13 m^3 for liquefied petroleum gas.

Note: There exists a standard for aboveground LPG tanks with a capacity of less than or equal to 13 m^3 (European standard NF EN 12817). The latter is not developed in this chapter, the capacity of the tanks on depots or storages in refineries being much greater.

Note: the guide HSG34 of the HSE is now obsolete. Following an accident involving a leak on buried LPG piping, consultation is in progress at the HSE for defining safety rules for LPG sites.

2.4.1.1 PRESENTATION OF THE CODE OF PRACTICE

UKLPG (www.uklpg.org), created in January 2008 by the grouping of two associations (the LP Gas Association (LPGA) and the Association for Liquid Gas Equipment and Distributors (ALGED)) represents the companies which produce, distribute and use LPG. It is a member of AEGPL, (European Association for the LPG industry) and of WLPGA (World LPG Association).

The association has the goals of:

- producing technical and safety standards for the industry (including Codes of Practice),
- promoting LPG to the general public,
- representing the industry at competent national authorities and European instances notably for regulations or certification,
- making sure that training is available and organizing this training,
- collecting statistical information on sales for the members,
- disseminating general information on safety.

UKLPG also provides its experience with national authorities such as HSE and European instances in order to develop and update secure procedures for the industry.

UKLPG and previously the LP Gas Association have published a certain number of textbooks relating to the design, construction and set-up of an LPG site, including the Code of Practice 1 / Part 3 - Examination and Inspection (2006): the minimum requirements for an inspection are described. The revision of the 2000 edition was carried out together with HSE.

Other codes exist which are presented in the INERIS DRA-08-85166-00650B report. Influence of teachings drawn from accidents involving storages of LPG in the development of guides of good practices abroad – September 2008. The latter are not detailed as they specially concern the design of the installations.

The guide provides tools on:

- The elements to be included in an inspection plan for bulk storage of LPG of 150 liters or more[36];
- The elements to be included in an inspection plan of distribution systems of more than 0.5 bars;
- The marking of a bulk storage as a result of inspections (« examination »);
- Recording the results of the inspections on bulk storages;
- Routine inspections to be conducted on bulk storages and their associated equipment;
- Periodic inspections of equipment associated with bulk storage.

The observance of other parts of the codes of practices relating to the design or to other equivalent standards is assumed.

The code does not apply to:

- Refrigerated storages and associated equipment;
- Containers for transport;
- Burners;
- Equipment and piping of less than 0.5 bars;
- Inspections, tests and maintenance of flexible hoses for transfer;
- Other installations such as the electricity, the air compressors…

The guide refers back to applicable regulations which influence the monitoring of equipment:

- PE regulations (PSSR 2000): requirement for the operator to have an inspection plan defined by a competent person (or have it validated by the latter) and to have inspections carried out according to this plan by a competent person.
- Regulations for hazardous installations (COMAH) which impose to establishments with more than 50 t of LPG to take all the necessary steps in order to ensure safety. The operators of sites with more than 200 t should conduct a safety study (« safety report ») in which they demonstrate that safety is ensured in the design, exploitation and maintenance of the equipment.

Three types of inspections are proposed:

- **Statutory inspections** (« examinations ») (to be planned and carried out by a competent person which may be a person from the site, a sub-contractor or an inspector from the authorities, subject to having the required experience and qualification) registered in the « written scheme of examination »; the code suggests intervals between inspections (10 years for aboveground tanks, 10 years for buried tanks with cathodic protection but yearly inspection of the cathodic protection, 5 years for buried tanks without any cathodic protection, 5 to 10 years for the valves depending on the type –cf. text, 10 years for thermal expansion valves on the lines, to be defined by a risk analysis on the pipings…) but it is recalled that the competent person who determines the frequency in the plan, notably by making use of knowledge from previous inspections. The code recalls that the faults have to be studied by a competent person by using a relevant method, with a particular attention paid to the systems without any passive fire protection. Reference is made to the BS 7910 guide. According to regulations, the plans are updated regularly.

[36] *The capacity of 150 liters of more applies to the whole of the discussed subjects*

- **<u>Periodic inspection</u>** subject to being recorded but which are not included in the inspection plan (from the regulations PSSR 2000) and are not necessarily carried out by a competent person (in the sense of the regulations PSSR 2000). These operations have to be described in procedures and carried out by trained persons. Their frequency is evaluated by risk analysis.
- **<u>Routine inspections</u>** (« routine inspection »), carried out by the operators, at higher frequencies, which consist in an external inspection of the visible portions of a tank. These operations should be described in procedures and carried out by trained persons. Abnormality reports should be issued if necessary.

The code specifies the elements to be inspected depending on the nature of the inspection.

For **<u>statutory inspection</u>**, the inspection of the tank and the inspection of the associated safety devices are imposed. Inspection of the insulation valves is also imposed. The inspection methods may be selected by the competent person. The methods which may be used are: external visual examination, hydraulic test, checking thickness by ultrasonics, detection of cracks by ultrasonics, internal examination (by entering the tank or by using other methods, acoustic emission, radiography, magnetic particle inspection, or other non-destructive testing methods. For tanks of more than 4 tons, external examination, thickness measurement or internal inspection and inspection of the safety devices are compulsory as well as the detection of cracks on the welds. Reference will be made to the guide for more details.

During **<u>periodic inspections</u>**, are suggested for example:

- an inspection of the pipings and in particular of the areas around the supports, checking the support, inspecting the insulation by removing it on suspicious areas;
- an inspection of the buried pipings;
- an inspection of certain number of instruments (gauges, temperature probes…);
- etc. (see guide).

For **<u>routine inspections</u>**, are for example suggested:

- an inspection of the environment (absence of combustible areas, absence of modifications which may generate ground movement);
- a check on the absence of differential settlement;
- a check on the absence of corrosion or deterioration on the tank, its supports, its fire-retardant lining,
- etc. (see guide).

2.4.1.2 Presentation of the standard NF EN 12819 (currently being modified).

It describes three types of checking operations to be carried out:

- **<u>Routine inspection</u>**: <u>external</u> visual inspection of the visible portions of the tank (with view to detecting external corrosion) and of its pieces of equipment, it includes:
    - an inspection of the safety units (condition of the drainages of the valves and checking the condition of the vent tubes of the valves, grounding connections, level gauges, verification of the responses of the remote-controlled valves;
    - inspection of the site (including the absence of deterioration of the possible protective systems against impacts, verification of the sound condition and without any damage of the supports and foundations, without any differential settlement and with anchoring bolts in good condition);

- **Periodic inspection**: external visual inspection of the visible portions of the tank and of its pieces of equipment, but at a lower frequency than routine inspections; it further comprises routine inspections of the maneuverability controls of the mechanisms of valve collectors, of pressure gauges, possible pressure switches, temperature measurement apparatuses, stop valves…;
- **Periodic requalification**: the latter comprises verification of the loading of the valve or of its modification, verification of the absence of corrosion on the pins, nuts… , maneuverability of the flow rate limiters and anti-return valves **and** at least **one** of the following **elements:**
  - Internal visual inspection;
  - Hydraulic test;
  - Acoustic emission monitoring;
  - Thickness check;
  - Another equivalent method.

The standard specifies that the interval between two requalifications should not exceed 12 years but does not give more information on the intervals between the different inspections.

3. TEXTS ASSOCIATED WITH FLAMMABLE LIQUIDS

This chapter presents guides of good practices specific to flammable liquid installations (essentially storage tanks).

The identified guides of good practices are:

- API 653 => this guide is presented in the USA regulations;
- HSG176 drawn up by the HSE;
- The EEMUA 159 guide => this document is dealt with in the report on storages in a refinery; the description is repeated below.
- The EEMUA 183 guide => this document is dealt with in the report on storages in a refinery; the description is repeated below.

3.1 GUIDE HG176: FLAMMABLE LIQUIDS (IN ABOVEGROUND TANKS [60])

The **HSG176 guide (1998)** drawn up by HSE is a guide relating to the design, the construction, the exploitation and maintenance of tanks for storing flammable liquids with a flash point $\leq$ 55°C or those stored at a temperature above their flash point, in tanks with a pressure close to atmospheric pressure. This document replaces the old guides HSG50 and HSG52.

It is applicable to many industries (chemical, petrochemical, painting, solvent industry, pharmacy).

The guide discusses the protection against corrosion (chapter Design and Construction). A chapter is dedicated to inspection and maintenance and more specifically to follow-up requirements (articles 192 to 197). It is specified that:

- The tank should be maintained and inspected by properly qualified persons and that this inspection should include the walls and the enclosures (« fences »).
- A good practice consists of planning the operations on the different components by giving details on the contents, the inspection intervals and the maintenance work. Particular attention should be paid to periodic inspections of the electric equipment and to the operations on insulation valves. There should be regular cleaning of the interceptors, of the bunds, vents, slop tanks, transfer installations… The fire protection equipment should be regularly maintained and tested if this is appropriate.

- The examination of the tank the pipings and the fittings should be carried out by a **competent person (an engineer specialized in inspection belonging to an insurance company or an employee with the required qualifications and experience).** An inspection plan should be approved between the operator and the competent person, including the field of the inspections and their frequency. The frequencies are determined by risk analysis, feedback from the maintenance of the tank and by the known corrosion rates.
- **Intermediate external examinations** should also be conducted.
- Recordings of the inspections are made.
- For floating roof tanks or tanks with internal roofs, particular attention should be paid to the absence of fouling or blocking of the connections of the pipings. Buoyancy of the roof or of the cover should be ensured.
- Regular inspection with view to detecting cracks and damages on the rim seal is recommended. The drainage system should also be regularly inspected in order to avoid accumulation of water.

3.2 EEMUA 159: « USER'S GUIDE FOR THE INSPECTION, MAINTENANCE AND REPAIR OF ABOVE GROUND VERTICAL CYLINDRICAL STEEL STORAGE TANKS ».

This guide aims at providing essential prescriptions relating to inspection and maintenance of aboveground vertical cylindrical storage tanks. The guide is built on practical bases and it is possible to use it without any other reference.

The EEMUA guide is produced from the construction code BS 2654 but it is specified that it may reasonably be used with any construction codes.

The following elements are found therein:

- The main degradation mechanisms and their consequences;
- The main inspection methods and check-lists of points to be checked. The distinction between:
  - Visual inspection during the round;
  - Complete external inspection;
  - Internal inspection.

  is then encountered.
- A preventive maintenance method integrating risk and costs. The method corresponds to a RBI method coupled with a preventive maintenance method based on failure probabilities (Reliability Centered Maintenance). It integrates the costs in a similar way to the risk.
- A detailed analysis of all **the sensitive parts** of a tank. Following information can be found for each part:
  - The different **possible degradation mechanisms**, the causes and the associated consequences;
  - The **detection methods** and the **acceptability criteria** to use during post-treatment;
  - Practical elements for exploitation and maintenance;
  - **Repair possibilities** according to the degradation.
- The **detailed hydrostatic test**, as well as the conditions causing it to be conducted (notable modifications);
- Recommendations on **the inspection frequencies** depending on the exploitation conditions (stored product, climate, refrigerated or heated storage, etc…).

In a first phase, the approach of the EEMUA consists of considering **three inspection steps**:

- **A routine inspection** carried out **regularly without exceeding 3 months** between two rounds by the operators acquainted with the tank and its contents. It should consist in a visual examination of the exterior surfaces. Any abnormality should be reported to the competent service.
- **An external inspection** conducted by a competent inspector. It consists in a complete visual examination of the tank during operation. **The guide specifies that the time interval between each completed inspection is less important than the quality of the achieved visual inspection.** However, the frequencies which are found in the table below are recommended. Optional checking of the thicknesses by the ultrasonic method may be carried out during this external inspection. The guide provides indicative elements for carrying out inspections with ultrasound. The guide also proposes the use of simpler, less accurate methods, but providing for a check of thickness over a vast surface (e.g.: electromagnetic method).
- **Internal inspection** is recommended. This inspection should allow determination of the corrosion rate of the container bottom, its minimum thickness and its integrity (no leak). **Its frequency depends on statutory conditions, on the experience of the industrialist on this type of tank, on the operating conditions (product, temperature, climate…) and on results of the inspections carried out during the last internal visit.** Frequencies according to the stored products are given as an indication. They are copied into the table below for a continental climate.

Two check-lists are to be found in the guide, one for the external inspection (about hundred points) and one for internal inspection (more than two hundred points).

Service condition of the storage	Current monitoring	Exterior inspection	Interior inspection
	Operator round	Complete external inspection	Inspection when empty
Heated or thermally insulated storages	3 months *	3 years *	6 years *
Crude oil	3 months *	5 years *	8 years *
Light oil products, treated water	3 months *	5 years *	10 years *
Heavy oil product not heated or thermally insulated	3 months *	8 years *	16 years *

(*) The whole of the frequencies is given for a temperate climate. The guide also gives values for tropical and desert climates.

The notions of « Risk Based Inspection »-RBI method and of « Reliability-Centered Maintenance »-RCM method are explained in the EEUMA guide which proposes combining both of these methods in order to obtain a probabilistic preventive maintenance application. The principle of the « Probabilistic Preventive Maintenance »-PPM is to **combine the inspection plans**, integrating a probabilistic risk reduction approach, **with maintenance plans**, attached to a probabilistic cost reduction approach.

The result of the PPM approach is the drawing-up of an inspection plan, of a maintenance plan and of a test plan (if possible) for each tank (or tank part) and each accessory.

The elements (flow chart and calculation values) required for performing the calculations are provided in volume 2 of EEMUA 159.

On the basis of the EEMUA 169 guide and of API 653, training sessions were set into place by EEMUA concerning inspection, interpretation of the results and determination of reliable measurements. These training courses lead to obtaining a certificate (Certificate of Capacity in evaluating the integrity of a storage tank according to the User Guide EEMUA 159). Two levels are proposed:

- level 1 is in connection with the design and the current problems encountered on the tanks, with the actions which should be applied for finding a remedy to them; the certificate is valid for 5 years and beyond this period, an examination has to be taken again;
- level 2 has the goal of better understanding the design and the operational aspects in the use of storage tanks, understanding and setting into place detailed inspection and maintenance plans, on the basis of RBI and RCM methodologies, making a selection among the different models for the maintenance of storage tanks (on the basis of duration, condition or risk), establishing budgets for inspection and maintenance tasks, programming maintenance tasks in a structured way, identical with those for shutting down the exploitation of major equipment.

3.3 GUIDE EEUMA 183[54]: « GUIDE FOR THE PREVENTION OF BOTTOM LEAKAGE FROM VERTICAL CYLINDRICAL, STEEL STORAGE TANKS »

This guide deals with the main failure mode of atmospheric tanks, the bottom leakage. It is a collection of information and recommendations aiming at improving the integrity of storage tanks.

This guide presents:

- Recommendations as regards the design of tanks bottoms;
- Detailed elements on the possible causes of leaks (degradation mechanisms);
- Elements on inspections and testing operations allowing detection of leaks during operation and upon shut-down;
- Elements on the protective methods with regards to possible degradations as well as a classification of these methods (efficiency and cost).

4. RBI METHODS

RBI methods are widely used in refineries in the United Kingdom.

A report from HSL gives the result of a comparative study conducted within the scope of a European program on applying RBI methods. On 50 companies contacted in 1999, half of them conducted studies of the RBI type. Several case studies on the basis of similar installations were then proposed to 7 industrialists from the petrochemical sector (industrialists and/or consultants in this sector) in order to show possible deviations in the results of RBI methods. The necessity of such a study appeared because of the use of many alternatives to the RBI method, with possible use of software packages marketed or developed by industrialists.

