Nature of ageing phenomena

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Ageing is a phenomenon that is present in all chemical process industries all over the world. It is sometimes mistakenly believed that ageing is about how old the establishment or the equipment is. Ageing of chemical plants has a wider meaning that goes far beyond corrosion management. Everything associated with a site and its various processes can age, including not only equipment, but also people and procedures. Some ageing phenomena are sometimes only perceived through the lens of a specific activity, such as management of change (e.g., new staff make decisions without full information, e.g., they are not aware of a process's linkages with another process) or in operational control, where the process itself is outdated relative to modern safety performance standards. In the worst case, an ageing problem may only make itself known through an accident or near miss. For this reason, the effectiveness of the safety management system over time relies on a constant awareness of all the types of ageing impacts – loosely defined as material degradation, obsolescence, and organizational ageing - that affects in equipment, processes and knowledge-based elements.

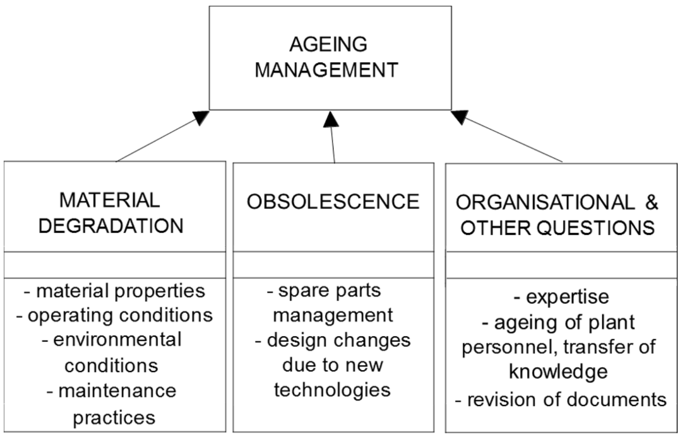

Figure 3: Categories of ageing (Source: ESReDA Report on Ageing of Components and Systems)

Material degradation

To some extent, there is a tendency to focus on equipment ageing because the signs of material degradation are so tangible. Carbon steel corrosion is the most well-known phenomenon although still, failure to address corrosion failure is a major cause of chemical accidents. In addition to fatigue and vibration, there are also some other forms of degradation that receive far less intention and are even ignored, in particular degradation of nonmetal materials, such as fiberglass and concrete.

Obsolescence

Obsolescence is a phenomenon that may adversely affect equipment, processes and procedures. Equipment reaches the end of its life cycle when the equipment is so degraded by the combination of all the deterioration mechanisms, small changes to operating conditions, and build-up of process fluids over the long term that it can no longer be maintained fit for service. An obsolete procedure is one that no longer can be considered applicable or appropriate because the situation to which it applied has completely changed. Obsolete technology creates risk that replacement parts may not be found or has inherent safety risks that would no longer be acceptable in accordance with current standards.

Organisational

The main concern of the ageing organisation is loss of knowledge and expertise. This particular ageing phenomenon is the most challenging to monitor and fix with systematic solutions because it is about trying to compensate for something that is no longer there or not accessible, referring specifically to people and documentation. Indeed, the degradation of performance due to aging of people and procedures can only sometimes be directly observed. On the one hand, procedures and documentation should be associated with each piece of safety critical equipment. Where there are particular imperfections of documentation, especially for older processes and equipment associated with important risk scenarios, the potential impact of lack of information should be assessed and addressed. On the other hand, there are the "unknown unknowns", such as when there is documentation missing about a change made in years past and no one remembers that it took place. To minimize these kinds of risks, audits and investigations should routinely give attention to ageing dynamics and question to identify where the ageing of various equipment, people and/ processes are emerging as a source of serious risk.

Statistics

This issue of the Lessons Learned Bulletin offers insight into the importance of approaching ageing as a strategic safety issue with examples of accidents that have learned this lesson only after suffering the consequences. In preparing this bulletin, 69 major accident reports in eMARS were studied together with accidents selected from open sources, such as the Japanese Failure Knowledge Database (*http://www.sozogaku.com*) and the ARIA database (*http://www.aria.developpement-durable.gouv.fr/*) operated by the French Ministry of Ecology, Sustainable Development and Energy. Events were chosen to provide a varied perspective on the types of ageing phenomena that can trigger a major accident . The chart below presents the analysis of the selected accidents, based on the type of ageing phenomenon.

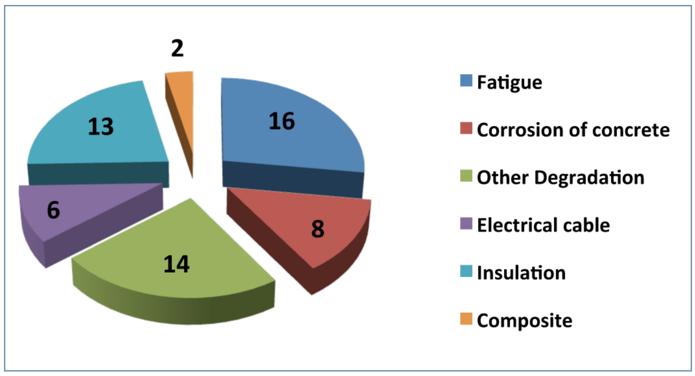

Figure 4: Number of major accidents by ageing phenomena (Source: eMARS)

The selected cases also include a number of other lessons learned, not all of which are detailed in this bulletin. The bulletin highlights those that it considers of most interest for this topic, with the limitation that full details of the accident are often not available and the lessons learned are based on what can be deduced from the description provided. The authors thank the country representatives who provided advice to improve the descriptions of the selected cases.

