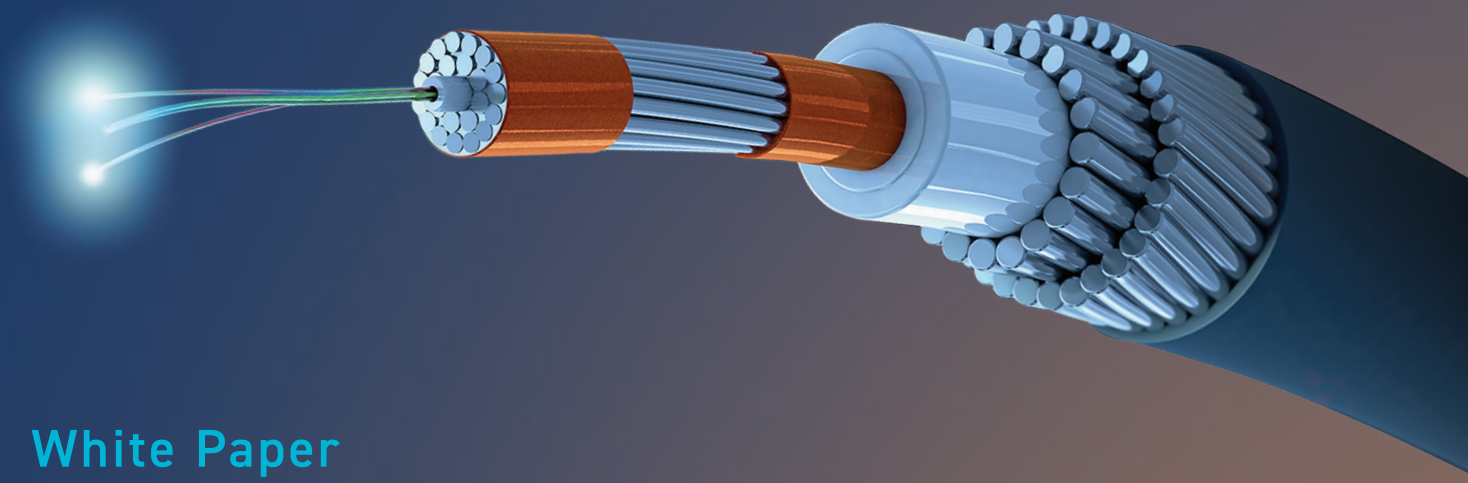
CUI-CONTROL



White Paper

TACKLING CORROSION UNDER INSULATION WITH FIBER OPTIC SENSING.

Stropkaai 55,
9000 Ghent
Belgium

www.cui-control.com
sales@fluves.com
+32 9 346 85 30

CORROSION UNDER INSULATION (CUI)

Major threat

Corrosion under insulation (CUI) is a major threat to various industries [1], particularly those that deal with metal infrastructure and equipment exposed to harsh environments such as oil and gas, petrochemical, chemical, power generation, and many others. Studies have shown that CUI can account for up to 50% of all corrosion-related maintenance costs in these industries [2]. Although the application of protective coatings will delay the onset of CUI, once the finite lifetime of these coatings is exceeded, catastrophic failures will still occur if CUI is left undetected and thus unattended [3]. As an illustration, a hydrocarbon pipeline at a refinery in the UK exploded due to an undetected CUI problem, leading to fires worth millions of pounds of damage [4]. To prevent CUI, industries have implemented regular inspection and maintenance programs.

Detection is a challenge

Detection of CUI is challenging for several reasons. The corrosion processes occur under insulation and weatherproof cladding, making it difficult to visually inspect for signs of corrosion. CUI can occur in places that are not easily accessible, such as inside pipes, tanks, and vessels, making it challenging to detect. There are limited diagnostic tools available for detecting CUI, and those that are commonly used can be costly and time-consuming. Regular maintenance and inspection, along with the use of non-destructive testing methods, can help detect CUI damage and prevent potential failures. Risk-based inspection (RBI) methods are employed to help determine when and where to carry out the inspections [5]. The currently available RBI methods, such as API 581 by American Petroleum Institute [6] and EFC 55 by European Federation of Corrosion [7] rely on the calculation of risks which requires the estimation of corrosion rates. But corrosion processes can be caused by a variety of factors such as temperature changes, humidity, and chemical exposure, making it extremely difficult to predict when and where they will occur.

