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Ageing and maintenance of industrial equipment
-
Feedback from France

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1. **National strategy and modernisation plan**

2. **Feedback from inspection campaigns**

3. **Analysis of accidents and near-miss incidents**

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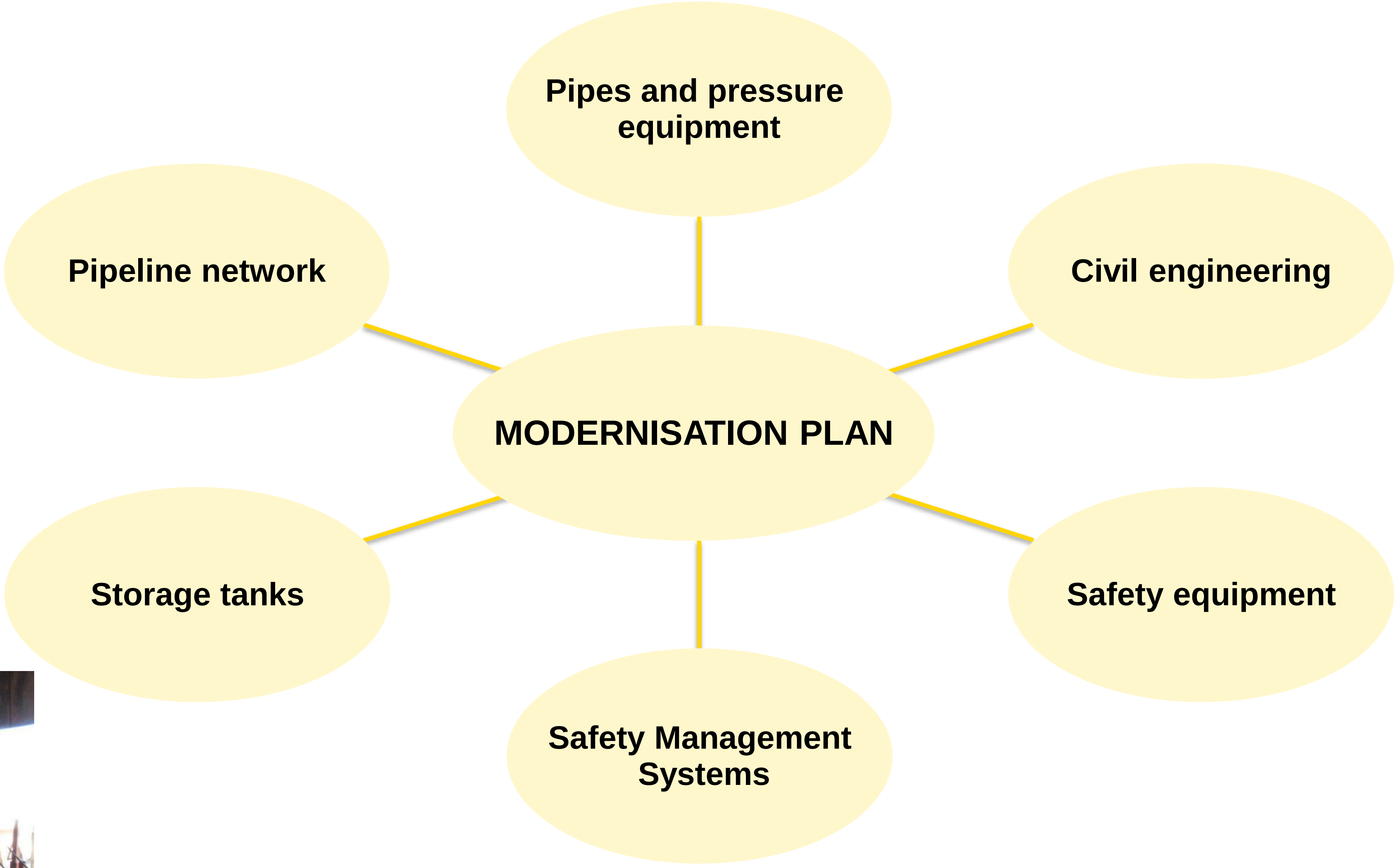
Plan for modernising industrial installations (PMII 2010)



