# WEBINAR ON RISK MANAGEMENT AND ENFORCEMENT ON AGEING HAZARDOUS SITES AND ON MAINTENANCE OF PRIMARY CONTAINMENT SYSTEMS

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## Inspection experiences on ageing infrastructure and equipment control: case studies

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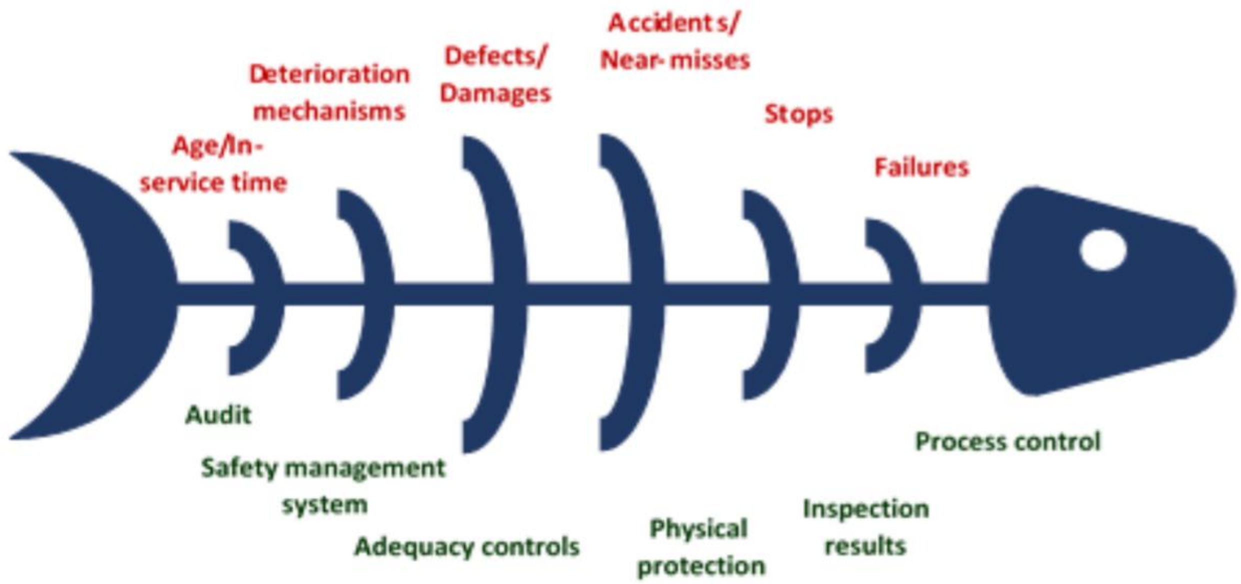
# IN ITALY: GL 'MANAGEMENT AND CONTROL OF AGEING OF EQUIPMENT AND PLANTS IN THE SEVESO PLANTS'

- updated version published on March 2021
- use of Fish-bone method, for evaluation of **ageing accelerating and retarding factors**



# FISH-BONE METHOD: EVALUATION OF AGEING ACCELERATING AND RETARDING FACTORS

- **accelerating** factors are marked with a negative score and are related to the ageing propension
- **compensation/retarding** factors are marked by a positive score and concur to calculate the ageing resistance
- the **combination** of ageing propension and ageing resistance is a score representing the overall adequacy with respect the ageing phenomenon; the combination shows how the ageing problem is a complex one, including more technical and managerial items
- **ACCIDENTS** caused by faults in ageing assessment /management: can be considered as a **combination with negative result**, meaning an unadequate management of the ageing phenomenon as a whole
- 2 case studies

# CASE 1: ACCIDENT LINKED TO THE AGEING OF OIL STORAGE TANK

- polluted water found inside a sewage pipeline of the wastewater treatment plant (WWTP), close to an oil storage plant with 4 tanks (A, B, C and D), designed in accordance with the API standards
- each of them: sheet steel tanks, 20.000 $m^3$ of capacity, 45 m diameter, height of 14.60 m, floating roof type, equipped with a basin (same capacity) and heating coil
- LOC occurred from the bottom of the tank D: 26000 $m^2$ area polluted from top surface down to groundwater level, environmental impact. Almost 400 tons of crude oil released
- detailed inspection of the tanks has been carried out, which showed the presence of corrosion in the bottom thank D
- no signals or alerts were detected in the tank D before the accident, which was assumed to be in ‘safe operation’ until the end of 2017-2018 when the double bottom installation was planned

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# CASE 1: ACCIDENT LINKED TO THE AGEING OF OIL STORAGE TANK - CAUSES