Market need

Most of the CUI testing methods, even if they are able to correctly assess the CUI condition, provide only a snapshot of the condition for a small part of the equipment. Because CUI can happen at any time and many locations can be at risk, there is a huge demand in the CUI-prone industry for a system that monitors many (square) meters of CUI sensitive equipment on a frequent basis.

This was the motivation for Fluves to build the CUI-CONTROL monitoring system, based on fiber optic sensing.

Why should innovative inspection techniques be added to manual inspection:

- Manual inspections only register a snapshot in time.
- Experience shows that corrosion is also found on spots where there is no visible indication on the outside.

FIBER OPTIC SENSING TECHNOLOGY

Distributed Fiber Optic Sensing (DFOS) has been successfully applied in the oil and gas industry for many years [8], first with Distributed Temperature Sensing (DTS), then Distributed Strain Sensing (DSS) and, most recently, Distributed Acoustic Sensing (DAS). In recent years, the performance of DFOS systems and the related knowhow have increased tremendously while DFOS hardware prices have dropped. This resulted in an expansion of the scope of fiber optic-based pipeline monitoring to new markets such as the chemical and manufacturing industry, where it is used to monitor the risk of corrosion under insulation on pipelines, tanks, and cryogenic facilities, it is also used in the utility sector (drinking water, sewage water, district heating, ...).

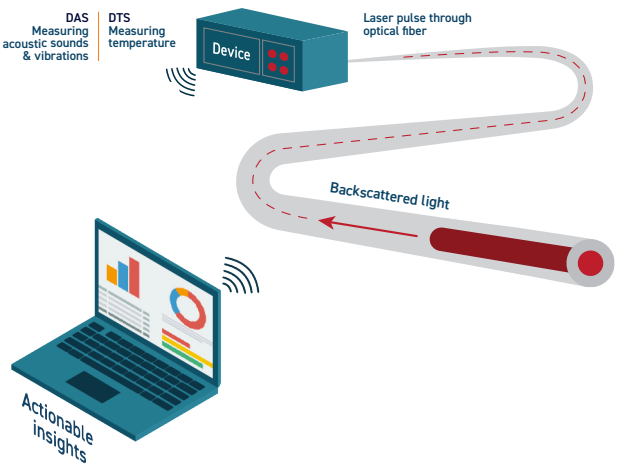
DAS and DTS working principles

Distributed Acoustic Sensing systems (DAS) and Distributed Temperature Sensing systems (DTS) are optoelectronic instruments that record acoustic vibrations and temperature along the length of a fiber optic cable. DAS and DTS differ from (industrial) IoT sensors by providing a continuous and distributed acoustic or temperature profile along the length of the sensor wire rather than at discrete measurement points. The physical principle behind DAS and DTS is as follows [9]:

1. The interrogator fires light pulses into the fiber using a highly coherent laser.
2. Photons reflect on small inhomogeneities in the glass matrix due to Rayleigh (for DAS), Raman or Brillouin (for DTS) scattering. These reflections are dependent on thermal and acoustic vibrations on the fiber and return to the interrogator where they are recorded and analyzed.
3. Since a pulsed light source illuminates only a piece of the fiber at a time, this allows for a distributed measurement of the scattering on the fiber that is highly spatially accurate, a principle known as OTDR (Optical Time Domain Reflectometry).

As a result, a DAS or DTS system essentially converts a single fiber into a string of thousands of highly sensitive acoustic vibration or temperature sensors. Due to the optical nature of the measurements, a single DAS or DTS device has a range of up to 90 km, is not vulnerable to electric interference, and is fundamentally ATEX-proof.