General methodology

1. To establish an **inventory** of equipment (tanks, pipes, etc.) that could lead to a **major accident** in case of failure

2. To **assess** equipment's **initial state** (good, acceptable or damaged) and compile a **technical dossier** with all relevant information (plans, characteristics, operating conditions, photos, monitoring, repair and maintenance history, etc.)

3. To **develop** and **implement** an **inspection programme** to be conducted by the plant operator:
   - **Routine** inspection: general state, structure, possible signs of deterioration
   - **Reinforced** inspection: targeted checks and controls

4. To **establish** and **maintain** a data base for keeping track of and **record inspection results**

5. To **carry out maintenance** and repair actions

Generic and targeted regulations

- Ministerial orders:
  - **Generic requirements** for monitoring **ageing** and **carrying out maintenance**
  - **Generic requirements** for taking ageing into account in the **safety management system**
  - Specific requirements for:
    - **aboveground storage** tanks containing flammable liquids
    - **Pipelines**
    - **Pressure equipment** and pressure **vessels**

Specific guidelines and targeted inspection campaigns

- Specific national working groups (trade associations, inspectors, experts, competent authorities)
- Specific national guidelines for each area of the modernisation plant:
    - How to identify relevant equipment
    - Possible failures and degradations
    - Targeted control points and associated control methods
    - Acceptance criteria
    - Monitoring frequency
    - Timeframe for repair and maintenance action / prioritisation
- Inspection checklist for plant operators

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Inspection campaigns by competent authorities

- **2012**:
  - deadline for plant operators to **comply with the modernisation plan**.
  - First **informal inspections**.
- **2013 – 2017**: formal inspections
- **Objectives**:
  - To **verify** the **appropriate implementation** of the modernisation plan by plant operators
  - To **check** its **follow-up** in the long run
- Average number of annual inspections: ~300

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Main compliance checks for competent authorities