The observations from this report are repeated as such below:

1- Considerable variations in the selection of the degradation modes, a step required for evaluation;
2- Failures although considered as impossible having occurred;
3- From identical data, the evaluation of the extent of the damages is variable;
4- When software packages were used in particular for evaluating the consequences, the assumptions made did not appear clearly and the software package is finally a « black box »;
5- Assumptions on human presence (internal or external to the site), on equipment, production and activity are not transparent;
6- A certain number of methods considering the likelihood and consequences in a dissociated way. Consequently, accuracy is lacking, which may give a separate analysis of each damage and of its consequence;
7- In certain uses, there is an average between the impacts on humans, on the production, the environment, so that the impact on the safety of persons does not appear clearly and may be underestimated by the effect of the average;
8- Because of the differences observed on damages as on consequences, the finally proposed plans are variable in terms of contents and periodicity;
9- In the same spirit as the 1st comment, degradation modes were sometimes automatically set aside;
10- Although a document from HSE recommends for high risk sites that samplings be performed for anticipating the degradation modes, not many samplings are made by the industrialists;

11- Given the diversity of opinion on the degradation modes, speculative inspections may be contemplated;

12- Guides recommending inspection periodicities are used by all the participants (including SAFed, API 510, Institute of Petroleum – model code of safe practice. Pressure piping systems examination, part 13 (1993) and Institute of Petroleum – model code of safe practice. Pressure vessels examination, part 12 (1993)). But in the majority of the cases, the interval does not exceed half of the remaining service life;

13- No limit is set on the intervals taking into account history;

14- Subjective opinions based on limited information may have led to notable changes in the inspection periods;

15- Generally, the inspection periods reflected the risk. However evaluation of the risk may be very different from one site to another, with more or less conservatism in the approaches.

After these observations, HSL issues recommendations:

1- Complementary guides for evaluating damages may be able to bring more transparency to the process for evaluating damages;

2- Software packages, expert opinions, expert systems all have advantages and should be more integrated;

3- A review on how the degradation mechanisms are dealt with on the basis on uncertain data will provide better confidence in the approach;

4- Clarifications on the elements for evaluating consequences are required;

5- Transparency is necessary at the stage of evaluating consequences, notably the assumptions made;

6- Guides for the inspection may be useful as well as « samplings » for high risk sites.

ANNEX H
Presentation of the regulations and professional guides in the USA

1. GENERAL REGULATIONS FOR MONITORING DURING OPERATION

1.1 PRESENTATION OF THE MAIN ORGANIZATIONS AND TEXTS FOR RÉFÉRENCE

1.1.1 OSHA: SAFETY OF PERSONS

The Occupational Safety and Health Administration (OSHA) is an agency of the US Department of Labor. The agency is in charge of making sure that the requirements of the regulations related to work safety which represent the « framework» document for the regulations of installations using hazardous products, are observed. It issues standards (OSHA Standard).

OSHA issues technical rules (CFR for « Code of Federal Regulations ») which are the federal regulations; The latter may then be stated per State.

Among the CFR, the series of Standards – 29 CFR relates to safety. The reference text is CFR 1910 « Occupational Safety and Health Standards ». In the series of standards 1910, is found the **Process Safety Management (PSM) of Highly hazardous chemicals (29 CFR 1910.119[68])** to which are attached standards relating to specific substances (ammonia, flammable liquids…).

As regards the inspections and monitoring during operation, only document CFR 1910.119 provides relevant information on the subject. The prescriptions relative to monitoring during operation are very general and correspond to regulations « per goal ». The operator is responsible for maintaining in a safe condition, pieces of equipment containing hazardous or pressurized substances. The following impositions are specified in the section **« mechanical integrity** » (chapter j) applicable to pressurized containers and to storage tanks as well as to pipings (including the components as well as the valves), to discharge and vent systems, to emergency shut-down systems, to monitoring systems (alarms, detectors…) and to the pumps:

- The employer should write up and apply procedures ensuring maintenance of the integrity of the equipment; it is recalled in an annex (informative value) that the 1st step is the identification of the pieces of equipment (see above the field concerned by the chapter « mechanical integrity » to which are added the fire-extinguishing systems). It is also specified in an annex that criteria for the acceptability of the results should be available.
- He should make sure that adequate training be guaranteed to the personnel intervening in the maintenance of integrity, including becoming knowledgeable on the installations, the associated risks and the applicable procedures;
- Tests and inspections should be carried on the equipment, according to recognized and accepted practices.
- Their frequency should be determined in order to take into account recommendations from the manufacturers and engineering rules; the inspections may be more frequent if feedback justifies this;
- The employer should provide a complete file on the inspections and tests, including the date, the name of the person in charge of the inspection, the identification of the equipment, the description of the operations carried out and results of the operations.

29 CFR 1910.119[68] does not give more details on the nature of the inspections, their frequency, the competence of the persons carrying out the monitoring operations. It is simply specified that recognized guides should be used. However, in an annex of the document (annex provided as information), guides are cited, the application of which allows observance of the general requirements of the regulations. These guides are notably:

- The National Board Inspection Code or those of the American Society for Testing and Materials (ASTM);
- those of the American Petroleum Institute (API);

- those of the National Fire Protection Association (NFPA);
- those of the American Society of Mechanical Engineers (ASME).

These codes provide (according to the annex of CFR 29) **criteria for external inspections** of various elements, for example:

- civil engineering elements such as foundations and supports, anchoring bolts (« anchor bolts »), concrete or metal supports;
- cablings;
- lances and sprinklers;
- bends on pipings;
- earthings (« ground connections »);
- external protective linings and insulations;
- external surfaces of containers and pipings…

The guides also provide information on **methodologies for internal inspections** and formulae defining the frequencies on the basis of a calculation of corrosion rate. It is recalled that (internal and external) erosion should also be taken into account for pipings and valves. If the corrosion rate is not known, a standard frequency will be adopted. **The guides provide information on the elements to be inspected and on the complementary measurements to be conducted (thickness measurements for example).**

Part of the inspections may be carried out by local of federal inspectors. But each employer should develop procedures for ensuring the quality of the inspections.

OSHA has thus launched inspection campaigns as national actions (National Emphasis Program - NEP) or local actions (Local Emphasis Program - LEP) in order to ensure observance of regulations in different industrial sectors. The practices in various sectors may be compliant with standards (CFR 1910.xxx) or with instructions such as CPL 02-00-103 (CPL 2.103): Field Inspection Reference Manual (FIRM) or OSHA Instruction ADM 03-01-005 OSHA Compliance for Programmed Inspections as of January 1995.

Thus, acknowledging that many major accidents had an impact on the sector of **refineries**, OSHA launched in June 2007, via the **OSHA Instruction CPL 03-00-004**: - Petroleum Refinery Process Safety Management National Emphasis Program, an inspection action on refineries over two years. The inspectors of the OSHA responsible for the inspections should have minimum competence (defined by qualification levels by the OSHA Training Institute – OTI). The instruction, which defines the inspection terms, refers to different sources:

- to the instructions mentioned above;
- to the ASME codes (Boiler and Pressure Vessel Code et ASME B31 – Process Piping);
- but also to guides such as API 510, API 570, API 579 and many other API guides.
- as well to the guides edited by CCPS (guidelines for writing Effective Operating and maintenance procedures, guidelines for mechanical Integrity, guidelines for Engineering Design for Process Safety…).

Note: the underlined documents correspond to the minimum documents required for the inspectors in order to conduct their compliance analysis.

The results are presented in chapter 2.1.

More recently, in July 2009, OSHA launched a campaign of inspections in the chemical industry (« the Chemical NEP »).

OSHA also edits manuals:

- The **OSHA Technical Manual (OTM)** is a reference for information on work (according to the **Directive TED 01-00-015** as of January 1999). This document is not a substitute for the OSHA standards but is a guide for guaranteeing compliance with the regulations. The directive refers to OSHA Instruction CPL 2.103 (FIRM). The OTM includes different sections and chapters. Section 4 relates to the risks. It is divided in 4 chapters:
  - chapter 3 deals with pressurized containers. « **Pressure Vessel Guidelines »**: this section provides technical information on the types of PE, the failure modes, the examination methods and the evaluations of risks. It is set aside from our study since it does not have general elements of interest and is focused on certain categories of process equipment;
  - chapter 2 presents processes in refineries with associated risks (degradation modes) but does not include any other information of interest on monitoring during operation. It is therefore not studied in the report.
- The guide **« Guidelines for Pressure Vessel Safety »**: OSHA Directive STD 01-10-001 [PUB 8-1.5] presents information on codes for design, construction, manufacturing, inspection and tests. To this day, the study has not given the possibility of specifying whether the inspections and tests only concern manufacturing or the whole life cycle of the equipment.

1.1.2 EPA: ENVIRONMENTAL SAFETY

The Environmental Protection Agency (EPA) is an agency of the US Department of Environment. It is responsible for making sure that the requirements of the environmental regulations are observed.

The first mission of the EPA consists of producing the environmental rules required for applying the laws. In particular, EPA is responsible for applying the « environment acts » of the « Risk management Plan ». These are complete programs intended to protect the environment. In particular the EPA is responsible for issuing rules related to management of the quality of air and of waters (Clean air act and Clean water act). The Clean Air Act Amendment notably requires observance of the OSHA Standards.

The EPA is managed by a general administrator appointed by the President of the United States. The organization is represented through regional agencies (10) and local agencies.

The EPA forms inspectors for checking application of the rules in effect. The main activity of the inspectors consists of monitoring the measures (operation, monitoring and maintenance) taken by the industries for reducing the emission of products into air and into water.

EPA has set into place regulations related to petroleum products: « *Oil prevention and Response; Non-Transportation-Related Onshore and offshore facilities* » (40 CFR 112[69]).

These regulations notably govern the plans for emergency intervention of the industries. As regards follow-up, these regulations entails, for all the industries storing an amount of petroleum products of more than 5,000 L at the surface and capable of affecting North American waters, observance of the « Spill Prevention, Containment and Countermeasure » plan (40 CFR 112).

These regulations protect the North American territorial waters against oil leaks by imposing minimum monitoring and maintenance of the integrity of the storages of liquid oil products. The meaning of the terms « capable of affecting the North American waters » is left to the interpretation of the agencies of EPA which notify the relevant industries.

These industries should carry out an « SPCC » plan for the whole of their storage equipment for petroleum liquids. **The owner or the operational head of the site is responsible** for the plan**.**

This plan notably requires for compliant management of the monitoring of atmospheric storages:

- The creation of a **so-called « SPCC » program for prevention, follow-up and repairs** of equipment likely to be the location of seepages and leaks of petroleum liquids;
- **The validation of the plan** by a qualified engineer *(Professional Engineer*) familiar with the regulation 40 CFR 112. The latter may be external to the site but should have visited and examined the whole of the site;
- **Minimum monitoring** should be introduced at a regular frequency (not specified) in accordance with good engineering practices. Inspection procedures should be set up while observing at least the following conditions:
  - Each piece of equipment should undergo an **integrity test** regularly and when repairs are carried out. The frequency of these tests should take into account the volume and design of the tank (floating roof, partly buried…);
  - **Visual inspections should be combined with other non-destructive monitoring techniques** such as radiography, ultrasonics**,** hydrostatic tests, magnetic fluxes…;
  - **The foundations and storage supports** should be inspected;
  - **The exterior of the storage should be frequently checked** in order to detect any alteration of the equipment, any accumulation of product in the containment dike or further any leak exterior to the pond**;**
- **Archiving** of the justification elements for preventive, monitoring or repairing acts for each piece of equipment;

For carrying out the monitoring, **the use of the standards is advised without it being statutory.**

During inspections of the EPA, **inobservance of these rules** leads to more or less substantial fines according to the present condition of the « SPCC » plan, observance of the inspection procedures and of time limits set in the program.

1.1.3 THE DOT / PHMSA: SAFETY RELATED TO HAZARDOUS MATERIAL TRANSPORT

The Department of Transportation (DOT) and in particular the Pipeline and Hazardous Materials Safety Administration (PHMSA) are a federal agency. They are responsible for making sure that the requirements of the regulations of hazardous material transport on the North American soil are observed. In particular, they are responsible for ensuring safety relating to the transportation pipelines (pipeline) and to the pieces of equipment which are attached to them.

The PHMSA is managed by an administrator appointed by the administrator of the DOT. The organization consists of about 400 employees, 140 of which are site inspectors.

The PHMSA is responsible for applying regulations related to the transport of hazardous materials in a pipeline: « *Pipeline Safety* » (49 CFR 190-199[70]). The regulations relating to pieces of transport equipment is very prescriptive and in majority targets off-site equipment. However, the regulations are also applied to equipment related to transport such as storages feeding pipelines, on-line storages or receiving storages.

In the case of atmospheric storages, monitoring of the containers should be carried out according to the standards of API 653, the principles of which are given in 1.3.1.4.

The DOT/PHMSA regulations are therefore more prescriptive than the EPA regulations but only apply to a limited number of pieces of equipment. Thus, the manager of a site concerned by both regulations has to set up an « SPCC » plan suitable for him on the whole of the tanks and carry out specific API 653 inspections on the tanks related to the transport.

1.1.4 THE OTHER ORGANIZATIONS AND REGULATIONS

Beyond federal instances, the States develop different policies with regard to hazardous industries. Thus, in certain regulations, prescriptions may be adopted concerning hazardous equipment. As an example, certain States have decided to prohibit exploitation of riveted tanks.

On the other hand, insurance companies prescribe strict monitoring rules (for example FM Global) to their client.

Given the diversity of the recommendations, of local rules and local standards available, these elements are not studied in this report.

1.2 NOTION OF COMPETENCE – ACCREDITATIONS – RECOGNITION

1.2.1 COMPETENCE OF THE INSPECTION PERSONNEL

The inspections are carried out by **authorized** inspectors, who are certified according to the used reference system. Thus if an API guide is used, certification according to API is required. If NBIC is used, certification according to NBIC is required (cf. chapter 1.3.2).

As an example, the qualification required for using APIs is relative to a standard. It is based on an examination again taking up the contents of the standard to which are added the following conditions:

- The written examination should be carried out by a third party designated by API;
- The inspector should meet a minimum level of experience in the field of the design, of the construction, of the operations, of the monitoring and of the maintenance of the equipment. The required experience relates to the education level of the inspector;
- The certification should be renewed every three years. The written examination is not required if the inspector has carried out a minimum of inspections.
- Every 6 years, the inspector has to prove that he is aware of the novelties related to the relevant standard. The standards are updated every 5 years.

The intervening inspectors may be inspectors from specialized or insurance companies or possibly inspectors from the site (or even accredited federal inspectors).

A certain competence is required for planning, carrying out the inspections, drawing the conclusions for safely maintaining the equipment in operation.

The inspection periods and the nature of the checking operations are determined on the basis of the analyses of risks carried out by the operator, with taking into account of the recommendations from the manufacturers, of the results from previous inspections…

1.2.2 COMPETENCE OF THE PERSONNEL CARRYING OUT NDT

NDT tests are conducted by companies certified according to the ASNT (the American Society for Non Destructive Testing). This organization has been developing plans for qualifying the personnel and for certification since 1987.