Due to the huge amounts of data produced by distributed sensing systems, a data management, processing, and visualization approach is essential. The interrogation devices are usually connected to a processing unit (such as an industrial PC or a server) that handles data storage and processing.



CUI-CONTROL

The CUI-CONTROL system was developed by Fluves, an engineering company specialized in fiber optic monitoring. It consists of several components:

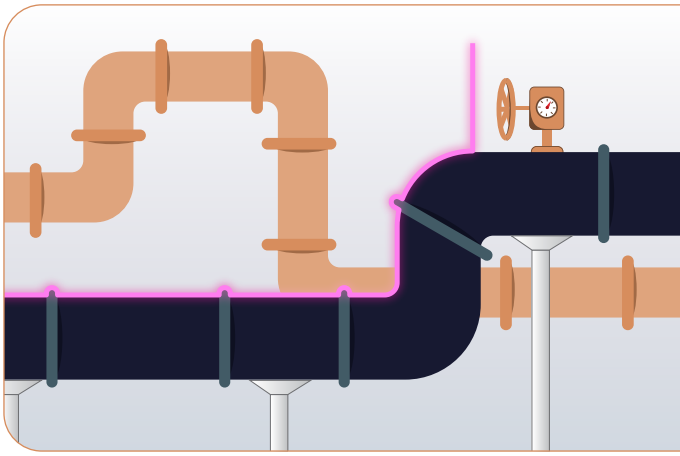
1. A fiber optic cable is attached to the outer cladding of the insulated pipeline, tank, or cryogenic facility. There is no need to dismantle or rupture the cladding, insulation, or pipe.
2. A DAS and a DTS system that record acoustic vibrations and temperature along the fiber, with a spatial resolution of 1 m.
3. Advanced signal processing and machine learning software, which scan the raw acoustic and temperature measurements for increased risks of corrosion. The CUI-CONTROL software runs on an edge server that is co-located with the DAS and DTS system and transmits its results to the cloud or the operator intranet.
4. An online dashboard that visualizes the asset (pipeline, tank or ice box) status in real time, shows the location and history of any anomalies, and sends alarm notifications via e-mail or SMS.

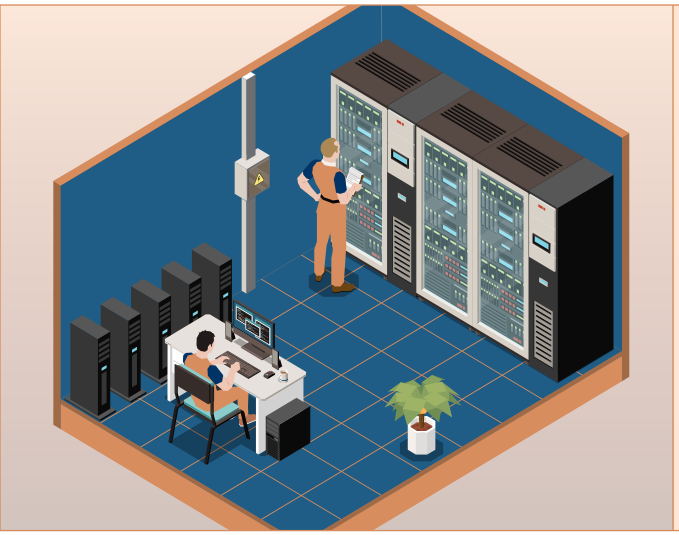
Every meter, every minute	Easily installed
Detect early-stage corrosion	Prevent corrosion
For existing pipelines, tanks and reactors	Full ATEX Proof

HOW DOES OUR TECHNOLOGY WORK

1. A uniquely designed fiber optic cable is attached to the outer cladding

The optical fiber is attached to the entire length of the outer cladding of your pipeline. This ensures that it is easy to install and perfectly applicable to existing pipelines or other infrastructure. Since there is no need to dismantle the insulation or cladding, the cable installation process is non-intrusive.