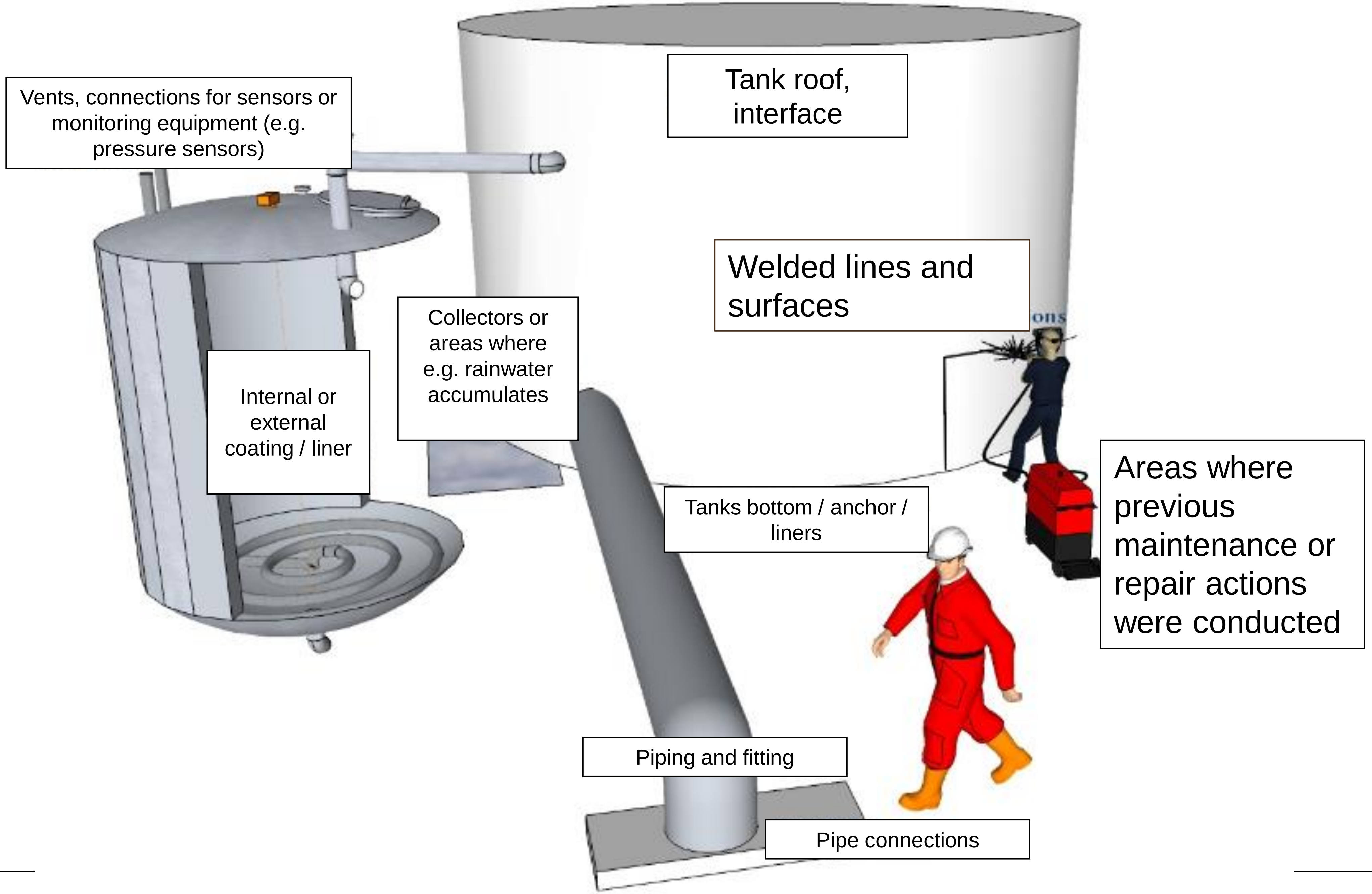
- Is the **inventory** of relevant equipment **exhaustive enough**?

- How was the assessment of **equipment's initial state conducted**? Is the **technical dossier complete**? Is it a **sound basis** for future assessments and controls?

- For each relevant piece of equipment, the following points are identified, checked and recorded by the operator: **degradation mechanisms**, **acceptance** criteria, **control** methods and **frequencies**, **repairs**

- Does the plant operator perform the necessary **controls in due time**? Is there a need to **update monitoring** and **repair frequencies**?

Example for storage tanks



Feedback from inspection campaign

- **More exhaustive** and **systematic identification** of relevant equipment
- **Improved maintenance** : maintenance actions are better **identified** and **scheduled**
- Better **understanding** of degradation mechanisms
- Improved **anticipation** and organisation for **maintenance** and **repairs**

- Technical dossiers are **not always available**, or are **incomplete**
- First assessment of **equipment’s initial state** is **not always (properly) done**
- **Maintenance** or corrective actions are **not always implemented** (or implemented in due time)
- **Outsourced maintenance**: possible difficulties/issues due to outsourced maintenance are not always identified

Lessons learnt and good practices

- Thorough and careful checks play a major role in **anticipating** and **preventing** ageing and failure of equipment

- Staff **awareness** and **involvement**: essential to involve all staff from top management to maintenance workers in the design of the modernisation programme

- Controls should be **increased** before and after plant **shutdowns** and **turnarounds**

- A good knowledge of main equipment types, and a good maintenance plan help **anticipate** the need for **replacement** and the management of **spare parts**

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BARPI
DGPR SRT
Interactive library of reference
in industrial accidents analysis