1.3 PRESENTATION OF THE ASSOCIATED PROFESSIONAL GUIDES (GENERAL– NOT RELATED TO A SUBSTANCE).

The codes applied in the industry in connection with the monitoring of equipment are essentially:

- The API codes specifically relating to inspection operations:
  - API 510 – Pressure Vessel inspection code; the description included in this annex repeats the description of the report « benchmark of storages in refineries »
  - API 570 – Piping Inspection code; the description included in this annex repeats the description of the report « benchmark of pipe work in refineries »
  - API 653 - Tank Inspection, Repair, Alteration, and Reconstruction**;** the description included in this annex repeats the description of the report « benchmark of storages in refineries »
  - API 580 and 581 (general RBI methods);
  - Other APIs exist specific to valves, components on pipings, etc… which have not been integrated into this study.
- The National Board Inspector Code (NBIC);
- The guides of the CCPS - Guidelines for mechanical Integrity systems.

The API guides are presented below.

1.3.1 PRESENTATION OF THE APIS

1.3.1.1 PRESENTATION OF THE API AND OF THE PROCESS FOR UPDATING THE REFERENCE SYSTMES

The American Petroleum Institute (API) is an American national organization covering all aspects related to the oil and natural gas industry. Founded in 1919, the API has more than 400 members, ranging from large industrial groups to smaller companies, grouping both producers, refiners, suppliers, pipeline operators and maritime carriers and service companies.

The API which published its first standards in 1924, today maintains their 500 standards and practical sheets covering all the fields of the oil and natural gas industry: construction, inspection, safety, protection against fire or even of the environment. The API also publishes specifications, codes and technical publications established on the basis of good industrial practices.

For this, there are more than 700 work groups and committees covering these various fields and technical subjects. They have the purpose of drawing up, improving and updating these standards and codes.

1.3.1.2 API 510[74]: PRESSURE VESSEL INSPECTION CODE: IN-SERVICE INSPECTION, RATING, REPAIR AND ALTERATION

This American guide allows the elaboration of an inspection plan for pressurized containers by an « Authorized Inspection Agency ».

It is based on the RBI method presented in API 580, the practice of which is detailed in the API 581. The whole of the document refers to these texts.

It may be considered that this guide is the American equivalent of DT84 for the RIS.

The contents and the method for elaborating the plan are similar. This is a collection of recommendations intended for a competent inspection service for carrying out a plan for inspecting pressurized containers. It is a basis which may be used without applying the whole of the RBI method. However, the latter is strongly recommended.

In this guide are found:

- elements for construction, setting into place and revision of the inspection plan;
- elements on the different steps of the monitoring (round, internal, external inspection;.);
- elements on the frequency of the monitoring in the case when an RBI method is not used;
- elements on the evaluation of the results of the inspections;
- elements on the methods for repairing pressurized containers;
- details concerning particular families of equipment.

The inspections are naturally broken down in the API guide differently than in French regulations.

Two monitoring steps will be found:

- an **external inspection carried out at most every 5 years associated with thickness checking operations for the walls, the frequency of which is not specified.**
- an **external inspection associated with an internal inspection or an inspection during loading (« *on-stream* »). The frequency of this inspection is of at most 10 years.**
- This value may be reduced if the remaining service life of the equipment is less than 20 years. In this case, this value is divided by two in order to obtain the maximum inspection frequency. The remaining service life corresponds to the difference between the measured thickness and the minimum design thickness divided by the corrosion rate.

The principle of the inspections is given below:

- **The external inspection** consists in **visual examination** of the whole of the apparatus**.**
- **The internal inspection** consists in carrying out a **complete visit of the inoperative apparatus.** The internal corrosion rate is then evaluated, the thickness measured and the remaining service life of the apparatus may be calculated. The visit may also give rise to revising the interval between two internal visits.
- An alternative method may be used for calculating the interval between two internal visits. It is recommended to calculate the maximum admissible pressure by means of a computation software package consistent with the design code of the ASME. The thickness used in the calculation is the thickness measured during the last internal visit, from which twice the thickness lost from now until the next inspection (by retaining the present corrosion rate) is removed).
- **The internal inspection may be replaced by an inspection during loading (« on-stream »)** if internal access is impossible. However if access is possible, the replacement may be accomplished subject to meeting the following conditions:
    - the measured corrosion rate is less than 0.125 mm / year;
    - the calculated remaining service life is more than 10 years;
    - the corrosiveness of the product and of its components in the container (also traces) has been known for at least five years;
    - the external visit does not report any problem;
    - the container operates at a temperature below the material failure temperature;
    - the container is not subject to cracks or damages due to hydrogen;
    - the container is not temporarily reinforced in any way (patches…).

    The on-stream inspection should allow verification of the whole of the sensitive points of the apparatus by using suitable non-destructive tests (NDT).
- **The hydraulic test** is only recommended in the case of an intervention and may possibly be replaced by a NDT test.

In the guide of the API, the RBI method is widely recommended, without being compulsory, its use implies that there is no limit to the intervals between the inspections. These intervals are determined by the method.

The guide API 581 is a book with which management of inspection on the basis of the risk of equipment of the oil industry may be applied in its integrality. Notably, the calculation of the criticality of the pieces of equipment, the central element of the method, is determined for each type of equipment and for each degradation mode.

	API 510
External inspection	5 years and no set limit if RBI
External and internal or over-stream inspection.	Max. 10 years or half of the remaining service life and no set limit if RBI

1.3.1.3 API 570[75]: Piping inspection code

This guide applies to the inspection, the repair, the modifications and the reclassification of metal pipings used in refineries and in the chemical industry which convey hazardous products (hydrocarbons, flammable, toxic products…). It is intended for inspection services certified by API according to the provisions of its annex A. It is completed by the guide API 574 « Inspection of Piping System Components » which describes the recommended practices.

The guide also regularly refers to the RBI approach presented in API 580 and described in detail in API 581. With it, it is possible to establish an inspection plan for pipe work.

- inspection of most of the singular points (injection point, dead-legs, thermally insulated pipings, ground/air interface) and of certain specific degradation modes;
- thickness measurements (localization of the points, methods, exploitation of the results);
- pressure tests;
- checking the quality of the materials during repairs and modifications and their traceability;
- inspection of valves, welds, flanges;

API 570 recommends maximum inspection periodicities depending on the hazardousness of the conveyed products distributed in three classes (from 1 the most hazardous to 3 the less hazardous). The classification is based on potential consequences in the case of a leak, in terms of safety (explosion, fire, toxicity) and of the environment. Nevertheless, the guide leads the opportunity to the inspection service to increase or reduce these periodicities depending on the results of an RBI analysis according to API 580.

Type	**Thickness measurements**	**External visual inspection**
Class 1	5 years	5 years
Class 2	10 years	5 years
Class 3	10 years	10 years
Injection points	3 years	According to the class
Ground/air interfaces	-	According to the class

For corrosion under insulation, API 570 also recommends, depending on the classes of pipings, the proportions of lines to be inspected with NDT, or for which insulation is to be removed. As earlier, these values may change in the case of application of an RBI approach according to API 580.

Part of the guide is dedicated to exploiting the results of the inspection in order to:

- determine the remaining service life, the long term and short term corrosion rate, the admissible maximum pressure, etc.;
- evaluate maintenance in operation with reference to API 579;
- analyze the thermal and vibratory stresses experienced by the pipework.

Finally, the guide dedicates a chapter specifically to the inspection of buried pipings. Like for aboveground pipings, a maximum inspection periodicity is proposed depending on the resistivity of the ground in the absence of cathodic protection.

1.3.1.4 API 653[74]: TANK INSPECTION, REPAIR, ALTERATION, AND RECONSTRUCTION

This guide is intended for the inspection service in order to carry out the essential prescriptions relating to the inspection and maintenance of tanks **built from the code API 650** but it is specified that it may be reasonably used for the whole of the construction codes. Different from PE guides, API 653 integrates into the approach, practical parameters. Indeed, the following elements are found in the guide:

- **Known failure modes** are detailed and **acceptability thresholds** are defined;
- The main **means for inspecting and evaluating the damage are presented;**
- A short description of **means for inspecting** and evaluating damages;
- A detailed list of points to be checked during the inspection of a tank. This part is very detailed and very practical. The distinction is notably found between:
    - current monitoring;
    - exterior inspection;
    - corrosion analysis by thickness measurements by ultrasonics;
    - an interior visit.
- Recommendations on the **inspection frequencies** according to the knowledge of the yearly corrosion rate of the tank;
- Recommendations are found with regards to **repair and reconstruction;**
- A **hydrostatic test** is required in the case of a major modification;
- **Methods** are provided in the case of the use of an **RBI and/or FFS method;**
- The elements required for **certification of the inspectors** and **qualification of inspection operators** are again found**.**

The **notion of Risk Based Inspection method and of Fitness For Service method is explicit** in the API guide which refers to the publications 579, 580 and 581 of the same organization. Thus, the API guide gives preference to these methods in terms of selection of the type of inspection, of their frequency, and of the occurrence of the hydrostatic test.

In terms of inspection, the following steps are again found:

- **<u>A routine inspection</u>** carried out **at least once a month** by operators acquainted with the tank and its contents. It consists in a visual examination of the exterior surfaces. Any abnormality should be reported to an inspector.

- **An external inspection** conducted by a competent inspector. It consists in a complete visual examination of the tank in operation. It should be carried out **at most every 5 years** if the corrosion rate is not know. **If the corrosion rate is known, this value is modified** as indicated in the table below**.**

- **Optional checking of the thicknesses** by the ultrasonic method. The relevance of this inspection is left to the discretion of the operator. If the latter is carried out, this should be done **at most every 5 years** if the corrosion rate is not known. If **the corrosion rate is known, this value is modified** as indicated in the table below, it should **never exceed 15 years**.

- **An internal inspection** is recommended**.** This inspection should allow determination of the corrosion rate of the bottom of the container, its minimum thickness and its integrity (no leak). **The frequency of the inspection depends on the corrosion rate and on the thickness of the bottom** which have been determined during the last internal visit. In the case when **the corrosion rate is unknown, the interval between two visits should not exceed 10 years**. **The interval should never exceed 20 years.**

In the case when an RBI method is set into place, the maximum interval between two visits is inferred from the method. The latter, presented in the guide and developed in API 581, allows this period to be extended by considering the whole of the information and of the known damage factors.

Two check-lists are provided in the guide, one for external inspection (about a hundred points) and one for internal inspection (more than two hundred points).

Operating condition of the storage	Current monitoring	Exterior inspection		Interior inspection
	Operator round	Inspection by an authorized inspection service	External monitoring by ultrasonics	Inspection when empty
N known	Maximum 1 month	Minimum between 5 years and RCA/(4*N)	Minimum between RCA/(2*N) and 15 years	Minimum between RCA/N and 20 years (*)
N unknown	Maximum 1 month	5 years	5 years	10 years (*)

RCA: remaining thickness **=** last inspection thickness – minimum thickness required by the code

N: yearly corrosion rate

(*): These frequencies should be considered in the case when there is no RBI method set into place. In such a case, the limits are set by the method.

1.3.1.5 API 580[72] AND API 581[73] – RISK BASED INSPECTION

API 581 was initially developed for pressure equipment (PE) but may be used for non-pressure equipment. The version 2 of 2008 also integrates pieces of equipment such as monitoring systems, critical utilities, instrumentation…

Its goal is to allow hierarchization of the actions to be led and reduction of the costs while focusing on equipment with the highest risk.

API 581 is to be used in parallel with API 580 which provides the general principles for defining inspection plans in petrochemical plants, refineries and chemical plants. API 581 provides quantitative data while API 580 remains on very general concepts.

API 581 – the September 2008 version is a revision of API 581 of 2000. In the latter, qualitative or semi-quantitative approaches were developed in parallel with a quantitative approach. Evaluation of the seriousness was also developed in this new version, with the appearance of certain weighting factors.

The principles are developed in annex K.

1.3.1.6 API 579[77] – FITNESS FOR SERVICE

Reference will be made to annex L of the general report for more details on this guide, the goal of which is to specify whether a flaw located on a piece of equipment is compatible with its being maintained in operation.

1.3.1.7 API 750[78] – MANAGEMENT OF PROCESS HAZARDS

This guide delivers recommendations for setting into place a specific management system having the purpose of preventing the occurrence or minimizing the consequences of a loss of containment of hazardous substances. It gets closer to the requirements of OSHA relating to process safety management (29CFR 1910 119) described earlier.

Like PSM, it integrates a specific chapter on « mechanical integrity ». The fields covered by section 8 « assuring the quality and mechanical integrity of critical equipment » of API 750 relate to the manufacturing, the installation, the maintenance, the tests and the inspection of the critical pieces of equipment which may be pressurized containers, storage tanks, pipings, decompression systems, emergency shut-down systems, monitoring systems, alarms or interlocks.

API 580 describes the interactions which should exist between the RBI approach and OSHA 29CFR 1910.119 or API 750 and the contribution of RBI in improving PSM as regards the « mechanical integrity » aspect.

In France, SGS which has a similar goal to that of PSM, does not integrate any equivalent requirement in terms of maintaining the integrity of critical pieces of equipment.

1.3.2 PRESENTATION OF THE NBBPI[79]

The National Board of Boiler and Pressure Inspectors was created in 1919 with view to promoting uniformization in the construction, exploitation and follow-up of pressure equipment.

It consists of inspectors responsible for checking consistency with regulations relating to pressure equipment.

The NBBPI notably has the missions of:

- Promoting with the authorities the necessity of developing new standards,
- Setting into place training programs for inspectors and professional pressure equipment;
- Delivering qualifying training sessions through a training curriculum under the responsibility of the National Board;
- Accrediting inspectors for repairs, modifications and monitoring during operation, at the end of a training curriculum / validation:
    - Within federal inspection agencies (**Federal Inspection Agencies - FIAs**): the agencies should meet the requirements of NB-390[37] and then request NB-393[38].

---

[37] NB-390 – Qualification and Duties for Federal Inspection Agencies

[38] NB-393 – Application for NB certificate of accreditation for FIAs

- within specialized organizations « **Inservice Authorized Inspection Agencies** » i.e. Inservice inspection AIAs). For example, the following companies belong to the Inservice inspection AIAs: the ACE American Insurance Company, American Boiler Inspection Service Inc, Arise Incorporated, Cincinnati Insurance Company, etc…They should meet, for monitoring aspects during operation, the requirements of NB-374[39], NB-381[40] and NB-372[41].
- or within the operator (« **Owner-User Inspection Organizations** » or OUIO); in this case in order to be described as a OUIO, the organization should establish inspection plans and meet the requirements of NB-371[42] on the inspection organization and procedures. In order to be further accredited by the National Board, the requirements of NB-234[43] should be met. For example, the following companies have a OUIO: ConocoPhillips, CITGO Petroleum Corporation, Chevron products, the Dow Chemical Company, ExxonMobil Joliet Refinery, BP Cherry Point Refinery, etc.

- Developing codes relative to the installation, the repair, the modifications and the inspection of the pieces of equipment (National Board Inspection Code).

The NBIC code is a guide for the use of inspectors in order to maintain the integrity of pressure equipment and of boilers. It consists of 3 parts:

- Part 1 relates to the installation;
- Part 2 relates to the inspection;
- Part 3 relates to repairs and modifications.

Part 2 presents for pressure equipment, pipings, valves:

- The inspections to be carried out: it presents the check points for external, internal inspections, the associated safety devices;
- Degradation modes;
- Non-destructive testing techniques.

Reference may be made to the guide for more information on the areas to be monitored and on the techniques which may be used. The guide gives no indication on the periodicity of inspections.

1.3.3 PRESENTATION OF THE CCPS

The CCPS (Center for Chemical Process Safety) was created in 1985, following the BHOPAL accident;, by the AIChe (American Institute of Chemical Engineers). The organization then included 70 companies and there are now more than 100 of them from the chemical, oil and pharmacy sector… Its goal is to promote safety by drawing up state of the art and management guides. The CCPS issued a 1st guide « Guidelines for Hazard Evaluation procedures » and then other guides in order to improve safety.