2. The cable leads to a control room where it is connected to a sensing system

The data is processed on site and you get to follow along using relevant metrics on a dashboard. As the sensing system sends light pulses through the fiber, the system is completely ATEX-PROOF.

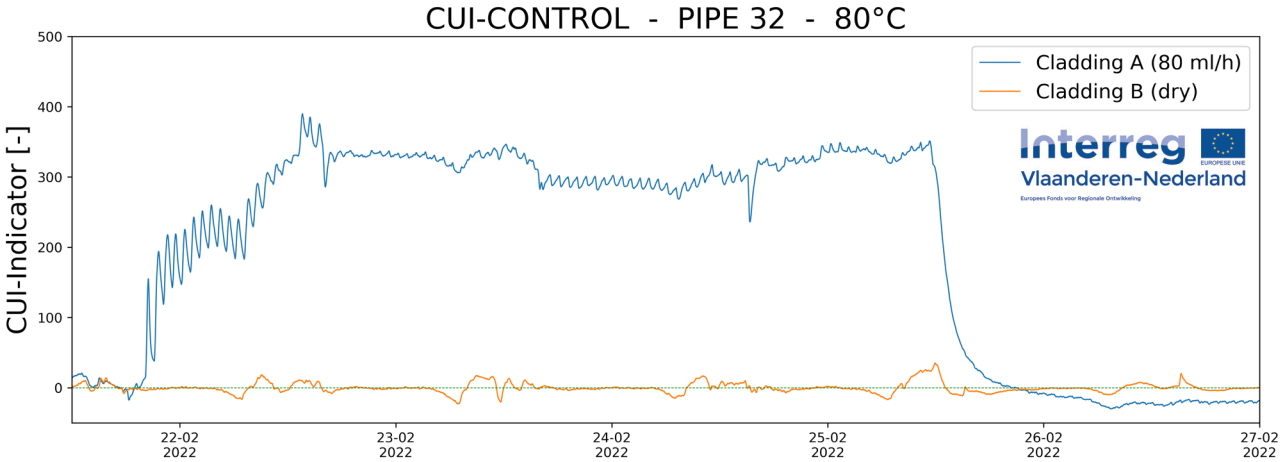
3. You are notified and alarmed when corrosion risks are detected

When necessary, alerts are automatically sent via e-mail, SMS, or SCADA and displayed on a real-time dashboard. Long-term monitoring results are summarized to support your maintenance strategy.

LAB TESTS

First, the CUI-CONTROL system was extensively tested in controlled lab conditions. In the Interreg Flanders-Netherlands research program "CorrosionLabs", a simulated industrial environment was created where specific corrosive conditions and environments can be mapped. Within this realistic test environment, Fluves tested the measuring principles in a unique setting. A wide range of 'preconditions' for corrosion were developed, and the measurements were analysed in great detail together with the CorrosionLabs research team. Different pipeline temperatures, moisture and environmental conditions were applied.

In the figure below, response of CUI-CONTROL is given on two locations along the fiber for a pipeline temperature of 82°C. A high CUI-indicator means a high CUI-risk. The orange and blue curve represent two pieces of insulation in the pipeline rack. The insulation of the blue curve corresponds with an hourly moisture injection of 80 ml, while the orange curve corresponds with a dry insulation. As can be seen from the figure, the blue curve shows a very distinct increase of CUI risk the moment the insulation reaches a certain degree of moisture content *(in the morning of 22/2/2022)*. The evaporation of moisture from insulation significantly reduces the CUI risk *(afternoon 25/2/2022)*.



CUI-indicator showing moisture injection (blue), dry insulation (orange).

USE CASE: BASF

First application of CUI-CONTROL was on site at BASF Antwerp. BASF is the world's largest chemical multinational. The German company has subsidiaries all around the globe, including one at the Belgian port of Antwerp. The company is taking the lead in applying technological innovations to detect CUI problems at their plants. Fluves set up a pilot test for the CUI-Control system at their site in Antwerp on a 300 m insulated MDI pipeline section.