BARPI and ARIA database

ARIA
DGPR SRT BARPI

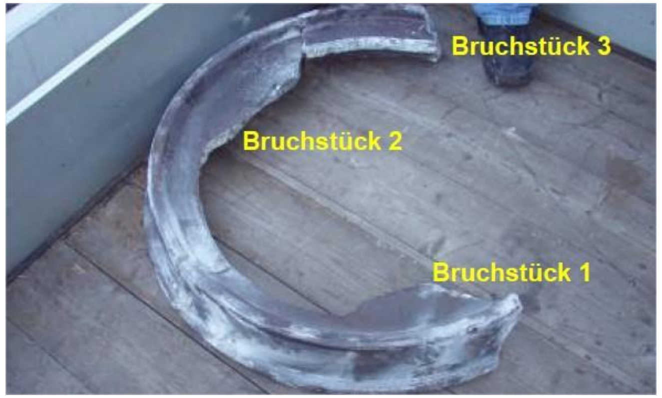
- Analysis of accidents extracted from the 'ARIA' database (Analysis, Research and Information on Accidents) database
- The BARPI: entity of the French Ministry for the Ecological Transition
- 57 000 summaries of technological accidents

- In France, **more than 2 330 accidents or near misses involving ageing** :
  - More than 1 450 in classified facilities
  - **More than 645 in Seveso plants**
  - About 300 in pipelines in Seveso plants (hazardous substances, gas, steam…)
  - About 100 associated with hazardous substances transportation (road, rail, sea…)

Causes of accidents involving material degradation

- Corrosion: 1st cause underlying accidents involving ageing of installations


- Fatigue is another recurrent cause

Accidents involving corrosion and fatigue in French Seveso plants during the last 10 years

- **215 corrosion-related** accidents: **60 %** relate to **piping,** rest to storages and tanks
- Frequent **difficulties in accessing the piping to inspect their condition**
- Difficulties to monitor due to the **significant length of sites** (or between sites)
- **Causes** of piping corrosion can be **internal** or **external**
- Most common cause of **internal tank corrosion**: **defective, inappropriate or missing internal coating**

- **About 70 fatigue-related accidents** (most commonly due to excessive vibrations)

Recurrent failures leading to corrosion

- **Inappropriate technical choices:**
  - Absence of protective coating against corrosion
  - Incompatibility between products and materials
  - Unsuitable ergonomics
  - Dangerous installations design
- **Insufficient maintenance:**
  - Lack in maintenance
  - Inappropriate non-destructive controls
- **Human errors:**
  - Default in assembly of a heat insulator
  - Shock leading to the damaging of a protective coating

Possible corrective measures to manage corrosion

- **Improvement of operation monitoring**
  - Updated pipeline network map, inventory of sensitive points
  - Trapdoors for inspection of thermal insulated pipes
- **Improvement of control procedures**
  - Regular thickness measurement on critical points
  - Leakage tests or hydraulic tests
  - Intensification of inspection programs
- **Modification of installations**
  - Use of more resistant alloys (hastelloy, stainless steel)
  - Modification of protective coating material
  - Removal of risky tapping
  - Enslavement of equipment to safety measures
- **Modification of the process**
  - Change in parameters such as temperature, pH, product flow
  - Reduction of operating pressure of equipment

Possible corrective measures to manage fatigue

- **Improvement of control procedures**
  - Increased inspection frequency
  - Identification of equipments subject to the same risks than those involved in an accident
  - Modification of inspection plans to take into account specific vulnerability to fatigue of some equipment
  - Increased critical equipment’s replacement frequency
- **Modification of installations and processes**
  - Changes in equipment design to make it more suitable for exposure to vibrations
  - Changes in operating procedures to limit stresses
  - Modification of operation parameters
- **Training**
  - Training of maintenance staff to the caution to be taken when manipulating sensitive equipements to limit their weakening
  - Enslavement of equipment to safety measures