Accident 5
Degradation of composite pipe

Sequence of events

On 7th August 2002, a pipe's monitoring system detected a 100 m3/h leak with a nominal flow rate 500 m3/h of acid waste water flowing from the manufacturing of dyes and pigments connected to a neutralisation facility located 18 km from a chemical plant. The leak was due to a 40 cm crack on a glass fibre reinforced polymer (GRP) pipeline (NB 400mm). Between 5th and 11th August, a succession of leaks was observed, eight in total. Out of these cases, six leakages occurred on the first two kilometres of the pipeline. The pipe complied with the provisions in the regulations and successfully passed the water resistance test at 15 bar, 20 days prior to the first leak. Following these failures, the pipeline was shut down on 11th August. After the sequence of leakage, a new GRP pipeline was installed which cost more than five million euros which included also the remediation of the polluted soil.

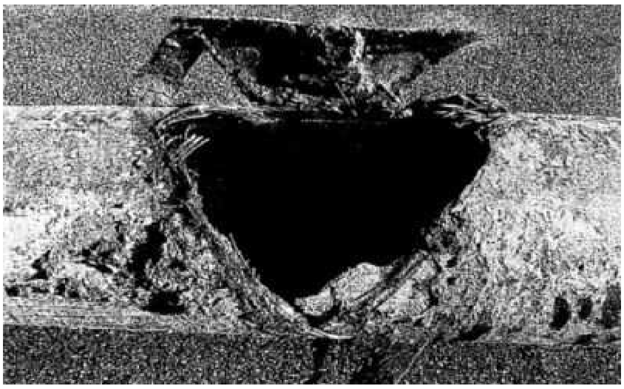

Figure 5: The damaged pipeline (Source: ARIA No. 23562)

Causes

Deterioration of the infrastructure was due to a corrosion mechanism occurring in an acid-stressed environment. A number of factors contributed to this accident. One factor is ageing. The corrosion of the pipe material caused an effective loss of strength. In addition, the process design did not adequately address the pressure surge that could occur when the pump is shutdown, in particular, insufficient number of vents made difficult to cope with this situation that is a routine part of the process. Furthermore, there was a failure in installation because of incorrect setting of the surge chamber pressure.

Important findings

- Normally, part of the acid water was conveyed via an NB 300mm pipe to the wastewater treatment facility. The other part of the water was directly released into the Bay of the Seine river, without any specific treatment. However, due to the expansion of the port nearby the chemical site, the plant operator was required to relocate the NB 300mm pipeline, which carried acid water to the wastewater facility, by 31st July 2002. The operator chose to send this water using a GRP NB 400mm pipe that was installed a year before.
- Leaks were primarily noticed adjacent to pipe elbows and during directional changes. The pressure never exceeded 5 bar vs. a 10-bar design pressure, in a diluted sulphuric acid medium with a temperature below 35°C. The maximum temperature allowed for GRP tubes was 50°C. Therefore, the fact that failures occurred near or at high points and near a change in direction, confirms the role played by hydraulic transitions.
- It was demonstrated that the damage to the pipe was due to a mechanism of stress corrosion in an acid environment. Stress corrosion is a fissuring mechanism that requires a combination of three factors, such as stress or permanent distortion, the material sensitive to the phenomenon and a corrosive environment.
- There was a design problem in this case, due to the insufficient number of vents available to cope with the pressure surge. This is a phenomenon that generally occurs in long pipelines; key factors are fluid velocity, pipeline and rate of valve closure, or in this case, pump shutdown. It can cause a very high pressure surge which travels along the pipe at the speed of sound in the fluid. The vents are provided to alleviate this surge as was the surge chamber - this to minimize any low pressure surge as the pump is shut down.
- It was also found that certain failures occurred in a zone where it was difficult to correctly compact the soil, nearby pipeline and concrete well.
- The majority of the failures, six out of eight, occurred in the first two kilometers in the zone where hydraulic stresses are greatest.

Lessons learned

- Although the pipes and their assembly complied with the provisions in the regulations as required by the project service order, the installation of the pipe and pressure control systems were not in accordance with good custom and practice. In particular, they were not compliant with the original installation specification, sizing of the buffer chamber and calculation of the number of vents required.
- The operator exchanged the NB 300mm pipeline that conveyed acid water to the wastewater facility with a GRP NB 400mm pipeline. Modifications to the process plant, either in equipment itself or in its connections, in instrumentation, in chemicals, or in process conditions can affect the design integrity and bring about additional risks. Normally, a management of change procedure should be conducted to ensure that changes are properly reviewed and approved prior to implementation.
- The investigation also revealed that the management of the project was the primary cause of several of the faults in design and installation. In particular, the systematic pre-checking of calculations and the installation conditions for the pipe and compliance with various rules for pressurising the facility did not conform with established requirements. When making changes to older processes, the project managers need access to all associated documentation.
- Deficiencies in project management should be addressed in the site's safety management system as well as the overall site management system, since poorly controlled projects can affect other outcomes besides safety. However, there is also a question as to whether the project contractors had access to the original installation specifications. This can demonstrate that process knowledge has to be maintained and transferred. Accident analysis should highlight these kinds of failure that occur most commonly in older plants.
- Even without the mistakes in design and installation, corrosion of critical components of the equipment would ultimately have led to failure, and therefore, should be subject to a systematic inspection program similar to all safety critical elements.

[EMARS Accident #417 ARIA No. 23562
Similar accident EMARS Accident # 771]