- accident caused by the corrosion of the bottom tank D
- oil leakage under the bottom due to possible cracks in the (flexible) bituminous membrane, in contact with the annular (rigid) concrete foundation
- oil vertical migration from the unsaturated zone (soil under the tank) towards the saturated zone (underground aquifer) for 6 meters
- internal inspection of tank D showed the presence of crater-like corrosion on the bottom, more pronounced in the perimeter area
- **localized corrosion** with the formation of 3 through- holes in the central plates, and 7 through- holes in the annular ring, 4-7 mm depth

Three through-holes in the central plates - localized corrosion

Seven through-holes in the annular ring - localized corrosion

# CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – ACCELERATION FACTORS

- since 2013, all the 4 tanks of (A, B, C, D) monitored with inspection activities (including control of the thicknesses of the fire-fighting system, and control of the thickness on the outer wall and annular ring); additional monitoring activities have been performed, like the introduction of samples for the check of corrosion
- after analysis and investigation post accident, it seemed that the rapid speed of corrosion in tank D bottom was caused by the **shutdown of the tank** in 2016, when the reduction of the oil level and roof, with stopping the agitation inside, created a discontinuity of operation for the tank: **this could promote the initiation and/or acceleration of localized corrosion phenomena caused by bacteria**, very dangerous since it could progress the corrosive phenomenon through the thickness at particularly high speeds. The rapid localized corrosion would have led to the formation of through-holes in just two years

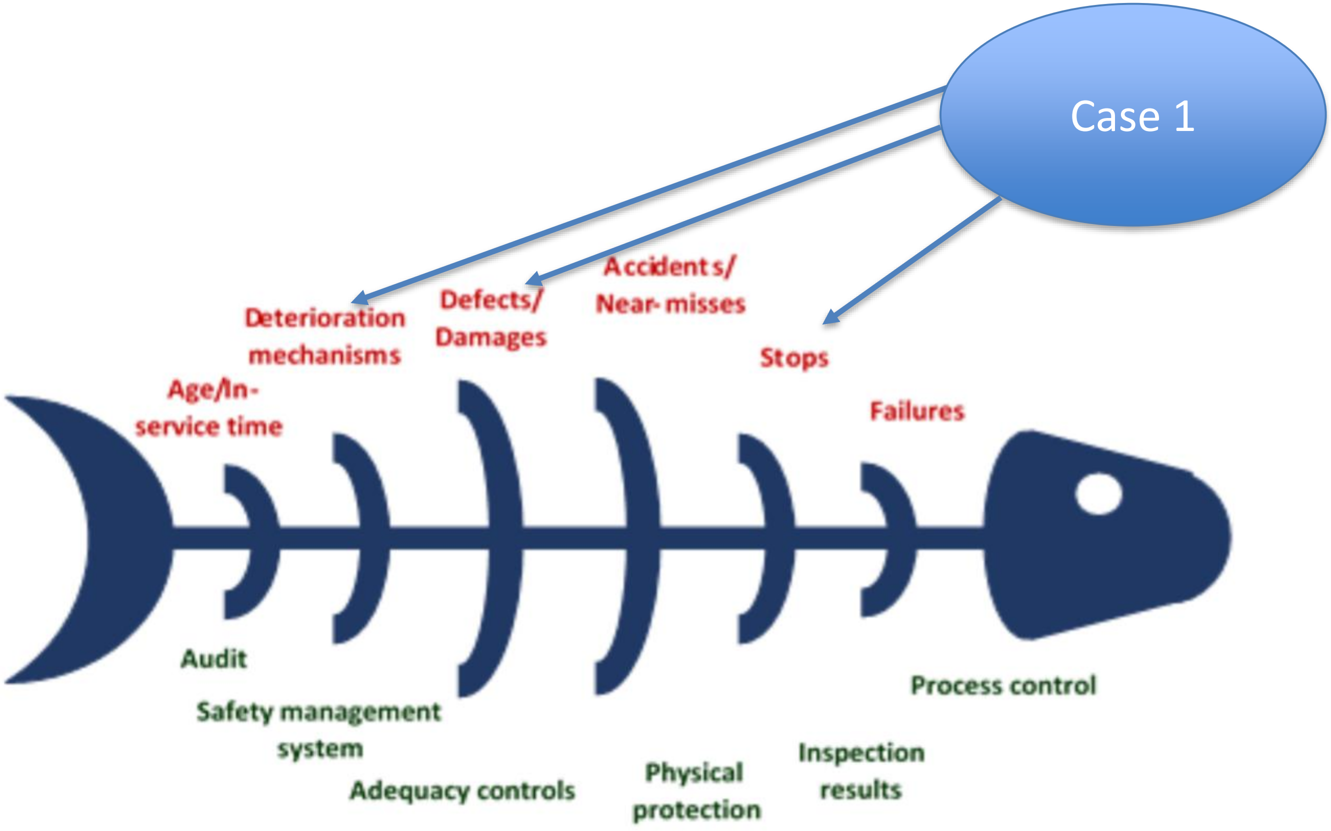
# CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – ACCELERATION FACTORS