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Fire in the distilling unit of a refinery
ARIA 54828 (in 2019)

***despite** the French regulation « modernisation plan for industrial facilities »*

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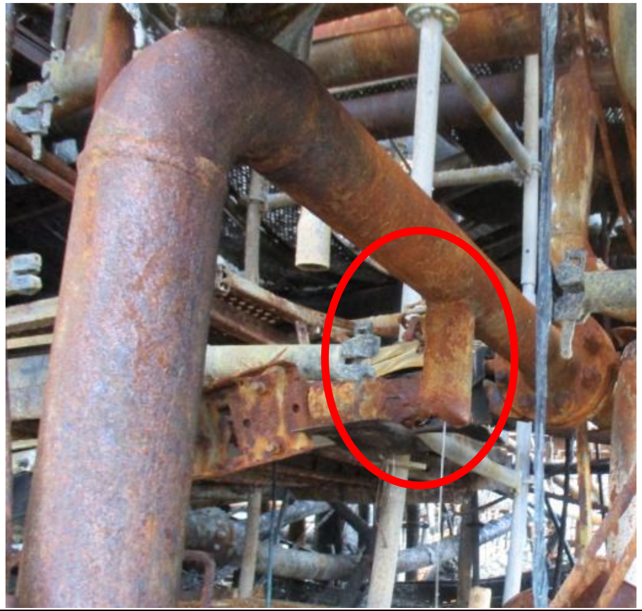
Fire in the distilling unit of a refinery

Gasoline leak and fire in the distillation unit at around 4 am on Saturday

The main focus of the fire was extinguished around 8 am, the secondary focuses were extinguished until Sunday 15 December around 2 pm

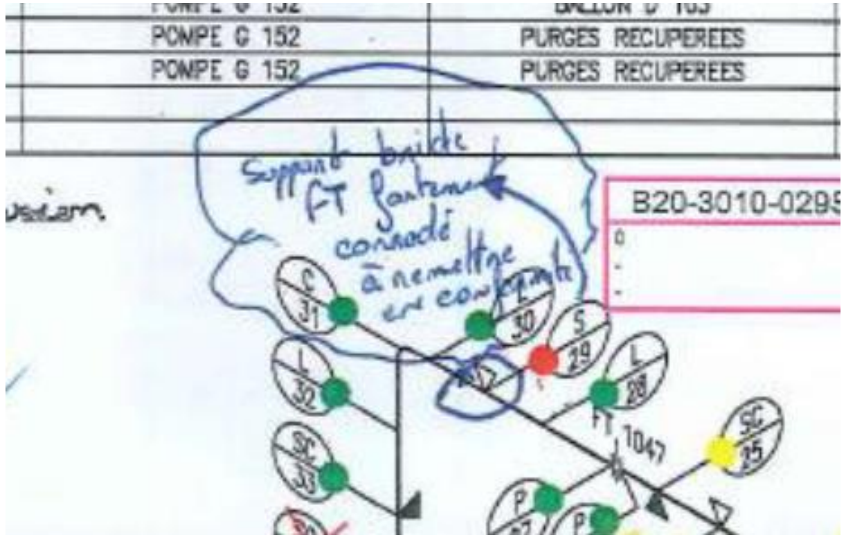
Dangerous materials released	■ ■ ■ ■ ■ □	400t of flammable liquids (upper threshold 50t)
Human and social consequences	□ □ □ □ □ □	
Environmental consequences	□ □ □ □ □ □	
Economic consequences	■ ■ ■ ■ ■ □	based solely on estimated operating losses of approximately €171 million



Corrosion of a pipe at a support

Support found to be visually **corroded but no inspection** of the pipe at the support due to:

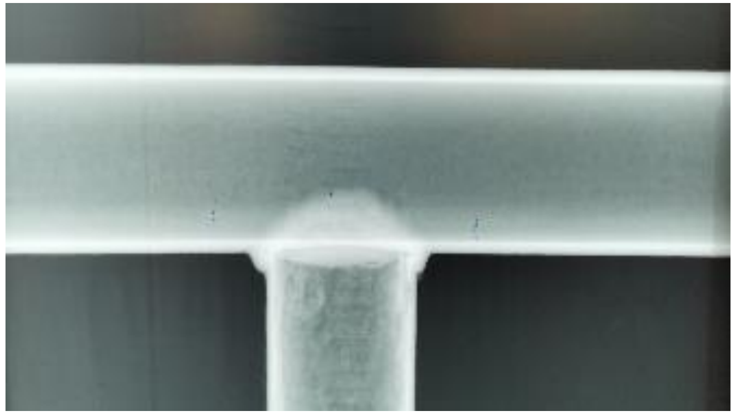
- **Incorrect identification** of the type of support in the document base and on the isometric, leading to an inappropriate thickness measurement
- **The various people working in the field do not realise** that the measurement carried out (by ultrasound) is not the one that should have been carried out according to the procedure in force (gammagraphy)
- **Failure to replace** the corroded support
- **Confusion between two substrates** in the definition of the work required of the intervening company: the work is carried out on the wrong substrate
- **No formal validation** stage for the **preparation of the work**
- **Acceptance of the work** does not allow these errors to be corrected

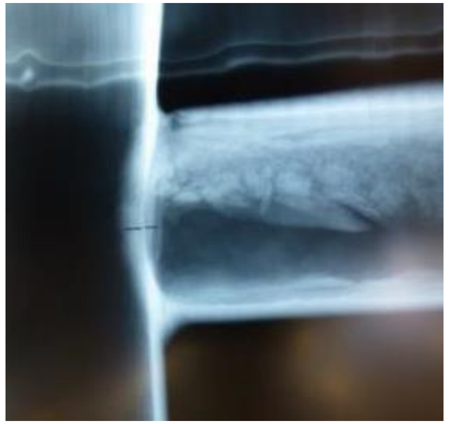


Action plan

- **Survey of pipe supports** in unit D11 and update of isometrics
- 61 493 items **inspected**
- 506 pipe supports **identified** in the unit

  (3 supports were not identified, 6 were incorrectly identified)
- Checking and quantifying the damage to the piping at the identified supports
  - 1 pipe shows a **significant loss of thickness**
  - 38 others show losses in thickness that need to be analysed
  - **Replacement** of pipes and supports
  - **Modification of the work management and acceptance tool**





Mercury rainwater tank rupture at a chemical plant ARIA 51102 (in 2018)

***NO subject** to the French regulation « modernisation plan for industrial facilities »*

Mercury rainwater tank rupture

- Tank used for the recovery of mercury-contaminated rainwater (628 m^3 capacity, steel, lined)
- Stoppage of mercury water treatment due to a reagent delivery failure
- AND heavy rainfall
- Use of a tank known degraded (since a precedent inspection)
- Internal instruction limits the filling to 60 % of its capacity
- Use of the tank to store beyond the maximum filling instruction

↳ Lack of anticipation of degraded situations, resulting in an inappropriate overfilling decision.

134 m^3 flowed into the River (a flow of 65 g with a concentration of 0.49 mg/l of mercury).

Conclusion on lessons learnt from accidents

- **Problem of anticipation** or detection in a timely manner (sometimes **in spite of many ‘warnings’**)
- Defective equipment or interpretation error during **verification campaigns**
- Insufficient temporary repairs or facility **renovation programs** scheduled **too late**
- **Large-scale industrial platforms** -> **large number of devices or piping involved**.
- **Full extent of degradation possibilities + identification of factors** capable of speeding the deterioration process.
- Pay attention to **critical points**
- Control and maintenance efforts within **inaccessible zones**

Thank you for your attention!

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