More Than Leak Detection:

Hybrid Solutions for Smart Pipeline Management

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Pipelines are very secure transport systems. However, there are still risks involved: They could rupture, leak, or be damaged or destroyed by improper operation. Leak detection and location systems should monitor critical parameters during operation of the pipeline and react quickly to leakages. At present, most pipeline operators use conventional, non-safety-related monitoring systems. The world's first hybrid solution based on a SIL 3 safety controller and a compliant leak detection and location system significantly increases pipeline safety. It complies with current and upcoming standards and regulations concerning pipeline operation. The solution reduces losses and liability risks, which can arise even from small leaks, protects the environment, prevents harm to reputation, and increases the profitability of pipeline operation.

1. Challenges of Pipeline Management

Pipelines are the most economic and secure transport systems for oil, gas, and other products. Every day, many millions of tons of liquids and gases are transported via overland pipelines or pipelines within facilities. As a means of conveying masses of material, pipelines must fulfill strict safety, availability, and environmental requirements. Due to the great distances that pipeline systems often cover, special conditions are set on the protection and operation of the pipelines. This is justified: According to a 2012 press release by the PTC (Pipeline Technology Conference), there are 2,000 incidents every year on the European pipeline network alone.

Danger of pipeline leaks

One particular pipeline hazard is leakage. If a leak occurs, it needs to be detected and located as quickly as possible – especially if the pipeline is transporting fluids or gases that can contaminate water or are toxic or flammable. The quicker that countermeasures are initiated, the less severe the damages caused by the leak. Damage to a pipeline can have various causes. Corrosion or wear are just as common causes as material defects. However, theft, cyberattacks, and terrorism or sabotage can also endanger pipelines.

Problems of conventional leak detection systems

The hydraulics of a pipeline leak can be explained as such: In pipelines that run horizontally, there is a steady flow with a constant flow rate and a linear decrease in pressure. If there is a leak, the hydraulics of the pipeline change – the inlet flow rate increases and the outlet flow rate decreases. This means that the decrease in pressure before a leak will be higher than after a leak. At the same time, the pressure drops marginally at both ends of the pipeline. Leak detection systems are designed to recognize these changes, determine whether there is a leak, and then locate it.

However, in practice, leak detection systems based solely on pressure sensors are too prone to false alarms. This is because

a pressure drop in the pipeline is not necessarily caused by a leak. It could also be caused by ordinary actions performed during the operation of the installation, such as when a pump is switched on or a valve is closed. If false alarms become too frequent, personnel might not pay enough attention to the alerts and possibly neglect to perform the necessary checks.

Effective deployment of leak detection systems

For a number of reasons, pipeline operators should implement a leak detection system for their installations. In many countries, it is compulsory to follow best practices for pipeline operation. If a pipeline is not equipped with an up-to-date leak detection system, the management can be held liable for any incidents that occur.

The threat of high costs

The consequences and cleanup of damages caused by pipeline leakages can cost the operator huge sums of money – not to mention the potential harm to people, the environment, and reputation. On the one hand, costs arise according to the value of the product that is leaking from the pipeline. The later a leak is discovered, the more money is lost in this way. But, in many cases, the costs arising from the subsequent cleanup and fines are many times higher than those caused by the loss of materials.

