PREVENTING LEAKS IN PIPING IN THE CHEMICAL INDUSTRY

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Abstract
Leaks are one of the main causes of failure in pressurized wastewater piping. In public areas, wastewater pipes are closely monitored for leaks. However, monitoring of underground pipes at industrial sites often lags behind, which can lead to hazardous situations. Leaking wastewater can cause soil contamination, reduce the quality of groundwater and affect the production of drinking water. Prevention is better than cure, and also cheaper. So, make sure your piping is checked on time.

Keyword: *chemical industry, underground pipelines, leakages, technology, prevention, soil contamination.*

1. Background

Replacing cables and piping in public areas is quite common these days. Pipes sometimes need to be replaced because of the material that they are made of, such as grey cast iron or asbestos cement. Old oil-filled pipes are also being replaced with durable plastic pipes, while many pipes have to be replaced because they have reached the end of their lifespan (Figure 1).

In parallel with the replacement of old piping, attention should be paid to the energy and chemical transitions. Various factors need to be taken into account, including:

- What is the lifespan of new modular cast iron pipes?
- Will green gas be chosen so that pipes can be reused to transport hydrogen, etc.?
- Will the trend towards "all-electric" solutions make these gas pipes obsolete?
- How can we adapt existing and new systems to make the chemical process sustainable?
- How can we prevent leaks in the wastewater system?

In the Netherlands, the replacement needs comprise research, remediation and replacement works. These works are mainly carried out in public areas. At industrial sites, the replacement of pipes is often not given enough attention. In chemical plants, a transition from underground piping to above-ground piping ducts can be observed. Nowadays, many underground pipes are still in use. These can cause potentially hazardous situations. For example, leaks are one of the main causes of failures in pressurized wastewater pipes. This can have major consequences for soil and groundwater quality.

A good example of a pipeline project, which could have had major consequences, concerns an industrial site in Maastricht, the Netherlands. It involved a search for a leak in an oil-cooled pipeline at an industrial site, which had led to the loss of a large amount of oil. Another project involved the search for a cooling water leak in Germany, responsible for the loss of 2.5 m^3 of cooling water per hour. In this case, the leaked cooling water could have washed away the foundations of the pipelines. These experiences show that every project and situation is unique. However, all these incidents can be traced back to the same basic principle: materials have a fixed lifespan and must be replaced after a certain period. The frequency of replacement depends on factors such as:

- type of material;
- use of pipe (fluid types, gasses, acidity, temperature, variation, etc.);
- soil type;
- groundwater level;
- effect of salt water;
- depth.

It is most likely that there is a link between these factors and the occurrence of leaks. This is an overall

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Figure 1. Example of a leakage in a cooling water pipeline.

analysis that the chemical industry should make: which essential factors have to understand for identifying the most significant hazards? These are the pipes that need to be dealt with first. Experience shows that any investment in preventing such leaks more than pays for itself, as dealing with the consequences of a leak often costs many times more than the costs of investing in detecting and preventing future leaks.

2. Innovative technologies for the detection of leaks in pipes

TAUW Group BV is a European consultancy and engineering company with offices in the Netherlands, Belgium, Germany, France, Spain and Italy. It has a strong position in environmental advice and the sustainable development of the living environment and is dedicated to a beautiful, clean, safe and sustainable living environment. The company is often dedicated to detecting leaks in underground piping. This work is usually performed using digital technologies for inspections like camera and drone systems. The latter allows to map the entire pipe in a 3D mode. For several TAUW projects, camera systems have been used for more than 2 decades to detect any scratches in sewage systems; in the last years, the use of these systems became more applicable because of further development of technologies and computing processing (like Elios 3 system which Flyability uses). Moreover, thanks to a partnership between Leiden University and Delft University of Technology, an improved camera system was developed for detecting even the smallest cracks. This new technology combines multi-sensor inspection with 'deep learning', a type of machine learning that allows computers to learn new things by analyzing large amounts of data. This learning can be assisted, semi-assisted or fully automated and is hopefully available on the market at short notice. More information is available at SewerSense – Multi-sensor condition assessment for sewer asset management (Sewer sense, 2023; Scholten et al., 2019).

Other technologies have also been developed: electrical conductivity and acoustics combined with fibre optic cables, while thermal variants offer a solution in some cases (Figure 2). Early warning systems that allow frequent measurements and prompt intervention in case of problems can also be used on a permanent basis.