Among these guides, the « Guidelines for Mechanical Integrity Systems » is designed for helping the operators in designing, setting into place and improving programs for maintaining integrity (« Mechanical Integrity » (MI)). The guide (version 2006) further includes a CDROM with analysis and information media. The guide provides tools of a methodological order. The contents of the guide are not detailed in this report.

---

[39] NB-374 – Checklist of quality program Elements for Accreditation of AIAs

[40] NB-381 – Quality program Elements for AIAs accredited to NB-369

[41] NB-372 – Application for Certificate of Accreditation

[42] NB 371 – Accreditation of Owner-User Inspection organizations

[43] NB-234 – Application for owner-User Certificate of Accreditation

The guide was written for chemical process industries but may be applied to any type of industry. Also, although drawn up in the United States, the guide is sufficiently general so as to be applicable to any country. It is not intended to give elements in order to be compliant with regulations but it contributes thereto indirectly.

The document is organized in this way:

- Chapter 1: Introduction,
- Chapter 2: Responsibility,
- Chapter 3: Selection of the equipment,
- Chapter 4: Inspection, tests and preventive maintenance,
- Chapter 5: Integrity management program (IM),
- Chapter 6: Procedure for IM,
- Chapter 7: Quality Assurance,
- Chapter 8: Managing flaws of the equipment,
- Chapter 9: Management of specific pieces of equipment (fixed equipment, valves, SIS, rotating equipment, pieces of electric equipment, fire protection systems, miscellaneous…). In this part the documents are specified, those which serve as rules of good engineering or monitoring practices for each type of studied equipment (Recommended and generally accepted good engineering practice – RAGAGEP).
- Chapter 10: Application of the IM programs,
- Chapter 11: Risk management tools,
- Chapter 12: Continuous improvement of IM programs.

1.4 PRESENTATION OF THE PROFESSIONAL GUIDES AND STANDARDS SPECIFIC TO LPG (ABOVEGROUNG PRESSURIZED TANKS)

This chapter presents guides of good practices used in the USA, issued from associations of professionals, for installations handling and storing LPG.

The identified guides of good practices are:

- API 2510, 8th edition[80] and API 2510A, 2nd edition[81]; the latter are detailed below.
- NFPA 58, 2004 edition => this guide does not apply to fixed industrial facilities and does not provide much information on monitoring; it is therefore not retained.

API 2510 and 2510A more specifically deal with LPG. While API 2510 gives the minimum requirements for designing and building installations for storing and handling LPG, API 2510A is focused on means for fighting against fire.

- API 2510, 8th edition (May 2001) deals with the design, the construction and implantation of LPG storage installations on harbor terminals and pipelines, on sites handling natural gas, on refineries, petrochemical sites or hydrocarbon depots. The standard covers storage, loading/unloading activities, transfers through pipelines and associated equipment.

  This standard does not apply for the design or construction of underground storages, buried or half-buried tanks or aboveground storages with concrete shell[44].

[44] This guide therefore does not apply to installations covered by
- NFPA 58 and NFPA 59,
- the reservoirs of the US Department of Transportation (DOT),

API 2510 essentially relates to the design and to the construction and does not include any interesting information concerning monitoring of equipment during operation. **It will therefore not be studied within the scope of this report**. However, reference may be made thereto for information concerning the design (codes applicable to the tanks but also rules for the supports, the foundations…). The good practices presented in the document are considered as pre-requisites for ensuring safety of LPG storage installations.

- API 2510A, 2nd edition (December 1996) covers the design, the exploitation and the **maintenance** of LPG storage installations from the point of view of preventing and controlling leaks, from the design of fire protection and measures for controlling fire. **Section 4: Procedures for maintenance are of interest to us in this report.**

  Several pieces of equipment are discussed:

  - **The tanks**

    It is recalled that the tanks have to be inspected and maintained by observing applicable codes, standards and regulations.

    The tanks should be periodically inspected in order to make sure that internal and/or external corrosion is absent or that other causes of failure are absent. As LPG is by nature not corrosive, the periods between the inspections may be spaced out by **several years.** It is the history or on-stream monitoring techniques (« on-stream ») which should determine the adequate periodicity. **Reference is made to the guide API 510**.

    Accesses should be provided at the external structure of the tank. If the tank is covered with lining (insulation for example) preventing access to the metal structure, accesses to the structure should however be possible in different locations of the tank. However, if the lining is impervious to the penetration of humidity (« moisture ») it is not necessary to remove portions of the lining. But a regular visual inspection of the lining should simply be ensured.

    Recordings of the inspections should be kept.

  - **The associated accessories, including the pressure relief devices**

    The safety systems mounted on the tanks should be maintained and regularly tested to ensure that they operate properly. Recordings of alarm tests or of other safety systems should be kept.

    The valves, the depressurization systems, the emergency shut-down loops, the anti-return valves (« back-flow check valves ») or other systems should also be regularly tested at a frequency defined according to the risk associated with the failure of these systems and according to feedback. The operating conditions should be safe (see API 576).

    A particular attention should be paid to the insulation devices between the tank and the pressure relief devices. A procedure should make sure that the insulation valves are in a safe position (servo-control devices…).

- the reservoirs of less than 2,000 gallons (7570 L),
- the sites of gas utilities, the pieces of equipment of a refinery process or of a refinery or of a gas plant, the upstream transfer systems for LPG storage.

- **Case of structures with flame-retardant**

  Flame-retarded surfaces have to be periodically inspected in order to reduce the risk of failure of the structure in the case of corrosion under the flame-retardant. The openings or the cracks on the lining which may allow introduction of humidity (« moisture ») have to be repaired. For vertical surfaces (legs of the spheres for example) protection should be provided at the design stage in order to prevent penetration of water. If failures of the lining are noted, the latter should be partly removed and repaired. The surface to be protected should be coated with anti-corrosion paint and then covered with the flame-retardant lining.

A paragraph relates to making the tank safe before or after intervention. It is not developed in this report.

2. PRACTICES

2.1 RESULT IN THE REFINERIES

The refineries a priori follow the professional guides of the API.

As stated in chapter 1, OSHA launched a national plan for inspecting 42 refineries in 1997 (over two years) in order to make sure that the Process Safety Management (PSM) was compliant with the requirements. The results show that the mechanical integrity section being subject to the largest number of non-compliances (more than 400). Failures on the inspections and the tests were noted in 198 cases (inobservance of the codes of good practices such as the APIs, readings of thickness measurements not consistent with what is defined in the inspection plan, absence of checks on certain critical lines…), failures in pieces of equipment noted in 95 cases (unacceptable operating conditions were reached without this leading to corrective measures), and failures in the writing-up of procedures in 77 cases (notably relating to the lack of procedures for monitoring critical pipings with possible corrosions under insulation, absence of procedures for monitoring safety equipment, absence of inspection planning…).

To this day, no practical information has been provided via the Eu-VRI questionnaire (no reply from refineries).

2.2 ATMOSPHERIC STORAGES

2.2.1 APPLICATION OF THE REGULATIONS

Several regulations may be involved on a same site. Indeed, to the general OSHA regulations may be added prescriptions from EPA and from DOT/PHMSA. It seems that coordination between the agencies responsible for applying each of the regulations is not always easy.

In terms of inspection, the number of inspectors seems to be insufficient for checking application of the regulations. In particular, the statutory specialization of the inspectors does not allow simple coupling between an OSHA and EPA inspection. This factor considerably reduces the possibilities of supervision of the industrialists. The administrative services should therefore prioritize their actions on the sites which appear to be the most critical.

2.2.2 THE STANDARDS

The regulations (except DOT/PHMSA) do not impose the use of a particular guide but recommend the use of standards. There exists a large number of standards produced by American professional associations such as API, ASME, ASTM or further NFPA.

It seems that, regarding monitoring of atmospheric containers, API 653 is the one used in majority.
In particular, it was adopted in 7 States as a main reference for the administration.
The standards of the API have a life-cycle of 5 years before revision, which favors their being maintained at a high technical level. Further, they are accredited by the American National Standards Institute.

2.2.3 THE INSPECTION

Generally, a method close to the API 653 method is carried out.

In terms of inspection, the following steps are again found:

- **Routine inspection** by operators;
- **External inspection** conducted by a competent inspector;
- **Internal inspection** is carried out depending on the degradation level at most every 20 years.

In terms of periodicity of the inspections, if most operators state that they observe the frequencies of API 653, various options for modifying these frequencies are sometimes used:

- The RBI method does not seem to be used very much in petroleum depots but is used more in refineries given the required skills and personnel. It gives the possibility of postponing without any fixed limit the internal visit of a container (beyond a period of 20 years).
- When the corrosion rate is not known, API suggests opening the container every 10 years. Certain petroleum groups have decided to set up a method based on control equipment. Subject to high similarity, the corrosion rate of the control equipment is assigned to pieces of equipment which are not very well known. With a safety factor related to knowledge on storage equipment, a similar method is proposed in API 653. By this method, the limit of 20 years is kept.
- Acoustic emission is a priori not used very much and no operator seems to postpone the standard limit of 20 years by this means.

It seems that for the REX related to the inspection, there is a gap as regards the sharing of the learning lessons, i.e. REX sheets produced by various professional or administrative group. The REX is mainly internal to the group.

On the level of carrying out the inspections, the industrialists have involved many external companies. It seems that this market is very competitive.

ANNEX I

Presentation of the regulations and professional guides in Germany

1. GENERAL REGULATIONS FOR MONITORING DURING OPERATION

1.1 PRESENTATION OF THE MAIN REFERENCE TEXTS

In Germany, the regulations are elaborated on a federal level and the observance of their application is under control by the Länder.

Federal reference documents as regards monitoring of equipment are:

- **Störfall-Verordnung of June 2005[82] (12th Ordinance on the Implementation of the Federal Immission Control Act (Major Accidents Ordinance – 12. BImSchV)): this is the federal transposition of the 2003/105/EC directive (amendment of the Seveso II Directive).** This text recalls the operator's obligation of preventing major risks and of making sure that his installation meets the requirements of the state of the art, which assumes permanent development of knowledge and technologies. Without this being explicitly stated in the text, it is notably assumed that the operator maintains his installation over time, in order to guarantee the maintaining of safe installations. Adequate maintenance of the installations should be carried out. In the safety reports, the operator should demonstrate that the monitoring operations give the possibility of maintaining the installations safe. He notably should (article 12) keep available to competent authorities, the documentation certifying inspections on the installations, regular maintenance, tests of the safety systems, repair operations… In the SGS (« Safety management System »), the operator should specify the procedures set up for guaranteeing safety (maintenance plans, organization, responsibility of each person, management of sub-contracting…) (annex III).
- **The Betriebssicherheitsverordnung[83] - Ordinance on Industrial Safety and Health – BetrSichV – September 2002 (Ordinance concerning the protection of safety and health in the provision of work equipment and its use at work, concerning safety when operating installations subject to monitoring and concerning the organization of industrial safety and health at work).** This text is the transposition of the directives relating to health and safety at work (directives 95/63/CE, 1999/92/CE, 2001/45/EC). **This text includes many requirements toward monitoring of equipment. It notably applies to pressure equipment (pressurized containers and pipings containing hazardous fluids45) but also to other installations (containers for storing flammable liquids, filing stations**…. These requirements are taken up again in the following paragraphs.

<u>Note</u>: There are no specific texts relating to the monitoring of pressure equipment, since the recent modification of German regulations. For the construction and manufacturing requirements, the reference is the « Equipment and Product Safety laws »

The regulations are always being developed: (with the Gewerbeordnung, GewO – Industrial Code), specific ordinances per substance previously existed, to which were attached technical texts.

[45] Pressurized pipings containing flammable, very or extremely flammable, corrosive, toxic or very toxic gases, fluids or vapors.

Thus among these technical rules, were found:

- TRB - Pressure Vessels (for example applicable to LPG tanks)
- TRG - Gases
- TRR - Pressurized pipework
- TRD - Boilers
- TRBF - Flammable Liquids
- TRAC - Acetylene and Calcium Carbide

The regulations are being developed in the direction of goal-oriented regulations. New rules are appearing (the TRBS, technical rules relating to safety) which will be classified according to the nature of the hazards and no longer according to the substances.

The old regulations remain valid up to December 31st 2012 at the latest.

Next, standards are applied (DIN, BSI, CEN…). In certain groups standards were developed which go beyond regulations.

1.2 NOTION OF COMPETENCE – ACCREDITATIONS – INSPECTIONS

1.2.1 COMPETENCE OF THE PERSONNEL

1.2.1.1 INSPECTION OF FIXED INSTALLATIONS

The Betriebssicherheitsverordnung specifies that the operator should carry out analyses of risks notably taking into account pieces of equipment in the neighborhood (domino effects).

As regards competence, the text specifies (section 3, article 3) that the employer should determine the nature of the required inspections, their contents, the intervals between inspections depending on the equipment. He should further himself define the expected requirements from the persons carrying out the inspections; he himself designates the involved persons.

It is defined that a competent person has sufficient technical knowledge for carrying out the inspections, notably thanks to his/her professional experience, to his/her training and to his/her present work in the inspection job.

But it is specified (section 15 – « recurrent inspections ») that all the installations subject to monitoring during operation entering the scope of the Betriebssicherheitsverordnung (majority of the installations in refineries, petrochemical industry…) should be subject to periodic inspections by an **approved organization** in order to ensure safe operation of the installations. **The monitoring methods are established by the operator on the basis of risk analysis. The contents (external, internal inspection, the check points, the acceptability thresholds…) are not imposed by regulations.** The operator then has 6 months for indicating to the competent authorities which are the retained intervals and for justifying it on the basis of documentation. **The proposed intervals are validated by an approved organization.** In the case of disagreements on the inspection intervals (the operator intending to space out the inspections), the approved organization informs the competent authorities **which then decide on the interval to be retained. It is possible to request the opinion of an approved third party organization,** the identity of which is approved by the operator, at the expense of the operator.

However, for a reduced number of pieces of equipment, the operator may decide to have the inspections carried out by competent personnel. These are « simple pressurized pieces of equipment ». There are no validation systems for these pieces of equipment estimated as being not very critical. It is the principle of the responsibility of the operator which is applied.

In Germany, there are many independent recognized organizations (the TÜV for example). These organizations are accredited via the ministries with which they operate. The majority of the approved organizations are third party organizations.

There are also independent experts recognized for the safety of processes.

In the sector of chemistry, it is possible to find accredited inspection services belonging to the company (the latter have great experience in the inspection job), but not in the sector of refineries where third party organizations are those which intervene for the inspections.

When the accredited or recognized organizations intervene in inspection, the operator should make sure that the inspections are properly carried out and he/she is responsible for the sub-contractors and for observance of the requirements.

The costs of the inspections (by competent organizations, recognized experts, or third party inspection services) are borne by the operator.

1.2.1.2 CHECKING THE PROTECTIVE SYSTEMS

Regular tests are necessary on safety equipment, such as detection of flame, gases… These tests are conducted by the operator or by the equipment supplier. In practice, these operations are no longer managed by the maintenance services of the plants. The operator is also responsible for identifying the components to be monitored and for observance of regularly carrying out of the tests. The manufacturers sometimes issue recommendations on the frequencies of tests. Within the scope of the inspection of installations subject to the Seveso II directive, the authorities make sure that the tests are actually carried out and followed up.

1.2.2 COMPETENCE OF THE PERSONNEL CARRYING OUT NDT

The accredited organizations are very generally authorized to carry out NDT.