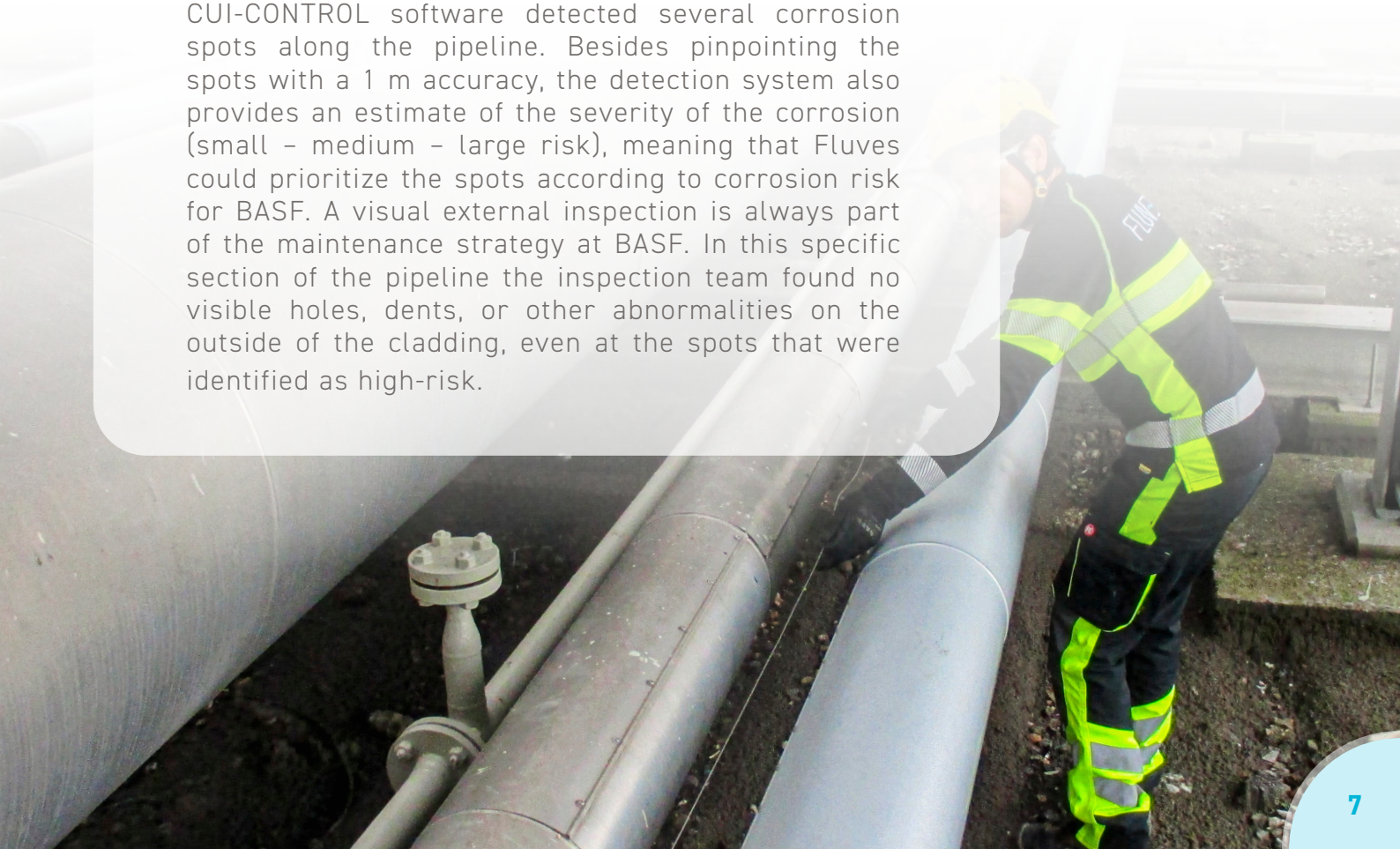
WHAT DID WE DO?