- accelerated **Microbially Influenced Corrosion** (**MIC**), accelerated by the action of microorganisms in the local environment. Facilities where MIC is prevalent include hydrocarbon storage tanks
- microbes, bacteria, fungi can be introduced into the storage tanks along with dust particles and water condensed moisture through atmospheric venting systems; once inside the fuel tank, they may adhere to overhead surfaces and/or settle through the product. Some adhere to tank walls, some collect at the fuel/water interface, and others accumulate at the tank bottom
- microbes require both water-nutrients to multiply, so the tank bottom interface is the most prevalent fuel/water interface
- **localized corrosion sustained by bacteria**: penetration rate is much higher than that for uniform corrosion. The transition from uniform to localized corrosion is likely caused by discontinuity of operation for the tank D due to the 6 months shutdown which took place in 2016

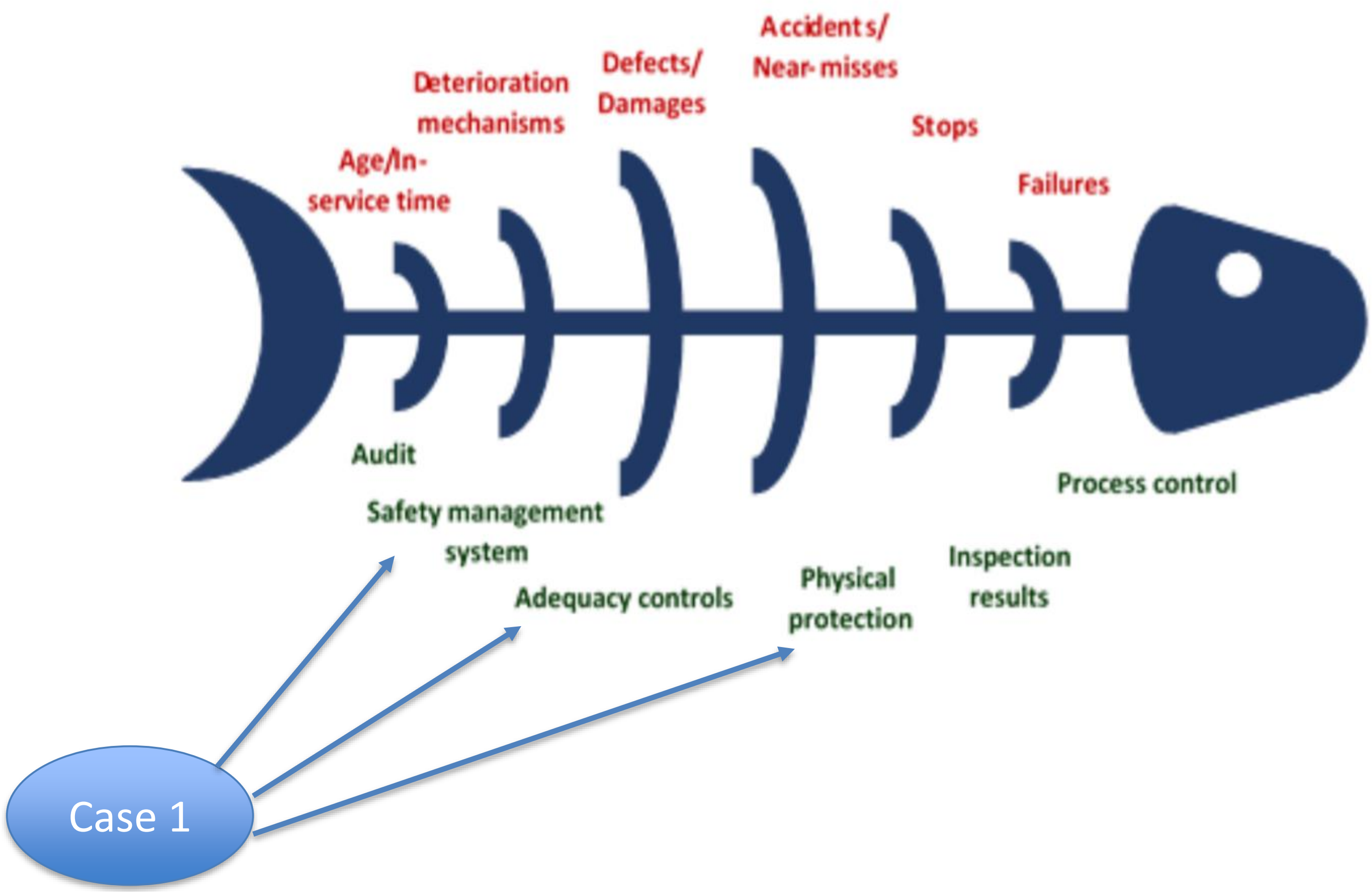
# CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – ACCELERATION FACTORS