1.2.3 CHECKING OPERATIONS BY THE ADMINISTRATION

The Länder are responsible for observance of the regulations and therefore carry out inspections on the sites.

For the Seveso sites, the frequency of the inspections is defined by regulations: it is a yearly inspection for High Threshold establishments and it has to occur at least once every 5 years for Low Threshold establishments.

For the other establishments, the frequency of the inspections varies depending on the site.

2. MONITORING CONDITIONS DURING OPERATION

2.1 REQUIREMENTS OF THE BETRIEBSSICHERHEITSVERORDNUNG[83]

Section 14 of the document includes requirements on inspections upon commissioning the equipment. These requirements are not detailed in the present report.

Section 15 specifies the requirements on the monitoring of equipment which is operating (« Recurrent inspections »), without setting any specific requirements on the nature of the inspections, the latter being defined under the responsibility of the operator.

2.1.1 PRESSURIZED EQUIPEMENT

However, for all **pressurized containers and for pipings under pressure containing hazardous substances,** the inspections should include:

- An external inspection;
- An internal inspection;
- A « force » inspection (« strength inspection »), equivalent to a strength test.

The external and internal visual examinations may be replaced by other methods.

Also, the strength tests may be replaced with another equivalent method or with NDT if the test is not feasible and/or if it is not adapted to the operating conditions.

Max. limit intervals are specified in the regulations; **the latter depend on categories defined in the regulations** of PE[46]. According to the categories[47], the maximum limit intervals are:

	External inspection	Internal inspection	Strength test
Tables 1 to 4 (containers)	2 years [48]	5 years	10 years
Tables 5[49] (pressure equipment)	1 year	3 years	9 years
Tables 6 to 9 (pipings)	5 years	/	5 years

For certain pieces of equipment (simple pressurized containers), the basis will be recommendations from the manufacturers and feedback from operation without being based on maximum limit values. Moreover, these are pieces of equipment followed by competent persons.

The competent authority may under certain conditions accept extension of the intervals between inspections if safety is ensured. **The regulations have become more flexible by introducing the justification by risk analysis.**

2.1.2 OTHER PIECES OF EQUIPMENT

For pieces of equipment other than pressure equipment, there are no longer any interval limits between inspections, nor information on the contents of the inspections. **However, validation of the intervals between inspections is carried out by an authorized organization** and finally the values of the old regulations are those which remain applied.

Operation permits also very often define maximum limit values.

For atmospheric containers of flammable liquids, acoustic emissions may be used for replacing the internal visit, but the relevance of the results and their exploitation is not unanimously approved in the profession: the application and exploitation requires a high level of experience.

---

[46] *Except for simple pressurized containers for which specific rules exist*

[47] *Respiratory and diving apparatuses are excluded from the scope of the study*

[48] *Upon reading the statutory text and the technical rule TRB514 it does not clearly appear whether the external inspection is compulsory or not for containers heated by a flame, exhausted gases or electricity..*

[49] *Except for certain containers with steam produced by recovery processes*

2.2 TECHNICAL RULES

2.2.1 PRESSURIZED EQUIPEMENT

For these pieces of equipment, the general technical rules are:

- TRB514[84] relating to Technical Rules, pressurized tanks, - Periodic inspections;
- TRB515[85] relating to Technical Rules, pressurized tanks, - inspection in particular cases;
- TRR514[86] relating to periodic inspections on pipings.

In TRB 514 (tanks), it is recalled that the goal of the inspection by the expert is to give a ruling on maintaining the equipment in a safe condition until the next inspection. It is the expert who is responsible for the conclusion. The terms of the different parts of the inspection are specified:

- The **interior inspection** may be visual and may be completed and possibly replaced with possible NDT or a pressure test. The ancillary parts of the equipment, including the safety devices are also subject to inspections including a test of proper operation for the safety devices;
- the **pressure test** may be replaced (if it is not possible because of the nature of the tank or if it is not necessary considering its operating mode) with checks for cracking by sweating or magnetic monitoring, by radiography or ultrasonics;
- the **external inspection** is a visual examination of the external surface also including examination of the safety devices (test of proper operation and comparison with the old data).

TRB 515 does not provide more practical elements but specifies the conditions requiring inspection by an expert (significant modifications of the tank, repairs, installation of a piece of equipment coming from another site …).

Also, in TRB 514 (pipings), it is recalled that the goal of the inspections by the expert is to give a ruling on the maintaining of the equipment in a safe condition until the next inspection. The inspection includes an external inspection and a pressure test. It is the expert who is responsible for drawing the conclusions. A time limit of 5 years between inspections is suggested, except for a different opinion of behalf of the inspection authority. The terms of the different parts of the inspection are specified:

- the **external inspection**, to be carried out on operating piping is a visual examination of the external surface including a check at attachment points, but also an examination of the safety devices (test for proper operation and comparison with the old data) and of connecting parts. The inspection deals with representative portions of the piping and not with its whole but all the attachment points should be checked. NDT may come and complete visual examination, in the case of doubts on the interior condition of the piping…
- the **pressure test** may be replaced by suitable NDT (if it is not possible because of the nature of the piping or if it is not necessary considering its operating mode).

For the tanks (TRR 514) and pipings (TRR 514), the expert issues at the end of the periodic inspection a **certificate** containing the data and the results of the inspections, while specifying the date of the next inspection. **In the case when flaws are reported, the expert should immediately inform the competent authorities.**

There exist then technical rules specific to given substances. These are the series 800. For example TRB 801 No. 25 explicitly concerns LPG.

This guide is not studied in this report.

2.2.2 OTHER PIECES OF EQUIPMENT

For flammable liquids, the rules are:

- TRbF20[87] relating to technical rules applicable to flammable liquids – storages; this text does not include a specific section relating to monitoring during operation of tanks of flammable liquids. It refers back to other technical rules series 600) which are obsolete today.
- TRbF 50[88] relating to technical rules applicable to flammable liquids – pipings. This text recalls that pipings for flammable liquids should be maintained so as to guarantee the safety of persons and third parties. The operator is required to maintain them in proper operating condition, including the safety devices in place; he should check these pipings with a periodicity to be defined. The text does not hardly provide any practical information on the monitoring of pipings.

3. RBI METHODS

Risk analyses are conducted by the operators for all hazardous installations including in refineries. These analyses will allow definition of the intervals between the inspections.

In the old regulations, intervals were able to be imposed. In new regulations, the intervals obtained at the end of the risk analysis are quite close to those defined in the old regulations.

However, when RBI type approaches are presented, the sought goal does not appear to be always safety but rather extension of the intervals between inspections. The authorities have identified there a point requiring vigilance.

From information collected during the inquiry, refineries in Germany do not use the API guides very much but as the inspections are carried out by third party organizations (TüV for example), the latter apply their own inspection guides.

4. FOLLOWING-UP CIVIL WORKS

The follow-up of constructive elements should be accomplished in the same way as the follow-up of process equipment. This is the responsibility of the operator.

For containment dikes, it is possible to make sure that the bottom of the pond remains intact and impervious, which for example assumes checking for the absence of growth of plants, grass…

Within the scope of managing changes, it should be made sure that the performances of the civil engineering elements are not altered (crossing of fire walls by new pipings…). Before any re-commissioning, a visual inspection should be provided.

During inspections by competent authorities, check-lists of the check points exist. The SGS should moreover have procedures with which it is possible to guarantee the existence of minimal inspections.

ANNEX J

Presentation of the regulations and the professional guides in the Netherlands

1. GENERAL REGULATIONS FOR MONITORING DURING OPERATION

1.1 PRESENTATION OF THE MAIN ORGANIZATIONS AND REFERENCE TEXTS

The statutory reference texts stem from European directives:

- Warenwet besluit Drukapparatuur[89]: this is the transposition of the Pressure Equipment Directive);
- Arbeidsomstandighedenwet[91]: this is the transposition of the Directive 89/391/EEC from the Council, as of June 12th 1989, relating to the application of measures aiming at promoting improvement in the safety and health of workers during work, this directive having been completed by the Directive 89/655/EEC from the Council, as of November 30th 1989, relating to minimum safety and health prescriptions for the use by working workers of working equipment (second particular directive in the sense of article 16 paragraph 1 of the directive 89/391/CEE). **This directive notably imposes that the employers maintain their equipment in a safe way to guarantee the safety of workers over time.**

There are more practical guides which specify the terms of the inspections including the PRD – Praktijk Regels voor Drukapparatuur[90].

<u>Note</u>: there are specific regulations for very toxic substances and highly explosive substances.

1.2 REQUIREMENTS RELATING TO PRESSURE EQUIPMENT

The classification for inspections is in accordance with the categories of the PED (article 3 of the PED).

1.2.1 INSPECTIONS: OBLIGATIONS AND RESPONSIBLITY

Monitoring of pressure equipment is compulsory. Monitoring is the responsibility of the owners. The Ministry of Work and of Social Affairs is the Ministry which then supervises the inspections: it checks that the inspections are carried out properly.

The external organizations carrying out inspections are the Dutch Council for Accreditation and the Ministry of Social Affairs.

1.2.2 INSPECTIONS: REQUIRED COMPETENCE OF THE ACTORS

Minimum competence requirements are required for persons carrying out inspections, planning them, drawing conclusions as to maintaining the equipment in operation or conducting NDT.

The competence assumes that the ISO 17020 standard has been followed and observance of the requirements defined by the « Dutch local Specific Accreditation Scheme ».

There are three ways for an operator to carry out periodic inspections:

- Sub-contracting them to an **authorized inspection agency** (« an Aangewezen KeuringsInstelling **AKI** ») in order to carry out the inspections;

- Having his own **certified inspection department (IVG)** and resorting to an authorized inspection agency (AKI) which will:
  - Validate the inspections carried out by the internal service on pressure equipment (an Inspectieafdeling Van de Gebruiker – IVG);
  - Follow the performance of the certified internal service (IVG);
  - Inspect or re-inspect part of the equipment according to the requirements defined in the law specific to the accreditation scheme relating to pressure equipment (Wet-Specifike Accreditatie Schema drukapparatuur – WESA scheme da);
- **Establishment inspectors « user inspectorates »** as mentioned in the PE directive (article 14) which may be authorized to carry out the inspections themselves. In this case, the authorization conditions are always based on the «WESA scheme » but also on the « RISA-scheme drukapparatuur (RISA: Directive-specific accreditation scheme for pressure equipment).

For conducting NDT, the requirements of the WESA-scheme should also be ensured.

They are therefore also applicable for IVG, UI and KVG. These rules are defined in the Warenwet Regeling Drukapparatuur.

1.2.3 Terms for monitoring the installations

There are three monitoring regimes:

- The **basic regime** (with intervals defined between the inspections) (cf. article 6 – Warenwet (Ministeriele) Regeling Drukapparatuur); for pressure vessels and pipings, intervals between inspections of 4 or 6 years are required. It is possible to reach 6 years, if feedback is good and does not testify any rapid degradation mechanism.
- The **regime of extended intervals** (cf. article 8 – Warenwet (Ministeriele) Regeling Drukapparatuur); it is possible to double the intervals between inspections to reach 8 to 12 years.
- The **regime of flexible intervals** (when risk based methodologies are applied) (cf. article 9 – Warenwet (Ministeriele) Regeling Drukapparatuur). The intervals between inspections may reach 16 to 18 years. It is then required to implement a RBI methodology.

The last two regimes are not applicable to all sites since they require significant knowledge and are justified when the installations include a large number of installations (see criteria in the PRD, katern 2.3).

The inspections are carried out by an **authorized** inspection service (of the authorities, either external or internal to the site). When the site carries out the inspection without being accredited WESA and RISA, there is **validation**, after inspection operations by an authorized organization. The validation deals with the results, the RBI method used, etc. (cf. annex 3 of the PRD – 2.3).

The inspections of pressure vessels generally include the following operations:

- **External inspection**: it comprises external visual inspection and possibly NDT,
- **Internal inspections**: it comprises visual examination and possibly tests with NDT. Testing with NDT may however replace the internal inspection.

- **Non-destructive testing** (NDT); non-destructive tests are not compulsory. They are defined in the inspection plan of the operator. The NDTs which may be applied are listed in the PRD regulations. If alternatives are used, they should be validated. The intervals between inspections are in accordance with the obligations of external and/or internal inspections. The NDT are performed by specialized companies **accredited** for NDT. There is no checking by a third party.
- An inspection of the **safety devices;** the inspection of the safety equipment is generally imposed by regulations, at the same frequency as the inspection of the vessels on which they are mounted. The inspection is performed after disassembly. The inspection consists in checking the settings and in checking the performances. Like for the inspection of the vessels, the inspections of the safety devices are carried out by an **authorized** inspection service (authorities, either external or internal to the site). When the site carries out the inspection, there is **validation**, after checking operations by an authorized organization. The safety devices are not changed systematically. They may undergo repairs and/or modifications of the operating conditions.
- A pressure **resistance test**. The pressure test in the form of a hydrostatic test is only performed when internal inspection is not possible (and/or when NDT methods are not feasible). The procedure meets the standards. The hydrostatic test is carried out by an authorized inspection service (external authorities or those from the site). When the site carries out the inspection, there is **validation**, after checking operations by an authorized organization.

For pressure pipings, the inspection terms are the same, except there is no internal inspection. It is then replaced by non-destructive tests (NDTs) which are carried out at the same time as the external inspection. The NDTs which may be applied are listed in the PRD regulations. If alternatives are used, they should be validated.

2. ATMOSPHERIC EQUIPMENT (TANKS AND PIPINGS)

Monitoring of this equipment is considered as being voluntary monitoring. **Work regulations simply impose to the employers that they ensure maintenance over time guaranteeing safety of the workers.**

The pieces of equipment not entering the field of PE are therefore not subject to specific inspection obligations. The operator determines the contents of the inspections under his responsibility.

The answers to the survey show that the inspection may then be carried out by the inspection/maintenance service and not be necessarily subject to validation by a third party. The inspection may include an external inspection, an internal inspection… the periodicities of the inspections vary depending on the installations.

However, for flammable liquids, there are some specific regulations which set monitoring requirements. These requirements are specified in the following chapters.

2.1 TERMS FOR MONITORING ATMOSPHERIC CONTAINERS

In order to apply the regulations, the authorities rely on the « Directive 29 for off-ground storage of flammable liquids in vertical cylindrical tanks[92] ». This textbook belongs to a set of guides intended for the authorities in order to provide practical support for applying the regulations. The directive 29 on the basis of the technical state of the art gives prescriptions, requirements, criteria and conditions which may be applied by the public authorities for controlling the inspection of atmospheric containers.

The directive prescribes the carrying out of an inspection plan and of a maintenance program following the guides. The latter has to be approved by the competent authority.

The recommendations concerning the inspection and maintenance of welded atmospheric containers are inspired from the **EEMUA 159**[53] guide. In particular, the refusal criteria cited in this guide may be directly applied independently of the construction code in effect. The directive recommends the use of the guides API 653 and RP 575 for inspecting riveted atmospheric containers.