2.1 An example of technology for leak detection

A good example of a technology able to detect leakages in existing underground pipelines is the

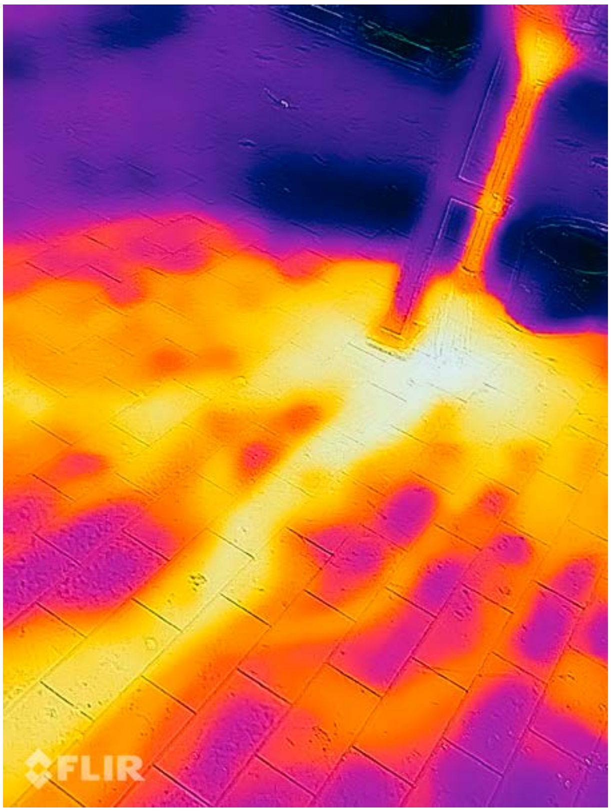

Figure 2. Example of usage of thermal imaging for detecting leaks. This picture shows a leak on the surface of a concrete floor with a simple FLIR-camera. Yellow/orange colors are higher temperatures and dark/blue colors are colder. The pipeline on the right top transports hot liquid and has a leak at the bottom, emitting(hot) liquid to the floor and distributing to the left-down corner. Having these kinds of thermal images shows things you can't see with your eyes, and brings insights in what is happening – even when pipes are under the ground or in walls.

DALI system—Distributed Acoustics for Leakage and Intrusions—(https://www.dalimonitoring.com/en) which is highly suited for retrofitting utility, steam, oil and gas pipelines. This technology combines a fibre optic cable inside the pipe and a Distributed Acoustic Sensing system, adapted to this cable outside the pipe. This allows existing pipelines to be retrofitted without new trenching, and leak sounds can be detected without concerns about the relative positioning of the fibre and the leak.

2.1.1 Widening the application range of fibre optic sensing

Distributed Fiber Optic Sensing (DFOS, Soga and Luo, 2018) has been successfully applied in the oil and gas industry for many years. Over the past few years, the performance of DFOS systems and the related know-how have increased, while DFOS hardware prices have dropped. This broadens the application range of fibre optic-based pipeline monitoring to include new markets, such as the chemical and manufacturing industry (to monitor the risk of corrosion under insulation of pipelines, tanks, and cryogenic facilities) and the utility sector (drinking water, sewage water, district heating, etc.). For the utility sector, and especially the drinking water sector, additional challenges arise compared to oil and gas pipelines. These include:

- The potentially very old pipelines (up to 100 years), with the pipeline condition and even the route not fully known at the start of a project.
- The use of a very wide range of pipeline materials (concrete, steel, cast iron, asbestos cement, PVC, polyethylene and several others).
- The presence of pipelines in heavily urbanized areas: under roads, railways, canals, and other infrastructures.

2.1.2 Locating leaks in water pipelines

For underground utility pipelines, such as trunk mains for drinking water, retrofitting by trenching an external fibre is uneconomical due to the presence of other infrastructures above the pipeline. For this reason, a pipeline monitoring system that uses a fibre optic cable installed inside the pipeline was developed: the DALI (Distributed Acoustics for Leakage and Intrusion) system. It was jointly developed by Fluves (https://www.fluves.com), an engineering company specialized in fibre optic monitoring, and Vigotec (https://www.vigotec.be), a manufacturer and distributor of pipe systems and engineered plastics. The DALI system comprises the following elements (Figure 3):

1. A fibre optic cable is installed inside the pipeline. The cable is housed inside a durable cable mantle that is certified for safe use in drinking water systems. An innovative installation system was developed that allows the installation of the cable in the pipeline while it is pressurized and in operation.
2. A DAS system (Distributed Acoustic Sensing), which records acoustic vibrations along the fibre, with a spatial resolution of 10 m.
3. Advanced signal processing and machine learning software, which scans the raw acoustic measurements for notable incidents such as leaks or third-party intrusions (TPIs). The DALI software runs on an edge server that is co-located with the DAS system and transmits its results to the cloud or to the operator's intranet.
4. An online dashboard that visualizes the pipeline status in real time shows the location and the history of any alarms and sends alarm notifications via email or SMS.