- failure of the primary protection system of the tank D: damage to the bottom due to a **corrosive phenomenon**, formation of through-holes and LOC from the tank - **deterioration**
- failure of the secondary protection system of the tank D: damage to the asphalt barrier and consequent cracking. The oil vertical migration in the layers below the bottom of the tank was due to the damage of the impermeable layer (bituminous conglomerate barrier) 80 mm thick under the bottom. Cracks might be generated by contact of the less rigid bituminous layer with the annular (rigid) concrete foundation, due to the different behavior of the two materials under stress - **damages**
- failure in the control of the corrosion phenomenon, in the application of the results of the operational experience and in the re-evaluation of the maintenance frequencies of the tanks

# CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – ACCELERATION FACTORS



# CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – FAILURE RETARDING FACTORS



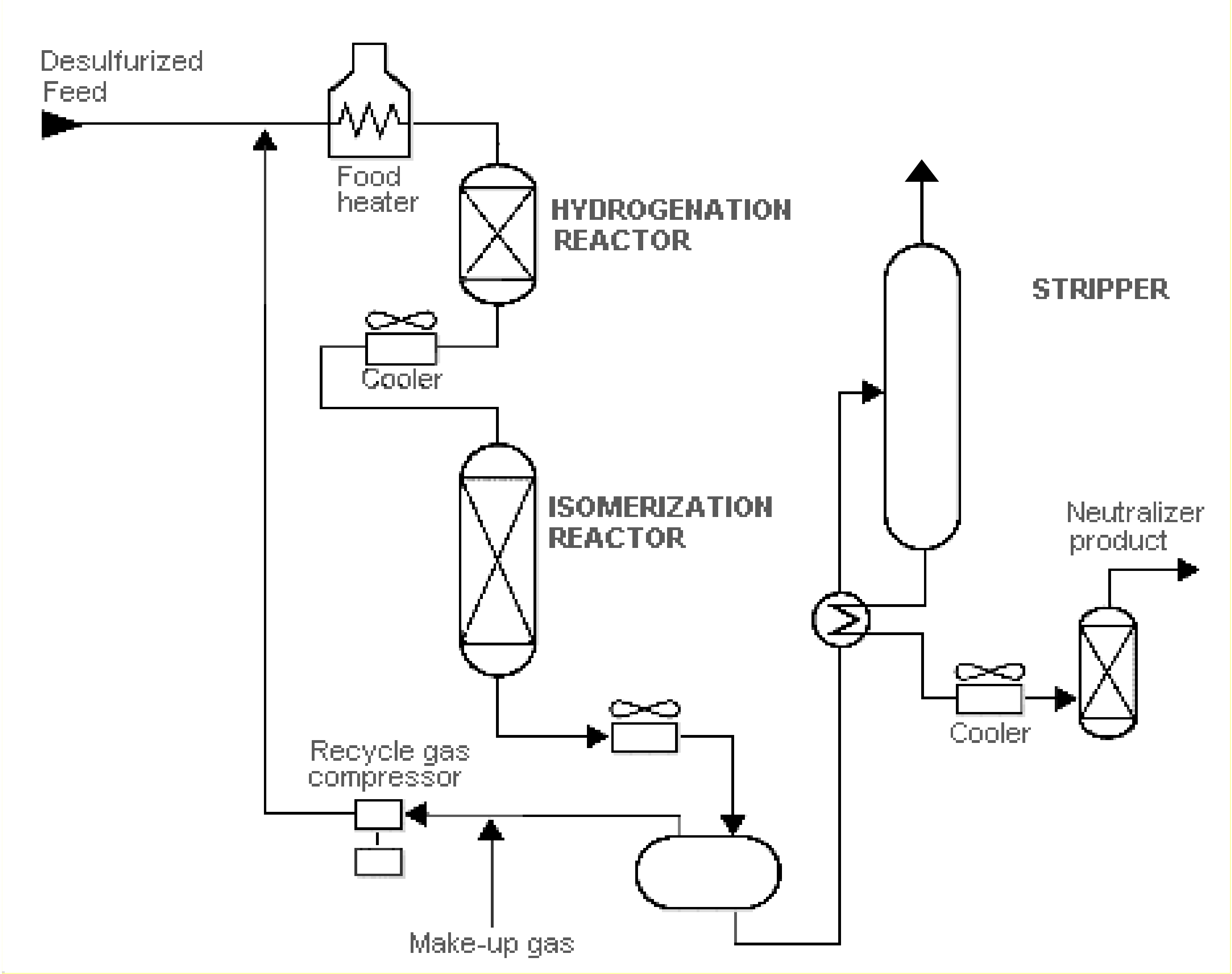
## CASE 1: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – FAILURE RETARDING FACTORS