The inspection program should comprise at least:

- A global inspection plan (type, method, frequency);
- A scheme for inspecting the bottom of the tank based on:
    - A regulated risk analysis method (Nederlandse Richtlijn Bodembescherming)
    - The « Probabilistic Preventive Maintenance » (PPM) methodology specific to EEMUA 159
    - A method specific to the industrial approved by the competent authorities.
- A scheme for inspection of the roof and of the wall based on:
    - The « Probabilistic Preventive Maintenance » PPM methodology specific to EEMUA 159;
    - A method specific to the industrial approved by the competent authorities.
- An inspection of the gaskets in agreement with the competent authorities and observing the conditions of EEMUA 159.;
- A scheme for inspecting the valves and pins allowing checking of the proper operation of the safety units and observing the following frequency limits:
    - Inspection 1 or 2 years after start-up;
    - Inspection subsequently at most every 4 years.
- An inspection of the valves with the obligation of sealing off the leaks or replacing the valves as soon as leaks are detected.
- Yearly inspection of the ladders, bearings and other similar elements.
- A yearly check of grounding connections by means of visual examination by an expert.
- A scheme for inspecting safety equipments based on risk and reliability related to the data provided by the equipment. The methodology should observe the following elements:
    - The high level alert indicators should be considered with maximum criticality;
    - A reliability goal and an inspection frequency should be established according to the risks related to safety;
    - An archiving system should be set into place for the whole of the operations affecting these elements;
    - An analysis of dysfunctions should allow adaptation of the inspection plan to these elements.

The inspection plan is validated by the administration.

2.2 TERMS OF THE INSPECTION OF THE PIPINGS

The pipings containing flammable liquids are also subject to prescriptions in the directive 29.

A yearly inspection should be carried out in order to check for:

- **Absence of collapse** in the network of ducts;
- **Operation of the valves** and other operational elements**;**
- **Absence of leaks**.

If the network is capable of being affected by corrosion, the directive recommends that an analysis of the network connected to an atmospheric container be carried out upon inspecting the wall of the latter.

ANNEX K

A few principles of the API RP 581 method

API RP 581 – 2nd edition – September 2008

Risk Based Inspection Technology

API 581[73] was initially developed for pressurized equipment (PE) but may be used for other equipment. Version 2 of 2008 also integrates equipment such as monitoring systems, critical utilities, instrumentation…

Its goal is to allow hierarchization of the actions to be performed and a reduction in the costs by focusing inspection efforts on equipment with the highest risk.

API 581 is to be used in conjunction with API 580[72] which provides guidance on developing a risk-based methodology in the refining and petrochemical,and chemical process plants. API 581 provides quantitative procedures to establish an inspection program using risk-based methods, while API 580 remains on very general concepts.

API 581 – September 2008 version is a revision of API 581 of 2000. In the previous versions, qualitative or semi-quantitative approaches were developed in parallel with a quantitative approach. Evaluation of consequences has also changed in the new version, with the introduction of certain weighting factors.

Software packages have been developed for applying quantitative methods: ORBIT by DNV, RB-eye by BUREAU VERITAS for the 2000 version. For the 2008 version, a software package was developed by the EQUITY Engineering company.

1. GENERAL PRINCIPLE

Regardless of the method used, the principle is the determination for each equipment failure of a **criticality** (risk) established from the evaluation of the parameters:

- **Probability of occurrence of the damage**;
- **Seriousness of the consequences**: the consequences may be evaluated according to the 4 parameters:
  - Effects on the on-site employees;
  - Effect on the off-site community;
  - Operational shut-down (business interruption);
  - Impact on the environment.

The potential risk is then determined as the product of the probability of occurrence by the consequence. The analysis is performed by equipment or per part of homogeneous equipment (for example, for a set of pipings in a same loop of iso-degradation, or on a part of equipment containing different phases and/or substances).

Potential accidents are then placed on a risk plot. Depending on the obtained risk more or less severe inspection plans are determined, **i.e. additional inspections are implemented if the risk is too significant.**

Note: the preliminary logic consists of evaluationg risk over a given period (until the next shut-down or the following one) and of checking, from known degradation rates (by previous measurements) or by tables (in the case of new equipment on which no inspection has been carried out), that the defined acceptability criteria are met (for example the required minimum thickness has not been attained). The principle is to consider that errors on the evaluation of the degradation rates are possible, which leads to evaluating a non-zero damage probability. By applying intermediate inspections, it is then possible to reduce the uncertainty on the degradation rates and therefore have an influence on the damage probability.

Note: there is no direct link between the number of inspections and the age of the equipment. However, the age of the equipment may be involved through formulae (for example, the relative thickness loss increases with time, so that the damage factor at a constant number of inspections increases which therefore requires more inspections in order to return to the same risk area.

2. DETERMINATION OF THE PROBABILITY OF OCCURRENCE

The method described here is that of API 581-version 2008.

The **failure probability is the product of three parameters**:

- A **generic failure frequency** stemming from data bases (such as those of Lees- 1980): the frequency is representative of the refining and petrochemical industry. It corresponds to a standard value, not necessarily corresponding to the environment and to the specific degradation modes studied in the site;
- A **damage factor**, specific to the studied equipment, insofar that it integrates the degradation modes specific to the equipment and the inspections set into place on this equipment;
- A **management system factor** which is the same for all the studied equipment and which accounts the influence of the facility's management system on the mechanical integrity of the plant equipment. With this factor it is possible to weight the probability found by a factor of 10 (either more or less).

2.1 GENERIC FAILURE FREQUENCY

The API presents for different types of equipment the generic frequencies stemming from data bases. The API thus provides generic frequencies for **4 standard** breach **sizes** (**1/4", 1", 4" and total rupture**);

For example,

- **for piping (PIPE-6) of diameter 6"**, the following frequencies are suggested:
  - Small leak: $8{,}0.10^{-6}$/year
  - Medium leak: $2{,}0.10^{-5}$/year
  - Large leak: 0
  - Full bore rupture: $2{,}6.10^{-6}$/year
  - ⇨ **Total: $3.06.10^{-5}$/year**

    The unit is expressed per unit length of piping (per foot).

- **for a tank (TANK650)**:

  The following frequencies are suggested for the roof (TANKBOTTOM):
  - Small leak: $7{,}2.10^{-4}$/year
  - Medium leak: 0
  - Large leak: 0
  - Rupture: $2{,}0.10^{-6}$/year
  - ⇨ **Total: $7.2.10^{-4}$/year**

The following frequencies are suggested for the shell (COURSE -1 to -10):

- Small leak: $7{,}0.10^{-5}$/year
- Medium leak: $2{,}5.10^{-5}$/year
- Large leak: $5{,}0.10^{-6}$/year
- Rupture: $1{,}0.10^{-7}$/year
- ⇨ **Total: $1.0.10^{-4}$/year**

2.2 DAMAGE FACTOR

The **damage factor**, specific to the studied piece of equipment, integrates the degradation mechanisms specific to the equipment under evaluation and the inspections implemented on this component; the applicable degradation mechanisms cover all the potential degradations (part 2 of the l'API), i.e.:

- **Thinning** (local and general);
- **Damaging of the linings**;
- **Stress corrosion cracking** related to the internal parameters and to the materials used (related to the substance, to the operating conditions and to the materials used); the API presents a very wide panel of possible degradation modes, and is aimed at specialists;
- **External damages** (corrosion under insulation and external corrosion);
- **High temperature Hydrogen** Attack;
- **Mechanical fatigue** (pipings only);
- **Brittle fractures**…

The API intends to pool the different calculated damage factors for each degradation mechanism in order to retain only a pooled factor. Weightings are performed (for example depending on the nature of the thinning: for example either local or general).

An overall damage factor is therefore evaluated per component under evaluation.

The damage factor involves different parameters depending on the degradation mechanism:

- For the thinning, a damage factor is evaluated from the thickness and from the calculated residual age also by considering the inspections set into place;
- For cracks under stresses, it is possible to pass through a step for evaluating the **severity** of the environment (presence of the critical substance, pH…). And then depending on the severity and on the design construction factors (for example nature of the welds), a sensitivity factor is determined. The **sensitivity** (4 classes from without sensitivity to high sensitivity) expresses the possibility that the degradation mode develops. Next tables again allow a link to be established with the damage factor as a function of sensitivity (defining a severity factor) and the damage factor.

Factors are then introduced in the sense that the identification of critical points (for example for thickness loss, the critical points are injection points, dead legs) leads to increasing the damage factor, except if specific steps for monitoring these areas are set into place.

The damage factor depends on the confidence which one may have in the assumed data (corrosion rate…). Consequently, the number of non-destructive tests and their nature give the possibility of **modifying the damage factor** considering the efficiency of non-destructive measurements. Tables are provided for each type of degradations. **The evaluation takes into account measurements already carried out and their relevance (cf. chapter 4.2).**

Further, it will be seen (cf. chapter **4.1**) that when an event is located in an unacceptable area of the risk matrix, complementary NDT will be applied which will allow to reduce the risk, while reducing the probability of occurrence by reducing the damage factor.

2.2.1 MANAGEMENT SYSTEM FACTOR

An audit grid allows an overall score to be given to the safety management system and to thereby weight the evaluations of probabilities.

A maximum score of 1,000 is possible.

A Pscore = Score/1,000 x 100 (in %) is then calculated.

The management factor is then $F_{ms} = 10^{(-0.02.Pscore+1)}$

Evaluation of the safety management is based on **13 parameters** which are repeated in the following table:

Subject	questions	points
Leadership and administration	6	70
Process safety information	10	80
Process Hazard analysis	9	100
Management of change	6	80
Operating procedures	7	80
Safe work practices	7	85
Training	8	100
Mechanical integrity	20	120
Prestart-up safety review	5	60
Emergency response	6	65
Incident investigation	9	75
Contractors	5	45
Management systems assessments	4	40
Total	**101**	**1,000**

With each parameter is associated a series of questions. The annex 2A of the API details the questions relating to each subject with their weighting.

Thus, for an average level (score of 500) the damage factor is not weighted (F_{ms} = 1); for a maximum score of 1,000, the damage factor is reduced by a factor of 10; for a score of zero, the damage factor is multiplied by 10.

3. DETERMINATION OF THE CONSEQUENCES

3.1 PRINCIPLES FOR EVALUATING THE CONSEQUENCES

The consequences evaluations, when they rely on API, are first based on recognized guides and methods[50] (dating from 1994 to 2001) for a majority of dangerous phenomena. For atmospheric dispersions, other methods are used for determining the flammable cloud sizes and the size of toxic clouds.

For a given LOC (Loss of Containment), several dangerous phenomena are possible. Event trees are used: an evaluation of the probability of each DP (dangerous phenomena) associated with a same LOC is then carried out and weighting of the consequences of each DP is performed by taking into account the probability of each DP in order to finally evaluate the consequences factor of a given ERC.

In the same way, weighting is carried out for four breach sizes, by weighting with the probability of occurrence, the generic frequencies associated with each breach size.

Detection and isolation systems and mitigation systems are taken into account (without considering the two cases associated with dysfunction and with operation). It is integrated according to the type of the detection systems (loss of pressure or flow detection or gas detection or cameras…) and to the type of isolation system (automatic isolation or shutdown system or systems activated by operators or manually-operated valves…):

- a **variable reduction factor of the release quantity of substances**; at best the presence of an automatic isolation system allows a reduction of the release by 25%. In the worst case, no reduction factor is applied;
- a **variable leak duration**, also depending on the size of the breach (the leak period naturally increasing with a reduction in the size of the breach); the leak values vary between 5 minutes (for efficient detection systems and automatic isolation systems, with a leak of 4”) and 1 hour (for ¼” leak with gas detectors suitably located or visual detection systems).

The consequence is evaluated in terms of either area or financial loss, with a direct relationship with the impacted surface.

Two methods are suggested:

- A 1st simplified method is suggested: for typical substances defined in the guide, consequence tables are proposed;
- The 2^{ne} method, a more rigorous one, is applicable to other substances not appearing in the guide. It is also applicable if the assumptions of the 1st level approach are not valid.

The API distinguishes the evaluations of the effects of flammable substances and those of toxic substances. It also considers other substances (vapor, acids…).

---

[50] The guides used are CCPS, Guidelines for Consequence Analysis of Chemical releases, 1999 / TNO, Methods for calculation of Physical effects (TNO Yellow Book) chapter 6, Heat Flux from Fires, CPR 14^{E}, 1997 / CCPS, Guidelines for Evaluating the characteristics of VCE, flash fires, and BLEVEs, 1994 / Lees, Franck P, loss Prevention in Process Industries; Hazard identification, assessment and control, second edition, 2001.

When the **areas** were evaluated for the whole of the fluids of a piece of equipment, pooling procedures are performed:

- For each type of impact (equipment or persons), the maximum area defined by the substances is retained; for effects on the equipment, only flammable fluids are moreover considered.
- The maximum value of two obtained surface area values may then be retained (effect on equipment or effect on persons).

Beyond the evaluation of the surface of the area, it is possible to evaluate **financial consequences** based on the cost of repairs or replacement, the cost of loss in production, the cost of injuries on persons and possible depollution.

3.1.1 FLAMMABLE SUBSTANCES I

For the method of level 1, the typical event trees are defined in the API, involving probabilities of ignition (immediate or delayed) on the basis of expert opinions.

It is then possible to easily express the retained weighted area associated with the flammable effects (by integrating pool fires, VCEs), in the form of a formula:

$CA = a.X^b$ wherein the a and b factors are provided in guidance tables for reference substances. The tables distinguish two conditions: instantaneous release (in the case of catastrophic rupture for example) and continuous release (in the case for example of a breach of small size). The API automatically classifies as an instantaneous release, a discharge for which more than 4,536 kg are discharged in less than 3 minutes.

In order to evaluate this consequence area, effect thresholds have been retained:

- ***On the equipment (domino effect)[51]:***
  - Overpressure: 34.5 kPa;
  - Thermal radiation: 37.8 kW/m² (pool fire, inflamed jet, fire ball);
  - Flash fire: 25% of the area defined by the LEL.
- ***On persons (injuries)[52]:***
  - Overpressure: 20.7 kPa;
  - thermal radiation: 12.6 kW/m² (pool fire, inflamed jet, fire ball);
  - Flash fire: area defined by the LEL.

Two types of areas are thereby defined:

- One for domino effects (impacts on the equipment);
- One for injuries on persons.

---

[51] As a comparison (PCIG decree as of September 29th 2005):

- *Overpressure: 200 hPa (20 kPa) = threshold of domino effects – 300 hPa (30 kPa) = threshold of very serious damages;*
- *Heat flow: 8 kW/m2 (= onset of domino effects = serious damages on the structure) 20kW/m² = concrete strength threshold – 200 kW/m² = concrete ruin threshold within a few minutes;*

[52] As a comparison (PCIG decree as of September 29th 2005):

- *Overpressure: 200 hPa (20 kPa) = significant lethal effects;;*
- *Heat flow: 8 kW/m² threshold of significant lethal effects;;*

Both areas are then processed separately.

In a certain number of cases, level 1 is not applicable and a specific evaluation of the consequences will be required. This is notably the case:

- If the fluid is not in the typical list of the guide;
- the stored fluid is close to its critical point;
- the effects of the two-phase releases, including liquid jet entrainment as well as rainout, need to be included in the assessment;
- If a BLEVE is possible (not evaluated in level 1);
- If overpressure effects generated by the pneumatic bursting of a pressurized vessel containing a non-flammable fluid need to be included in the assessment;
- If the weather conditions of the site are not those retained in the API, i.e. average conditions in the Golf of Mexico – 21°C, 75% RH, wind 12.9 km/h, stability class D, roughness parameter 30.5 mm).

Other assumptions are made (pond size of 30.5 meters by 30.5 meters in order to evaluate the consequences of a pool fire, inflammation probabilities…)

Various weightings are then carried out.

3.1.2 TOXIC SUBSTANCES

An area associated with injuries on persons, based on probit laws, is evaluated in the API.

Fighting means (water curtains…) are taken into account in the evaluations.

3.1.3 OTHER SUBSTANCES

Consideration of non-flammable or non-toxic fluids (for example steam) is also retained in order to evaluate consequences on persons.