1. Installation of a fiber optic cable on 300 m insulated MDI pipeline section

To monitor the pipeline, we attached a fiber optic cable to the outer cladding. Since August 2021, the pipeline has been continuously monitored.

2. CUI-CONTROL software detects several corrosion spots

Soon after installing the fiber optic cable, the CUI-CONTROL software detected several corrosion spots along the pipeline. Besides pinpointing the spots with a 1 m accuracy, the detection system also provides an estimate of the severity of the corrosion (small – medium – large risk), meaning that Fluves could prioritize the spots according to corrosion risk for BASF. A visual external inspection is always part of the maintenance strategy at BASF. In this specific section of the pipeline the inspection team found no visible holes, dents, or other abnormalities on the outside of the cladding, even at the spots that were identified as high-risk.



3. Validation by BASF

In April 2022, a BASF team removed the cladding and insulation on the monitored section and inspected the locations that were identified by Fluves' CUI-CONTROL system in detail. At all identified points, the corrosion risk matched perfectly with the CUI-CONTROL predictions. Also, the spatial coverage as forecasted by Fluves' CUI-CONTROL system matched 100% with the reality, so the locations were pinpointed very accurately (1m accuracy). This also means that the CUI-CONTROL system is able to locate corrosion risk hotspots that could not be detected by external visual inspections.

CUI-CONTROL, powered by Fluves, is able to find the exact locations of potential corrosion sites. The system is able to measure the degree of corrosion risk with great precision. Their system has the added advantage that it can be applied on the outer layer of the jacketing, without having to dismantle anything.

Robin Guldentops,
asset manager ESP/IL
at BASF Antwerp

BASF
We create chemistry

USE CASE: LANXESS

But there are more applications. CUI-CONTROL can be applied to new and existing pipelines. But the system is also applicable to other types of infrastructure, such as tanks or reactors. To further illustrate this, we deployed the CUI-CONTROL system on a large storage tank at the Lanxess site in Antwerp, Belgium.

CUI-CONTROL IS THE RIGHT CHOICE FOR YOUR INDUSTRIAL ASSETS

- Save time and money on repairs due to accurately marked corrosion spots
- Receive automatic alerts when there's a risk
- Count on 24/7 monitoring of your pipelines
- Follow the system's real time data on a user-friendly dashboard
- No need to remove cladding or insulation. The fiber optic cable is retrofitted at the outside of the pipeline/infrastructure.
- Detect early-stage corrosion or even prevent it
- Extend the lifetime of your industrial assets

WWW.CUI-CONTROL.COM

BUSINESS CASE CUI-CONTROL

How much direct financial gain does CUI-CONTROL provide? How much increase in efficiency and how much reduction in costs can be attributed to CUI-CONTROL? To provide an objective answer to those questions, it is important to be aware of all the benefits the system will provide. In summary, these benefits are the following:

- Receive 24/7, up-to-date information about the health of every meter of your asset.

- Your inspection is converted from a theoretical risk-based inspection to a data-driven inspection. The effectiveness of your inspection team will increase drastically. They will only have to remove the insulation on those locations and moments where CUI-CONTROL indicates it is necessary to do so. This will lead to a strong reduction in the inspection cost.

- The system removes the blind spots in your current inspection routine and warns you before you have to act. This will lead to a reduction of the damage to your valuable assets and will lead to strong reductions in welding costs, clamp cost, urgent leak repair and ultimately in downtime costs. CUI-CONTROL gives you the opportunity to safely extend the lifetime of your investment.

- The system provides you with active leak detection and fire detection on your pipelines and will lead to a safety increase and a reduction of the environmental risk from leaks.

- CUI-CONTROL warns you where your insulation is damaged or deteriorated, giving you the chance to repair the damage leading to a significant reduction in energy losses.