- **SMS – failure in risk analysis:** inadequate consideration of the accident occurred and of all the appropriate safety measures to prevent and mitigate it
- **unadequacy controls**: failure in the control of the corrosion phenomenon, in the application of the results of the operational experience and in the re-evaluation of the maintenance activities of the tanks
- **no physical protection**: failure in the adoption of "compensatory" prevention / protection measures expected from the construction of the double bottom. Lack of in-depth knowledge of the geological situation (composition, structure, risks, etc…) of the area below the plant, resulting in an underestimation of the evolution of any loss of crude-oil in the underground

# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR

- Establishment: petroleum refinery
- units involved: isomerisation (TIP) and Bensat (aromatics saturation with catalyst to reduce the benzene contained in the distillate)
- equipment source of LOC: reciprocating compressor B located in TIP unit, used to recycle a gas mixture to TIP and Bensat units. Works in parallel with a twin compressor (A). Works at P from 15 to 21 bar and at T from 40 to 60 °C. Gas mixture recycled: hydrogen (70% vol), methane, ethane, propane and butane (30% vol)
- release of a big quantity of highly flammable gas mixture from the B bottom, that immediately found ignition; strong burst, followed by jet-fire starting from the compressors and impinging the near bensat unit (14 m apart)
- parts of the bensat unit failed causing the release of gasoline and hydrogen, which led to the extension of the fire; strong material damage

# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR – TIP UNIT



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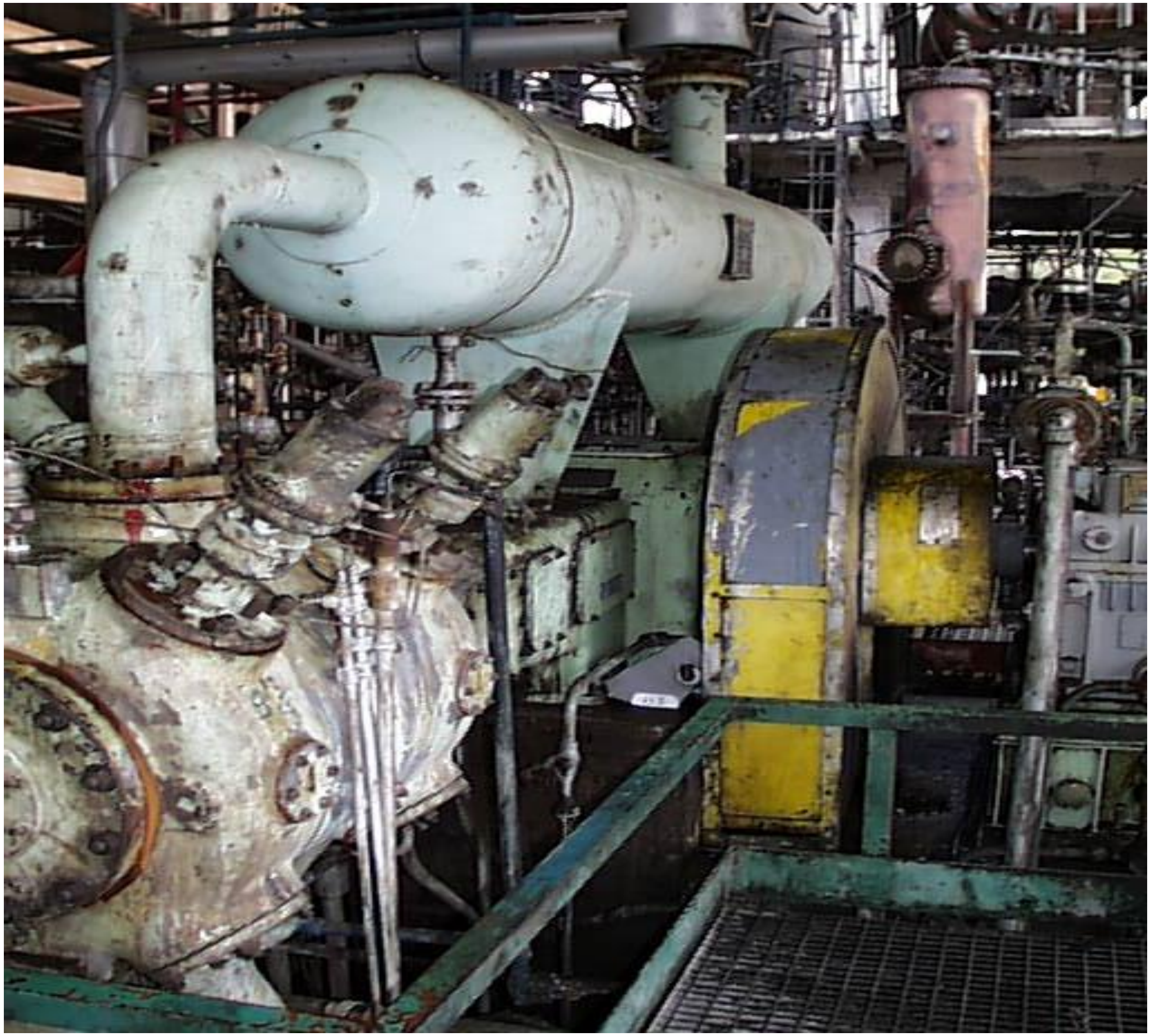
# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR
# DIRECT CAUSES AND CONSIDERATIONS