3.2 COMMENTS

The following comments may be made:

- Consequence calculations are based on a certain number of assumptions. In the case of the use of software packages, it should be made sure that the parameters used correspond to the parameters of the site and of the investigated fluid;
- The principle of the evaluation of consequences is a weighting system, so that the consequences of total rupture are attenuated by the weighting of the probabilities. The final surface obtained is a fictitious surface which does not correspond to the maximum envelope;
- When a surface is retained, the nature of this surface should be questioned in other words whether it corresponds to an impact on the persons or on the pieces of equipment, this in order to determine according to which criterion the hierarchization of inspections is carried out;
- The method is based on the calculation of surface area, or even on financial losses. The number of potential victims is not taken into account; therefore, it is possible not to deal with priority a piece of equipment close to the boundary limits which may, in spite of a reduced area, have an impact on a larger number of persons than a piece of equipment in the centre of a unit for which the surface area even larger would not lead to impacting the persons on the outside of the site. The counting of the persons as this is done in safety report may be integrated into the evaluation.

- It would be worth clarifying the consideration of the impact on the environment through the financial parameter. Direct impact in terms of pollution (pool, soils…) does not seem to be taken into account; a more extensive analysis would be necessary, which was not conducted by INERIS for lack of time.

4. DETERMINATION OF RISKS

4.1 PRINCIPLE

Risk is the product of the probability (time-dependent) by consequence (constant function of time). Risk therefore changes over time.

The API adds the risk related to **each degradation mechanism** in order to define per equipment or equipment part, an overall risk (damage probability x consequence).

Note: sometimes industrialists distinguish the damages and process them separately.

A risk matrix is used (5 x 5 in the API) with which are associated 4 areas of risks: high / medium-high / medium / low. As the consequences may be evaluated for the impact aspects on persons (via the surface area) or for financial impacts, both matrices are possible.

A maximum risk goal which should not be exceeded is set, which depends on the investigated consequences (environment or financial impact). The acceptability of the risk is set in API 581.

Note: industrialists often develop risk-based methods, with matrices which are their own.

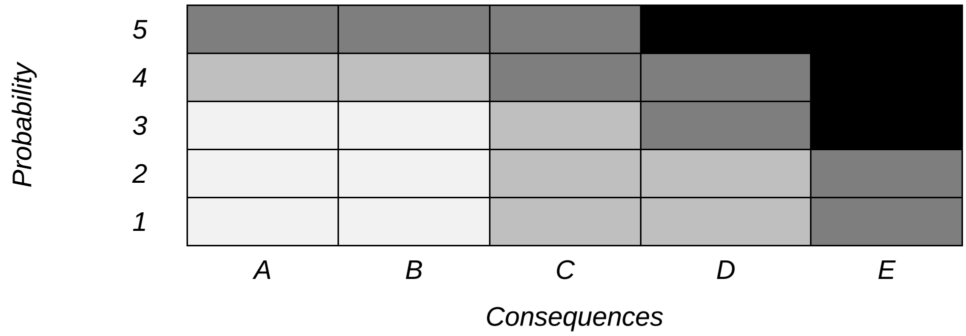
Category classes (API 581-Sept. 2008)

Probability category		Consequence category	
1	$D_{f\text{-}total} \leq 2$	A	$CA \leq 9.29\ m^2$
2	$2 < D_{f\text{-}total} \leq 20$	B	$9.29\ m^2 < CA \leq 92.9\ m^2$
3	$20 < D_{f\text{-}total} \leq 100$	C	$92.9\ m^2 < CA \leq 279\ m^2$
4	$100 < D_{f\text{-}total} \leq 1000$	D	$279\ m^2 < CA \leq 929\ m^2$
5	$D_{f\text{-}total} > 1000$	E	$CA > 929\ m^2$

Not: *$D_{f\text{-}total}$is the damage factor of the equipment.*

CA is the calculated area for the consequence (case of an impact other than a financial impact)

Risk matrix (API 581-Sept 2008)



Caption of the risk matrix

	High risk
	Medium high risk
	Medium risk
	Low risk

The principle is that the intermediate inspections give the possibility of having better knowledge on the actual condition of the equipment and thus reduce uncertainty. Therefore, the resulting failure probability is directly related to the amount of information available and provided by the inspection and also depends on the capability of the inspection of quantifying the damages.

Therefore, in RBI, reduction of uncertainty is directly related to the performance of the monitoring techniques applied. The inspection is then a parameter which allows reduction of the probability and therefore of the risk. Most often the situation before and after the inspections will be illustrated in order to evaluate the gain thereof.

4.2 EFFICIENCY OF THE INSPECTION

The inspection program **should therefore be adapted to the identified and planned damages.** The efficiency of the program depends on various parameters including:

- The coverage rate of an area subject to damages by means of NDT;
- The performances of each NDT for identifying and quantifying such or such damage, depending on the material and on the area to be covered (geometry, temperature…);
- Training and skills of the personnel for using these tools;
- Quality in the writing-up of the procedures;
- Possibility of damage as a result of abnormal operation of the installation (shut-down, triggering…);
- Quality of the analysis of the results of the inspections leading to the evaluation of general trends.

The efficiency of the inspection will be all the greater since the **amount of available information will be large** and the latter will be based on **recent data**, the condition of the equipment having been able to change as a result of modifications of operating conditions for example.

The efficiency of the inspection is evaluated in a semi-qualitative way in class A (better efficiency) to class E (no inspection). But the above factors have also to be integrated into the evaluation.

Effectiveness category of the inspection		**Description**
Highly effective	A	The inspection methods used allow identification of the actual damage in nearly every case (confidence level from 80 to 100%)
usually effective	B	The inspection methods used allow identification of the actual damage for most of the time (confidence level from 60 to 80%)
Fairly effective	C	The inspection methods used allow identification of the actual damage in half of the cases (confidence level from 40 to 60%)
Poorly effective	D	The inspection methods used do not give much information allowing identification of the actual condition (confidence level from 20 to 40%)
Ineffective	E	The inspection methods used are deemed to be inefficient for detecting flaws and giving an actual condition of the damage (confidence level of less than 20%)

The API presents **for each type of possible degradation modes, a typical efficiency table of the inspection** and then proposes for a given degradation mode an efficiency involving the type of NDT and the coverage rate for example.

For example, for the general thinning (p. 2-28):

Effectiveness category of the inspection		**Intrusive inspection example**	**Non-intrusive inspection example**
Highly effective	A	50% to 100% examination of the surface (partial internals removed) + thickness measurements	50% to 100% ultrasonic scanning coverage (either manual or automatic) or profile radiography
usually effective	B	Nominally 20% examination (no internals removed) and spot external ultrasonic thickness measurements	Nominally 20% ultrasonic scanning coverage (either automatic or manual), or profile radiography or external spot thickness (statistically validated)
Fairly effective	C	Visual examination with thickness measurements	2 to 3% examination, spot external ultrasonic thickness measurements, and little or no internal visual examination
Poorly effective	D	Visual examination	Several thickness measurements and a documented inspection planning system
Ineffective	E	No inspection	Several thickness measurements taken only externally, and a poorly documented inspection planning system

There is a correlation between the efficiency factors of maximum efficiency inspection and more numerous but less efficient inspections:

- 2B = 1A (in other words, two usually efficient inspections are equivalent to a highly performing single inspection);
- 2C = 1B
- 2D = 1C

For each degradation mode and each type of equipment, there is a specific table providing a link between the number of inspections, their efficiency and the residual damage factor.

Example: for thinning, the damage factor depends on the remaining thickness and on its position relatively to the designed thickness. If the damage factor has the value 1,200, in the absence of inspection (efficiency E), if an inspection plan allows the efficiency level B to be attained, then the damage factor is reduced by a factor of 2.

In order to plan the inspection, it should made sure that the risk threshold is not attained over a period covering **one or more shut-downs**. If this threshold is reached, an inspection is carried out with an efficiency providing sufficient reduction of the risk.

<u>Note</u>: the API determines a number of required inspections but does not define when they should be carried out. The evaluations of coverage rate refer to specific plans applied on each site, with the experience of corrosion engineers. For example, if the detailed inspection plan of the site on piping defines 100 sensitive areas on which measurement points are required, a coverage rate of 25% means that only 25 points will be subject to checking operations

ANNEX L
Presentation of Fitness-For-Service methods

This annex presents a description of the Fitness-For-Service methods: BS7910 and API 579, which are the two main guides used in Europe.

<u>Preliminary note</u>: The information in this annex stem from the document HSE "plant Ageing" and from the article of CETIM on procedures for evaluating the remaining service life of structures.

1. PRESENTATION OF BOTH GUIDES

BS 7910

BS 7910 is applicable to **metal structures** in **many industries, without being specifically dedicated to pressure equipment.** It is highly centered on flaws within welds and around welds. **The flaws specifically covered are essentially cracks.** The main procedures, repeated in three sections, concern the evaluation:

- of sudden ruptures (section 7);
- of propagation under fatigue (section 8);
- of creep crack growth (section 9).

Other damages are dealt with, such as leaks, erosion, buckling, cavitation, corrosion under stress… but are only subject to very general considerations.

The use of the guide requires expertise in fracture mechanics and knowledge of specific data, on the characterization of cracks on the one hand (like their dimensions, orientation relatively to main stresses, location relatively to the welds…), on the toughness of the material on the other hand (values from tests or from elasticity). The analyses should be conducted by qualified engineers.

The use of the guide is not limited to the use of specific design codes or from specific industries.

API 579-1 / ASME FFS-1

API 579 is centered on the evaluation of equipment in **refineries and in the petrochemical industry. It is highly oriented toward pressure equipment and notably toward those built according to the ASME codes** (Boilers and Pressure Vessel Code) **and pipings (B 31) and by the API for storage tanks.** The evaluations of the FFS are consistent with tolerances given in these codes. In particular, the 1st level analyses are based on formulae in these codes. If other codes are used, the application of FFS requires an interpretation on behalf of the user.

The different types of degradation specific to refineries and to the petrochemical industry are covered. The scope of this guide **is wider than BS 7910** which is limited to the study of cracks. Thus, the damages dealt with are:

- brittle fracture due for instance to low temperature;
- general metal loss;
- local metal loss;
- pitting corrosion and hydrogen blisters and hydrogen damage;
- weld misalignment and shell distortions;
- crack-like flaws;
- problems related to high temperatures and to creep;
- fire damage;

- dents, gouges and dent-gouge combinations;
- laminations.

It also deals with cracks but does not cover the whole of the field of cracks. Other cracks may be covered by BS 7910 but without this guide being exhaustive.

Consideration of the metal loss

Before undertaking an FFS method, it is important to **be well acquainted with degradation phenomena which may have led to a metal loss** and to identify all the degradations likely to occur and which may lead to reduction in the strength of the piece of equipment (general corrosion, local corrosion, intergranular corrosion, stresses which may cause ruptures…).

The basic principle (level 1) is to consider that the equipment has the minimum thickness measured on the whole of the check points. It may then be simply considered that if the minimum thickness is larger than the given minimum thickness in the code, the equipment remains « fit for service ». **But care should be taken that this thickness remains compatible with the most strict requirements on the particular areas (such as tappings …). Further the applicable overload should take into account the whole of the loads (pressure + overload related to the environment).**

This approach is simple but **very conservative**, notably in the case of very local thickness loss. Specific procedures exist in both guides for dealing with the cases of local thickness losses.

The remaining service life is then evaluated while taking into account the remaining margin on the thickness in order to reach the minimum thickness defined in the calculation code and by taking into account the degradation rate (corrosion or other degradation mechanisms) evaluated in a conservative way.

2. REQUIRED QUALIFICATIONS

The use of API 579 is designed for **three types of users**:

- **Level 1 corresponds to plant inspectors** having minimum knowledge on inspection and on the components.
- **Levels 2 and 3 may only be used by expert engineers.** They require collection of a lot of information on the equipment, on the possible encountered degradation mechanisms… Consequently, the investigations are carried out by a set of competent persons (process engineer, NDT examinators, corrosion specialist …). Level 3 implies more extensive calculation methods (of the finite element type) and requires more consequent computer means than level 2 and therefore specific qualifications of the persons. Generally, if level 2 already gives satisfaction, level 3 is not undertaken.

  In the USA, as a result of abusive uses of the FFS method, the US administration has set into place a license for organizations which may carry out FFS studies of level 3.

The use of BS7910 also includes three levels for the analyses of brittle fracture and of fatigue. For BS 7910, level 1 already requires extensive skills.

3. DEVELOPED SOFTWARE PACKAGES

Application software packages have been developed.

In the U.K., a software package was developed for crack propagation (Crackwise software).

In the USA, an API software package was developed for FFS.

In France, CETIM developed a software package Cetim-Secure which covers level 3 of BS 7910.

4. COMMENTS

The following comments may be made:

- For comparison between both guides API 579 and BS 7910, reference will be made for more information on the relevance and comparison between both methods, to the article –« CETIM - Evaluation of the harmfulness of cracks – comparison of the BS7910, API 579-1/ASME FFS-1, RSE-M and FITNET procedures » [16]. The flaws covered by API 579 are more general (pits for example). For damages dealt with by both guides (local metal loss), both guides give close but not identical estimations of the residual strength;
- Level 1 of API 579 does not practically require any calculation and does not have any equivalent in BS 7910. But let us recall that 1st level analyses are based on formulae from ASME, B31 or CODRES codesIt is possible to use API 579 for equipment built according to other codes, but this may required adjustments. **Adaptation requires specific competence from the users (materials have to be matched);**
- **It is generally very difficult to obtain the data required for applying the method and to know the reliability.** NDTs are not 100% certain and the required information (depth of the crack, size…) may have to be given by different NDTs having performances adapted to the size of the degradation which one intends to measure. It is wise, but this is not always applied, to conduct a sensitivity study on the considered parameters (degradation rate, dimensions of the crack…) in order to ensure stability of the conclusion drawn.