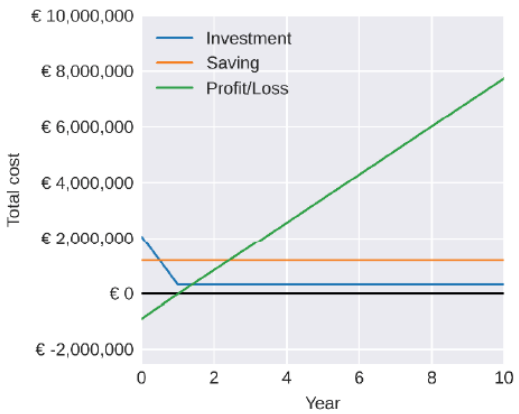
Extra benefits are the positive publicity associated with your innovative steps, while at the same time avoiding negative publicity on environmental risks. A fiber that is placed on assets (pipeline, reactor, tank, ...) also opens the door to add-on applications such as steam trap monitoring or pipeline vibration monitoring.

Fluves used historical data about benefits and costs related to CUI to calculate the return on investment of CUI-CONTROL.

We have received anonymous maintenance data from several plants and combined them to make a fictional chemical plant with 200km of insulated pipeline, which is representative of a large chemical production facility. For our business case, we only took into account the easy-to-verify costs:

- Reduction in inspection cost
- Reduction in welding cost
- Reduction in clamp cost
- Reduction in urgent leak repair information

By taking into account the easy-to-verify benefits, the return on investment (RoI) of installing the CUI-CONTROL system could be calculated. The RoI for this fictional plant appears to be less than two years.



The return on investment of installing CUI-CONTROL is typically less than two years.

ACKNOWLEDGEMENTS

The infrastructure of CorrosionLabs is developed with funding from The European Regional Development Fund (ERDF), under the Interreg Flanders - The Netherlands program, for the project 'Praktijklab Corrosie & Isolatie'.

We gratefully acknowledge BASF for their enthusiasm during the whole pilot process and the further roll out of the CUI-CONTROL system.

REFERENCES

1 Javaherdashti, R., Corrosion under Insulation (CUI): A review of essential knowledge and practice. International Journal of Computational Materials Science and Surface Engineering, 2014. 1(2): pp. 36-43.

2 Fitzgerald, B.J,. et al., STG 36 Oral Presentation, *CORROSION*, 2004.

3 Caines, S., et al., *Demonstration of increased corrosion activity for insulated pipe systems using a simplified-electrochemical potential noise method. Journal of Loss Prevention in the Process Industries*, 2017. 47: pp. 189-202.

4 Geary, W., *Analysis of a corrosion under insulation failure in a carbon steel refinery hydrocarbon line.* Case Studies in Engineering Failure Analysis, 2013. 1(4): pp. 249-256.

5 Veritas, D.N., *Risk Based Inspection of Offshore Topsides Static Mechanical Equipment.* 2002, Oslo: DetNorske Veritas.

6 Segment, A.P.I.D., *Risk-based inspection technology.* 2008: American Petroleum Institute.

7 Winnik, S., *Corrosion under insulation (CUI) guidelines.* 2014: Elsevier.

8 Smolen, J.J., and A. van der Spek, *Distributed Temperature Sensing: A DTS Primer for Oil & Gas Production* (May 2003), Shell International Exploration.

9 Hartog, A.H., *An Introduction to Distributed Optical Fibre Sensors* (1st ed.). CRC Press. https://doi.org/10.1201/9781315119014, 2017.

QUESTIONS? FEEL FREE TO ASK US.

Fluves' CUI-CONTROL system can extend the lifespan of your industrial infrastructure by multiple years. Get in touch with us for more information on how we can help you monitor corrosion under insulation on your industrial assets.

Timothy Van Caelenberghe
Sales Advisor

+32 9 346 85 30
sales@fluves.com
www.cui-control.com
@fluves