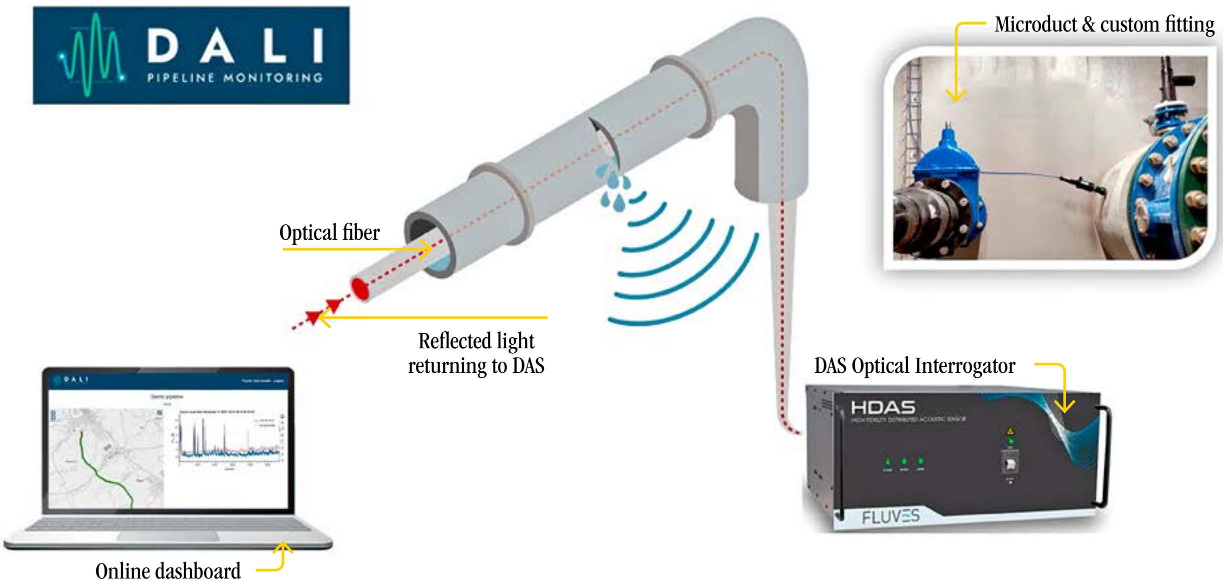

Figure 3. An overview of the DALI system. The fibre optical cable is inserted in the pipeline (right top picture shows an example of the blue cable that is inserted through a custom fitting into the pipeline) and at the top af the fibre the DAS optical interrogator is installed. This DAS sensor is able to do a measurement which detects reflecting light returning to the DAS sensor and is able to locate a leak through an online dashboard.

2.1.3 Deployment types

Following successful validation, DALI can be installed on existing infrastructures with a novel system that allows the insertion of the cable without taking the pipeline out of operation. Several types of use are possible:

- Permanent monitoring, in which the fibre optic cable and the DAS sensor are permanently installed on the pipeline, allowing for permanent, 24/7 tracking of the pipeline status. This is most applicable to large, critical pipelines.
- Semi-permanent monitoring, in which the fibre optic cable remains permanently in the pipeline, while the DAS sensor (the costliest component) is connected periodically (e.g. every quarter) or based on needs (if there is a suspected leak) to assess the pipeline condition.
- Mobile monitoring, in which a short cable (up to approximately 2000 m) is inserted in a pipeline and connected to a DAS sensor. Measurements are performed for a few hours to localize leaks, after which the cable is retracted from the pipeline. This is especially applicable for small and residential water pipes.

3. The right measurement method and solution

The key is to understand what the specific problem is and what technologies, or a combination of technologies, can be used to solve it. Keeping track of technology developments in the market is essential. What kind of technologies are being developed, and in what situation is a specific technology applicable or not applicable. You can compare the various systems and present a realistic assessment of the feasibility and impact of each option. Are you curious to find out whether all your underground piping is still intact? 'Risk-based surveys of leaking underground piping in the chemical industry is a smart idea. We see that the importance of these surveys is already recognized in public areas. The chemical industry must now follow suit!' ■

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