USEFUL REFERENCES

General references

1.	Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment
2.	Directive No. 96/82/EC of 9 December 1996 on the control of major-accident hazards accidents involving dangerous substances
3.	Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work
4.	Council Directive 95/63/EC of 5.12.1995 amending Directive 89/655/EEC concerning the minimum safety and health requirements for the use of work equipment by workers at work (2nd individual Directive within the meaning of Art.16 (1) of Directive 89/391/EEC)
5.	Directive 99/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)
6.	Directive No. 2008/1/EC as of 15.01.08 relating to integrated prevention and reduction of pollution
7.	IEC NF EN 61508 "Functional safety of electric / electronic / programmable electronic systems relating to safety "
8.	IEC 61511 "Functional safety – Safety-instrumented systems for the process industry sector"
9.	NF EN ISO/IEC 17025: General requirements concerning the competence of calibration and test laboratories
10.	NF EN ISO/IEC 17020: General criteria for the operation of different types of organizations proceeding with inspection
11.	NF EN 13306 – Terminology of maintenance – June 2001
12.	Evaluation et maîtrise du vieillissement industriel – collection EdF R&D – André Lannoy et Henri Procacia – Lavoisier 2005 *Translation in English : "Evaluating and managing industrial ageing"*
13.	Bilan de l'application de la DM-T/P 32510 du 21 mai 2003 concernant les dispositions de reconnaissance du service inspection d'un établissement industriel – Marc PIC – DRIRE Bourgogne (document downloaded from the Internet) *Translation in English : "*Results of applying DM-T/P 32510 of 21 May 2003 relating to the measures for recognising the inspection department at an industrial facility"
14.	Presentation note of Ed Haynes and Guy Baylac –Israël conference – September 2007.
15.	Extracts from Procédures d'évaluation de la durée de vie résiduelle des structures : pratiques industrielles - Remaining life assessments for structures: industrial practice - A. Chaudouet - Cetim - 2007
16.	Evaluation de la nocivité des fissures – comparaison des procédures BS7910, API 579-1/ASME FFS-1, RSE-M et FITNET - Anne Chaudouet – Cetim – 2007 Translation in English "Evaluating crack noxiousness - Comparison between procedures BS7910, API 579-1/ASME FFS-1, RSE-M and FITNET
17.	RIMAP articles
18.	Corrosion in refineries – European federation of corrosion – Publications Number 42 – J.G Houston and F. Rapital

References in France (statutory references and guides)	
	PRESSURIZED QUIPEMENT
19.	Décret initial du 18 janvier 1943 modifié portant règlement sur les appareils à pression *Initial decree of 18 January 1943 modified regulating pressure equipment*
20.	décret n° 99.1046 du 13 décembre 1999 relatif aux équipements sous pression, modifié ensuite par les décrets respectifs 2003-1249 du 22 décembre 2003 et 2003-1264 du 23 décembre 2003 *Decree No. 99.1046 of 13 December 1999 relating to pressure equipment, subsequently modified by decrees 2003-1249 of 22 December 2003 and 2003-1264 of 23 December 2003*
21.	Arrêté du 21 décembre 1999 relatif à la classification et à l'évaluation de conformité des équipements sous pression *Act of 21 December 1999 relating to the classification and conformity evaluation of pressure equipment*
22.	Arrêté du 15 mars 2000 modifié, relatif à l'exploitation des équipements sous pression (modifiés par l'arrêté du 13 octobre 2000 et par l'arrêté du 30 mars 2005) *Act of 15 March 2000 modified, relating to the operation of pressure equipment (modified by the Acts of 13 October 2000 and of 30 March 2005)*
23.	Décision BSEI n° 06-080 du 06/03/06 relative à la réglementation. Conditions d'application de l'arrêté du 15 mars 2000 relatif à l'exploitation des équipements sous pression *BSEI Decision No. 06-080 of 06/03/06 relating to regulations. Application conditions for the Act of 15 March 2000 relating to the operation of pressure equipment*
24.	Décision BSEI n° 08-159 du 04/07/08 portant approbation d'un guide professionnel relatif à l'établissement de plans d'inspection *BSEI Decision No. 08-159 of 04/07/08 approving a professional guide relating to the establishment of inspection plans*
25.	Décision BSEI n° 06-194 du 26/06/06 portant approbation d'un guide professionnel relatif à l'établissement de plans d'inspection *BSEI Decision No. 06-194 of 26/06/06 approving a professional guide relating to the establishment of inspection plans*
26.	Décision BSEI n° 07-107 du 13/04/07 relative au remplacement de l'épreuve hydraulique, lors de la requalification périodique de certains équipements sous pression, par un essai sous pression de gaz contrôlé par émission acoustique *BSEI Decision No. 07-107 of 13/04/07 relating to the replacement of the hydraulic test when periodically requalifying certain kinds of pressure equipment, by a pressure test using gas checked by acoustic emissions*
27.	Instruction DM-T/P n° 32510 du 21 mai 2003 relative à la « reconnaissance d'un Service Inspection d'un établissement industriel » *Instruction DM-T/P No. 32510 of 21 May 2003 relating to the "Recognition of an Inspection Service at an industrial establishment"*
28.	Arrêté du 22 juin 2005 portant habilitation de l'APAVE Groupe, de l'ASAP et du Bureau Veritas. *Act of 22 June 2005 approving APAVE Groupe, ASAP and Bureau Veritas*
29.	Guide AFIAP: « Le guide de bonnes pratiques pour les contrôles par émission acoustique des équipements sous pression » - généralités et annexe 1 de mai 2004 + annexe 3 de mai 2004 (sphères) + annexe 4 de juin 2005 (réservoirs GPL dits petits vracs) + annexe 6 de mai 2004 (équipements sous pression cylindriques) – approuvés par BSEI n°07-107 de avril 2007. *AFIAP guide: "Guide of best practices for checking pressure equipment by acoustic emissions" - General and Annex 1 of May 2004 + Annex 3 of May 2004 (spheres) + Annex 4 of June 2005 (so-called small bulk LPG tanks) + Annex 6 of May 2004 (cylindrical pressure equipment) – Approved by BSEI No. 07-107 of April 2007.* Note: Annex 8 (reactors) was not retained for the study
30.	Guide AQUAP: « Inspection réglementaire des équipements sous pression revêtus extérieurement ou intérieurement » - révision 2 – décembre 2005 – approuvé par BSEI n°06-

	011 de janvier 2006 *AQUAP guide: “Regulation inspection of pressure equipment with an outside or inside lining” - Revision 2 - December 2005 - Approved by BSEI No. 06-011 of January 2006*
31.	Guide AFIAP: « Le guide de classification des modifications ou réparations de tuyauteries d’usine soumises à la réglementation française » - février 2004 – approuvé DM-T/P n°32 969 de Mai 2004 *AFIAP guide: “Guide to classifying plant piping modifications or repairs subject to French regulations” - February 2004 - Approved by DM-T/P No. 32 969 of May 2004*
32.	Guide AQUAP: « Le guide de classification des modifications ou réparations des équipements sous pression soumis à la réglementation » - révision 3 – mars 2004 – approuvé DM-T/P n°32 969 de Mai 2004 *AQUAP guide: “Guide to classifying pressure equipment modifications or repairs subject to French regulations” - Revision 3 - March 2004 - Approved by DM-T/P No. 32 969 of May 2004*

	Other specific guides used in PE regulations (CFBP)
33.	*Procédure CFBP de requalification périodique de certains réservoirs de GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – novembre 2007 - approuvé par BSEI n° 08-032 de janvier 2008* *CFBP procedure for periodically requalifying some aboveground “small bulk” LPG tanks aged 40 or over (made prior to 1973) - November 2007 - Approved by BSEI No. 08-032 of January 2008*
34.	*Procédure CFBP d'évaluation des groupes de lots de réservoirs GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – juin 2005 - approuvé par BSEI n° 08-032 de janvier 2008* *CFBP procedure for evaluating groups of aboveground “small bulk” LPG tank batches aged 40 of over (made prior to 1973) - June 2005 - Approved by BSEI No. 08-032 of January 2008*
35.	*Procédure CFBP d'inspection renforcée de certains réservoirs GPL « petit vrac » aériens âgés de 40 ans ou plus (fabriqués antérieurs à 1973) – juin 2005 - approuvé par BSEI n° 08-032 de janvier 2008* *CFBP procedure for reinforced inspection of some aboveground “small bulk” LPG tanks aged 40 or over (made prior to 1973) - June 2005 - Approved by BSEI No. 08-032 of January 2008*
36.	*Cahier des charges CFBP pour la fabrication et l'exploitation des réservoirs GPL moyen et gros vrac – février 2008 - approuvé par BSEI n° 08-063 de mars 2008* *CFBP specifications for making and operating small and medium size bulk LPG tanks - February 2008 - Approved by BSEI No. 08-063 of March 2008*
37.	European standard NF EN 12817: LPG equipment and accessories. Inspection and requalification of LPG tanks up to and including 13 m^3 - December 2002, modified in June 2006
38.	European standard NF EN 12819 (standard being revised), LPG equipment and accessories. Inspection and requalification of LPG tanks greater than 13 m^3
	General guides for establishing inspection plans (France)
39.	Guide pour l'établissement des plans d'inspection (périodicités IP et RP 5 et 10 ans) - UIC/UFIP/CTNIIC document DT 32 révision 2 – juin 2008 *Guide for establishing inspection plans (frequency PI and PR 5 and 10 years) - UIC/UFIP/CTNIIC document DT 32 revision 2 - June 2008*
40.	Guide pour l'établissement des plans d'inspection permettant de définir la nature et les périodicités d'inspections périodiques et de requalifications périodiques pouvant être supérieures à cinq et –dix ans - UIC/UFIP document DT 84 - juin 2006 *Guide for establishing inspection plans for defining the type and frequency of periodic inspections and requalifications that may exceed five and ten year intervals - UIC/UFIP document DT 84 - June 2006*
41.	DT 75 – guide pour le choix des méthodes de contrôles des matériaux et équipements - mai 2002 *DT 75 - Guide for choosing equipment and material inspection methods - May 2002*
	ATMOSPHERIC STORAGE TANKS
42.	Arrêtés Ministériels du 9 novembre 1972 et du 19 novembre 1975: Aménagement et exploitation des dépôts d'hydrocarbures liquides *Ministerial Acts of 9 November 1972 and 19 November 1975: Layout and operating liquid hydrocarbon depots*
43.	Arrêté Ministériels du 4 septembre 1967: Aménagement et exploitation des usines de traitement de pétrole brut, de ses dérivés et résidus. *Ministerial Acts of 4 September 1967: Layout and operating plants for treating crude oil, its derivatives and residues*
44.	Circulaire BSEI 07-206 *BSEI circular 07-206*
45.	Guide pour l'inspection et la maintenance des réservoirs métalliques aériens cylindriques

	verticaux d'hydrocarbures liquides en raffinerie – UFIP – Edition Août 2000 *Guide for inspecting and maintaining aboveground vertical hydrocarbon metal cylindrical tanks at refineries – UFIP – Edition August 2000*
46.	*Note de doctrine du 15 octobre 2008 – BRTICP/2008-514/CBO : effet de vague dans les dépôts de liquide inflammables (y compris stockages au sein de sites industriels tels les raffineries)* *Doctrine memo of 15 October 2008 – BRTICP/2008-514/CBO: Wave effect at flammable liquid depots (including storage at industrial plants such as refineries)*
	SAFETY DEVICES
47.	Standard NF EN 764-7 (July 2002) - Pressure equipment - Part 7: Safety systems for unfired pressure vessels
	References in the United Kingdom (statutory references and guides)
48.	Health and Safety at Work Act 1974
49.	The Control of major Accident Hazards regulations 1999 (COMAH)
50.	Management of Health and Safety at Work Regulations 1999 (MHSWR)
51.	Management of Health and Safety at Work Regulations 1999 (MHSWR) - Approved Code of Practice (L21) – 2000
52.	Provision and Use of Work Equipment Regulations 1998 (PUWER 1998)
53.	Provision and Use of Work Equipment Regulations 1998 (PUWER 1998) - Approved Code of Practice (L22) – 2008
54.	The Pressure Systems Safety Regulations 2000 – January 2000
55.	Safety of pressure systems – Pressure systems safety regulations 2000 – Approved Code Of Practice – – L122 - HSC – HSE books - 2000
56.	EEMUA Publication 159, Users guide to the inspection, maintenance and repair of above ground vertical cylindrical steel tanks, ISBN 0 85931 1317, 3rd edition, 2003
57.	EEMUA 183, guide for the prevention of bottom leakage from vertical cylindrical, steel storage tanks
58.	SAFed Pressure systems: Guidelines on Periodicity of Examinations – November 2003
59.	SAFed- Guidelines for Competent person – In-service examination of pressure systems pipework – October 2008
60.	Institute of Petroleum – Pressure Vessel Examination – part 12 of the Model Code of safe Practice in the Petroleum industry – March 1993
61.	Institute of Petroleum – Pressure Piping Systems Examination – part 13 of the Model Code of safe Practice in the Petroleum industry – March 1993
62.	UKLPG – code of practice 1 – Bulk LPG storage at fixed Installations – Part 3: 2006 – Examination and Inspection
63.	HSG 176 – The storage of flammable liquids in tanks – 1998
64.	Guide British Standard BS 7910:2005 – Guides on methods for assessing the acceptability of flaws in metallic structures, British Standards Institution, London, 2005
65.	UKAS (United-Kingdom Accreditation Service – RG2 – Accreditation for In-Service Inspection of Pressure Systems / Equipment – draft version – February 2009
66.	Rapport HSE – Plant ageing: management of equipment containing hazardous fluids or pressure – Prepared by TWI LtD, ABB Engineering Services, SCS (INTL) Ltd and Allianz Cornhill Engineering for the Health and Safety Executive – 2006 – RR509 Research Report
67.	HSL – Risk Based Inspection: A Case Study Evaluation of Onshore Process Plant –

	HSL:2002/20 – W Geary
68.	Hazardous installation Directorate – Semi permanent circulars – atmospheric storage tank – integrity of atmospheric storage tanks (available on the HSE site)
69.	*HSE Report 'Best Practice for Risk Based Inspection as a Part of Plant Integrity Management'.*
70.	*206 Risk Based Inspection - A Guide to Effective Use of the RBI Process - 2006, ISBN 0 85931 150 3*
References in the United States (statutory references and guides)	
71.	OSHA - Regulations (Standards - 29 CFR) – 1910 - Occupational Safety and Health Standards - Subpart H -- Hazardous Materials - 1910.119 Process safety management of highly hazardous chemicals
72.	Code of Federal Regulations - **Title 40: Protection of Environment -** part 112 – oil Pollution Prevention -
73.	Code of Federal Regulations - Title 49—Transportation - CHAPTER I—pipeline and hazardous materials safety administration, department of transportation – part 190 to 199

74.	*API 571, DAMAGE MECHANISMS AFFECTING FIXED EQUIPMENT IN THE REFINING INDUSTRY, 1st edition, December 2003*
75.	API 580: “Risk-Based Inspection” 2002
76.	API 581: “Base Resource Document on Risk Based Inspection” 2008
77.	API 510: “Pressure Vessel Inspection Code” 2006
78.	API 570: « Piping Inspection Code » 2003
79.	API 653: “Tank Inspection, Repair, Alteration et Reconstruction” 2008
80.	API 579-1: “Recommended practice for Fitness-for-Service”, June 2007
81.	API 750: « Management of Process Hazard », January 1990
82.	The National Board of Boiler and pressure Vessel inspectors – National Board inspection Code – 2007 – part 2: inspection
83.	API standard 2510 – design and Construction of LPG Installations – May 2001
84.	API publication 2510A – Fire protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage facilities – December 1996
References in Germany (statutory references and technical rules)	
85.	Störfall-Verordnung dated June 2005 (12th Ordinance on the Implementation of the Federal Emissions Control Act (Major Accidents Ordinance – 12. BImSchV)): Transposition of the Seveso II Directive.
86.	Betriebssicherheitverordnung - Ordinance on Industrial Safety and Health – BetrSichV – September 2002 (Ordinance concerning the protection of safety and health in the provision of work equipment and its use at work, concerning safety when operating installations subject to monitoring and concerning the organization of industrial safety and health at work).
87.	TRB514 Relating to technical rules, pressure vessels - Periodic inspections.
88.	TRB515 Relating to technical rules, pressure vessels - Controls in special cases.
89.	TRR514 Relating to periodic controls on piping.
90.	TRbF20 Relating to the technical rules applicable to flammable liquids - storage
91.	TRbF 50 Relating to the technical rules applicable to flammable liquids - piping
References in the Netherlands (statutory references)	
92.	Warenwet besluit Drukapparatuur: this is the transposition of the Pressure Equipment Directive
93.	Praktijk Regels voor Drukapparatuur: specifies the terms of the inspections of pressure equipment
94.	Arbeidsomstandighedenwet: this is the transposition of the Directive 89/391/EEC
95.	PSG29 - Richtlijn voor bovengrondse opslag van brandbare vloeistoffen in verticale cilindrische tanks: October 2008 (Directive for off-ground storage of flammable liquids in vertical cylindrical tanks)

Note: The documents shown in italics are not covered by a detailed analysis or were not studied in this report. They are shown in view of possible later more in-depth use.