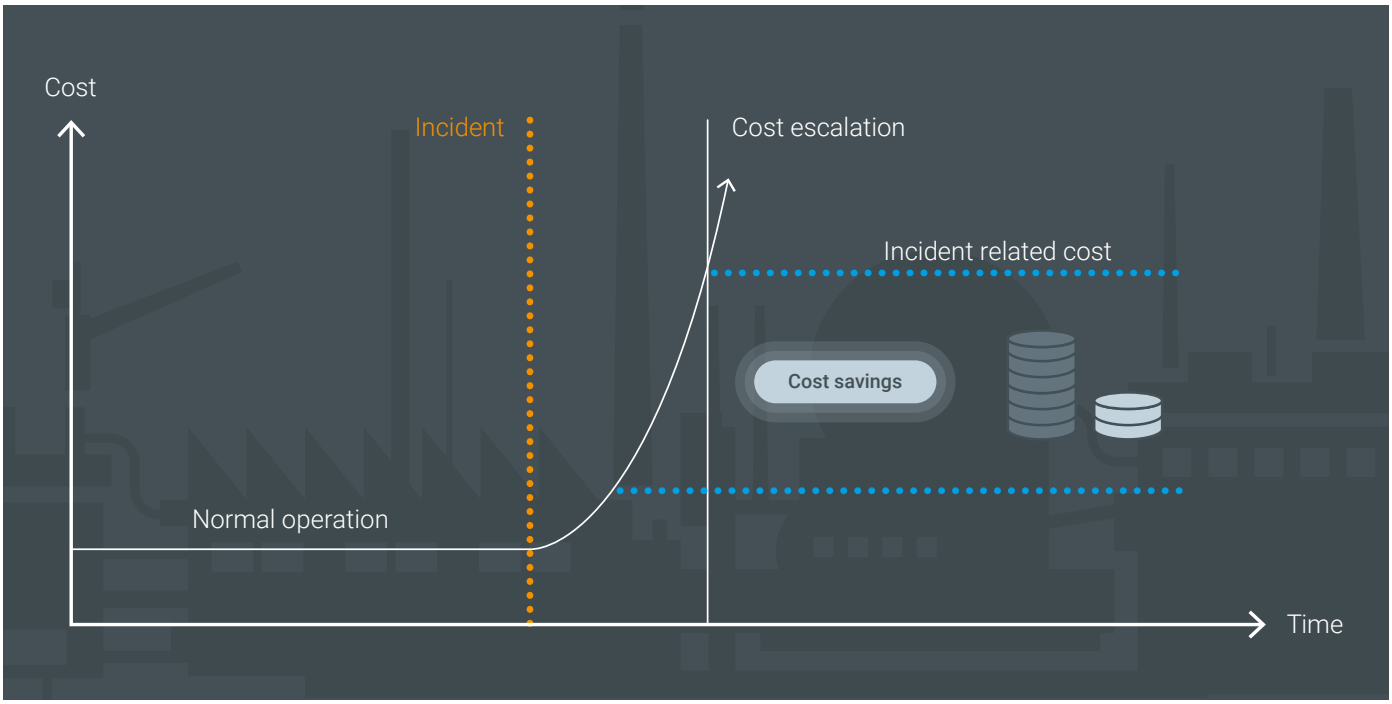
Rapid leak detection can significantly reduce these costs. Here are two examples: In January 2010, a pipeline ruptured near the small town of Neche in North Dakota, USA. Around 600,000 liters of crude oil were released. The cost of property damage alone exceeded four million US dollars. And in February 2012, a leak in a pipeline supplying kerosene to Frankfurt Airport caused considerable damages. One million liters of kerosene seeped into the earth, contaminating an area larger than four hectares. Experts believe that the cleanup of the subsoil could take up to ten years to complete and cost several millions.

Furthermore, insurance companies can adapt their policies subject to leak detection technology and decline insurance if such a system is not used. In contrast, they may lower insurance costs if there is a sophisticated and reliable leak detection system in place.

Increasing legal requirements

Around the world, pipeline operators are facing increasing legal requirements concerning safety and cybersecurity. Today, they already have to take into account a wide variety of international standards on pipeline integrity management. The most important are the American standards API 1160, API 1130, and API 1175 (first edition). API 1160 is a general recommended practice covering pipeline integrity management, standards for planning, construction, and operation of pipelines, and how to respond in emergency situations. API 1130 is a set of guidelines specifically for pipeline monitoring. And API 1175 describes the recommended practice for pipeline leak detection.

Pipeline Management Challenges



Every minute matters: Early leak detection saves money

New compliance issues arise from legislation, such as the California Assembly Bill 864, which was introduced in response to oil leaks. The bill stipulates that pipeline operators in environmentally and ecologically sensitive areas must use the best available technologies to limit the amount of oil released in an oil spill. It explicitly states the requirement to use a combination of leak detection technology and safety systems.

Safety and risk reduction
Safety is an abstract term that describes the absence of danger. Since complete safety is unattainable, the priority is to reduce risk to a tolerable level. This tolerable level depends on legislation, standards, or individual evaluations and is typically defined by the relationship between cost and benefit. From a technical point of view, the reliability of automated safety functions needs to be ensured, i.e., the probability of the safety system failing to work when it is needed must be reduced to a tolerable level. The challenge is to minimize the number of dangerous, undetected faults in the safety system. To do this, the safety system should be monitored for internal errors during its operation. If a potentially dangerous fault is detected, the system is put into a safe state.

When creating approval planning documents for a pipeline, a risk assessment needs to be carried out. If the identified risk is higher than the tolerated risk level, risk reduction measures are required. Depending on the necessary risk reduction, there are various technical measures to implement. A risk reduction factor of 1,000 can be achieved by using an SIL 3 safety system. Systems of this kind should experience only one dangerous failure per ten million hours of operation.

Implementing risk reduction
There are a number of ways to minimize risk. One option is to introduce work instructions that limit the number of people that are permitted to be in a dangerous area at one time. However, the majority of operative restrictions that need to be considered do not allow risk minimization to be limited to simple measures like this.

Another strategy is to implement technical risk minimization measures that help mitigate the consequences of unwanted incidents. An example of this is gas detection systems that identify the release of flammable gases. Although these systems do not prevent gas leaks, they can limit the consequences by triggering evacuation procedures or even shutting off potential ignition sources. If such solutions are included in the design of an installation and contribute to the installation's safety, then a safety system is required to minimize the risks. In principle, a similar rule applies to pipeline leakages. In view of the operational safety of the pipeline, the negative consequences of leakages must be minimized. Therefore, leak detection systems must be implemented in combination with safety methods and technologies.