- rupture of the crankshaft-rod mechanism in the compressor, consequent hitting action of the piston on the bottom of the cylinder no.2
- the combined effects of hitting-action with the internal pressure (20 bar) led to the failure of the screws, which hold the bottom
- regular controls/maintenance activities on the compressor B since the last 3 years (according to the technical manual and the supplier's indications: pumping part revision (east and west side), valves substitution (east and west side), speedy joint substitution, compressor general revision, substitution of nuts of crank-rod, revision of sealing packages
- leader supplier on the market

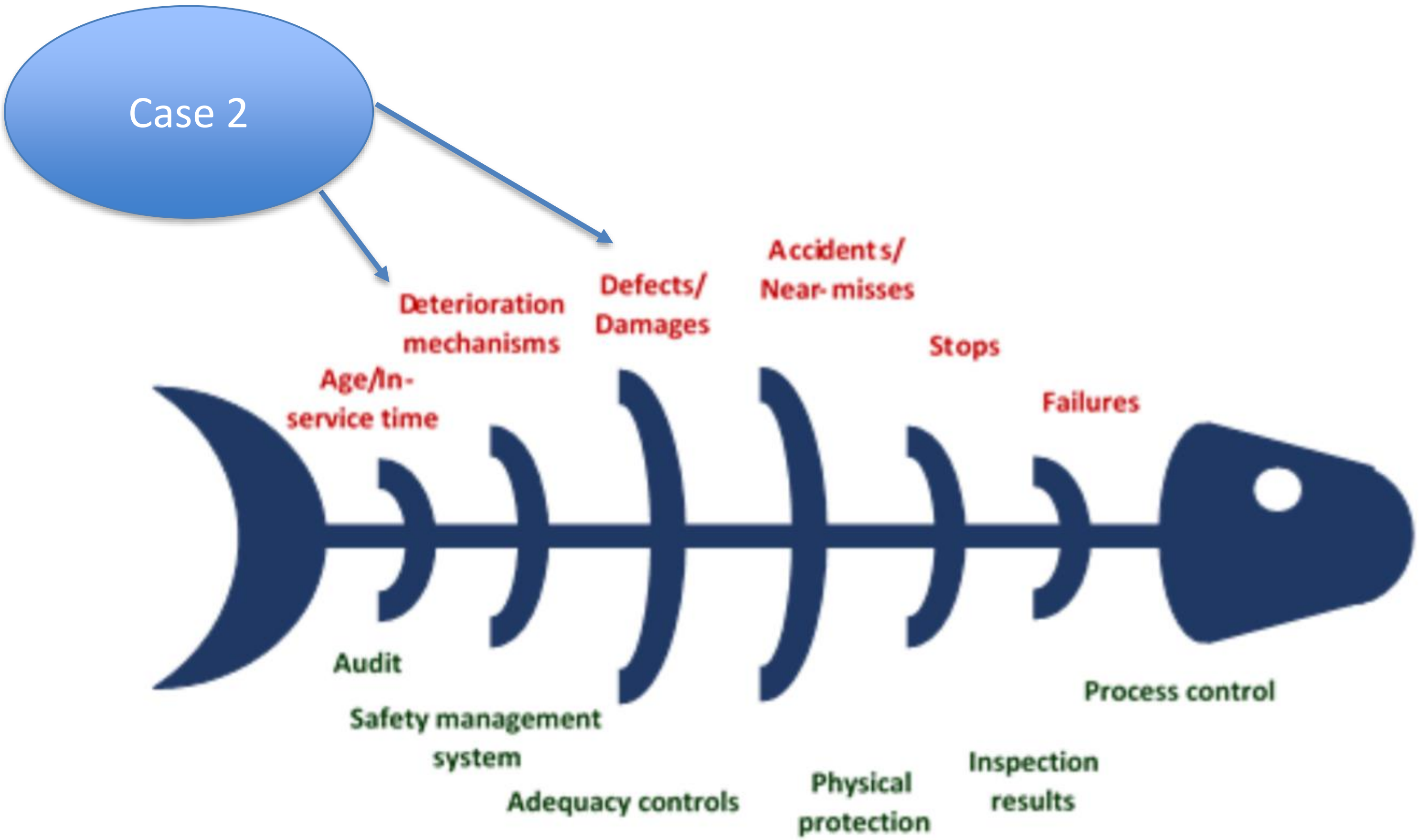
# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR – TIP AND BENSAT UNIT

# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR – COMPRESSOR B



# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR

## ACCELERATION FACTORS



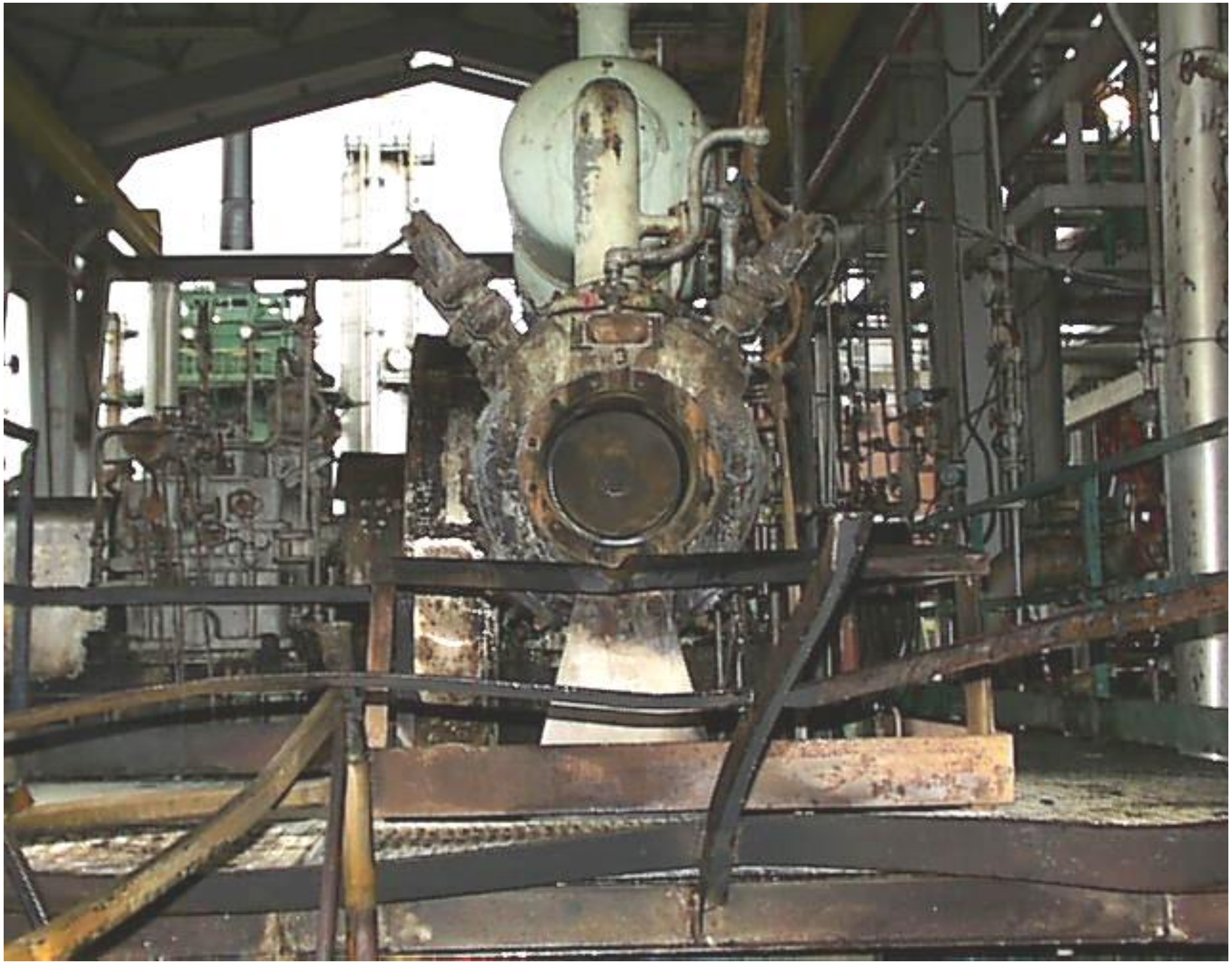
# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR

## ACCELERATION FACTORS

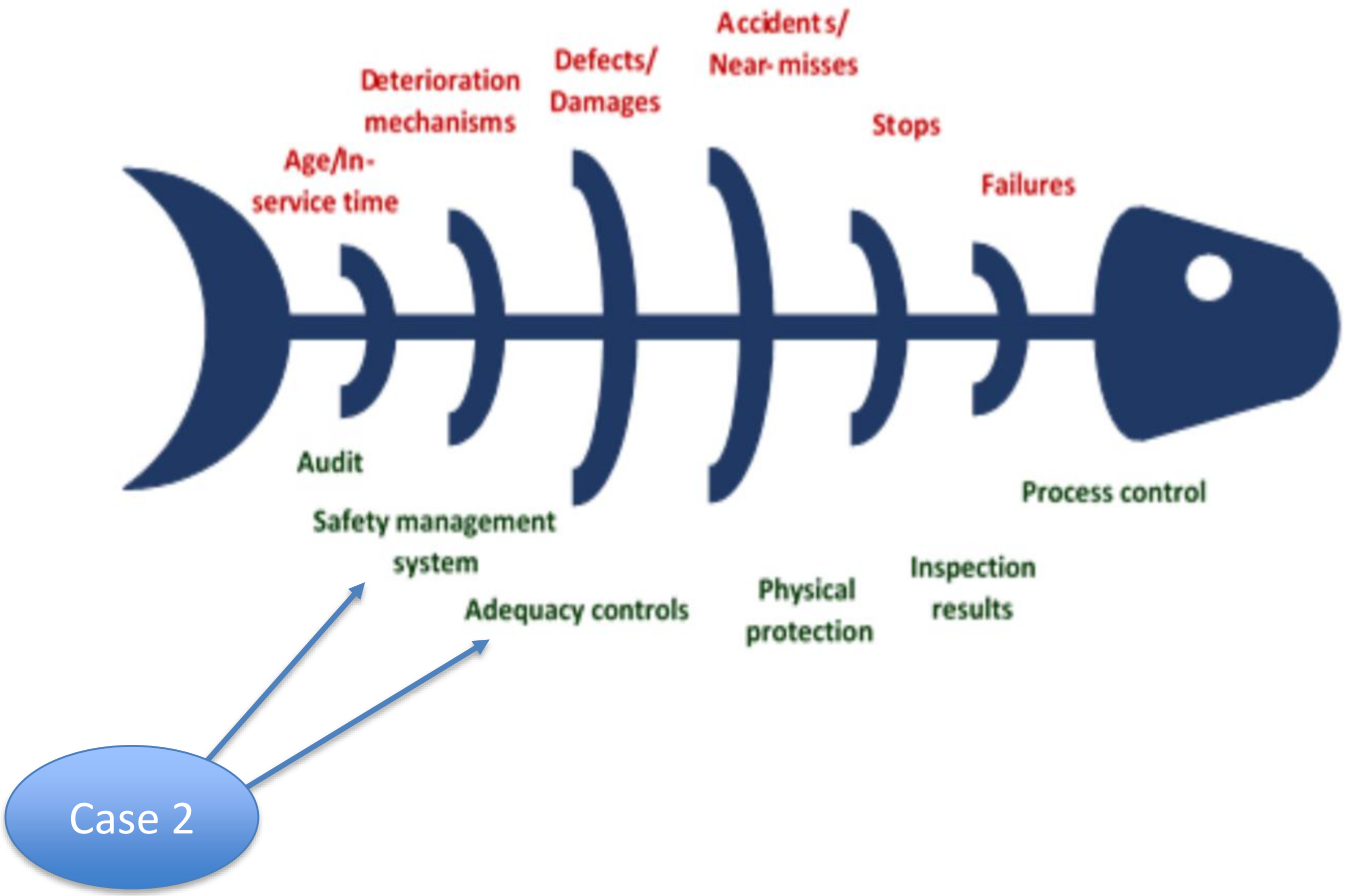
- **Defects/damages**: mechanical failure of the bottom of compressor; rupture of the crankshaft-rod mechanism: tests and analysis of the materials of the mechanical parts broken showed defects at the origin (production defects, already present at the moment of the supply)
- **Deterioration**: overly stressful conditions of exercise for the kind of compressor; other compressor deficiencies were found: orientation, vibrations detector system, hand stop-valve in suction. A substitution of the two reciprocating compressor by a centrifugal compressor was planned and realized, together with use of interception electro commanded valves in suction lines in order to limit possible gas release

# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR SCREWS DETERIORATION

# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR FRONT VIEW WITHOUT THE BOTTOM



# CASE 2: ACCIDENT LINKED TO THE AGING OF OIL STORAGE TANK – FAILURE RETARDING FACTORS



# CASE 2: ACCIDENT LINKED TO THE AGEING OF RECIPROCATING COMPRESSOR

## FAILURE RETARDING FACTORS

- **SMS – failure in selection and evaluation of suppliers:** excessive trust in the historical supplier (leader on the market) and failure to revaluate its requirements
- **unadequacy controls**: Excessive delegation of maintenance activities to the supplier; need of a revision of the control, inspection and maintenance procedures for installation, also in consideration of their criticalities