2. HIMA and Pipeline Safety

For around 45 years, programmable logic controllers have been one of the most frequently used pieces of equipment in the process industry. To enable use of this technology for safety applications, HIMA engineers developed the first safety controller based on the diagnostic principle and introduced it to the market in 1988. This control system was equipped with sophisticated fault diagnostics to find and resolve internal errors.

A new concept for minimizing risk on pipelines
HIMA has been working with monitoring technology for the pipeline industry for around ten years and has launched risk minimization solutions targeted at this market. The result of this development is a brand-new leak detection concept that has already been deployed in a range of applications around the world.

When it comes to ordinary pipeline leak detection, HIMA developers identified four principles that are accepted by the market. Commonly, methods based on volume differences, pressure differences, or pressure fluctuations are used. However, these come with their own pros and cons. Based on best practice assessments, HIMA decided to combine the methods to create a comprehensive solution. A systematic problem is that all pipelines deteriorate due to a wide variety of factors, including corrosion, changing valve properties, and the accumulation of residue and debris in the pipes. These factors mean that normal pipeline monitoring systems need to be maintained regularly and the respective mathematical models need to be adapted to safeguard functionality.

HIMA's leakage monitoring solutions minimize the impact of the abovementioned physical effects or even eliminate the impact entirely. This has two results:

1. The HIMA leak detection system is reliable enough to migrate an HMI-based monitoring function to an automated function that automatically shuts down the pipeline if a leakage is detected.
2. The leak detection system is accurate enough to identify theft in a pipeline, enabling appropriate countermeasures to taken.

Based on this 2015 development, HIMA began to implement this functionality on its advanced safety control system HIMax. In early 2016, the new solution was installed on a chemical pipeline that runs through a highly populated area and a nature reserve. To cover all the safety aspects that were identified in the risk analysis, the company operating the pipeline opted for a SIL-compliant leak detection system that can be included as part of an automated safety function. The solution is successfully running today. The inspection procedures that are required for the solution to be SIL compliant are currently being carried out for the software. The solution will then be one of the first leak detection systems to be implemented in an SIL 3 compliant platform and fully SIL classified. This enables the leak detection system to be an integral part of the automated safety function.

HIMA combined software and hardware to create a unique safety solution for pipelines. This is the first time that an emergency shutdown system and a leak detection system have been successfully integrated. For this reason, HIMA calls it a hybrid solution.

3. A New Hybrid Solution for Safety and Leak Detection

The hybrid solution for pipeline management not only protects the installations involved, but also controls and manages safety-relevant processes. The system can monitor pipelines end to end, automatically shut them down in hazardous situations, and prevent or significantly reduce damages.

The SIL 3 safety system and the compliant leak detection and location system are core components of the integrated hybrid solution. It enables pipeline operators to implement both safety control and critical control applications. The comprehensive solution ensures the long-term availability and cost-efficiency of pipelines – with the maximum level of safety.

A system for safety and security

The safety control system is based on XMR technology by HIMA that combines SIL 3 safety technology with a scalable, fault-tolerant architecture. This helps prevent false alarms. It is possible to carry out unlimited alterations, modifications, extensions,

improvements, and even mandatory proof tests while the plant is in operation. Benefits include uninterrupted system operation, maximum availability, and, as a result, significantly increased productivity throughout the entire lifecycle of the pipeline.

In addition to functional safety, the safety control system also fulfills all applicable cybersecurity requirements. If operational interfaces or the required integration into a programmable logic controller present a risk that endangers the functional integrity of the pipeline automation, then cybersecurity also need to be given as much attention as pipeline safety. When built in the proper way, the secure control system forms the last line of defense against cyberattacks. This combination of functional safety and cybersecurity ensures the overall safety of the plant or installation.

The number of cyberattacks via networks is increasing – even on pipelines. For example, in 2012, hackers attempted to gain access to the control systems of several gas pipelines in the USA via the Internet. Even in its default settings, the HIMA safety system fulfills all applicable cybersecurity requirements. The safety control system offers a range of protection to ensure secure communications – the CPU and communication systems are separated. Using hardware and software developed by HIMA makes it significantly more difficult for hackers to gain unauthorized access. Moreover, the time-consuming patches that are required by most standard software today are no longer necessary.

Pipeline software for leak detection and location

The second part of the hybrid solution is software that reliably detects and locates leaks, minimizes false alarms, and reduces maintenance costs. In addition to leak detection and location, the software can map additional main functions, such as batch and pig tracking, data archiving, and data analysis. Furthermore, the system supports pressure and temperature corrections. The SIL 3 leak detection system complies with relevant standards such as API 1130 and TRFL. Leakages are analyzed and located using multiple methodologies simultaneously. This ensures that the system will be available in all phases on the pipeline and allows the system to detect the smallest of leaks while minimizing false alarms.

The software can also detect pipeline ruptures, thereby minimizing the operational risk of the pipeline and the amount of product released. In order to do this, the safety system acts rapidly and automatically. Moreover, the rupture detection system ensures that the damaged pipeline segment is automatically blocked off in case of a rupture.

4. New Opportunities for Pipeline Operators

The new integrated hybrid solution for pipeline management offers pipeline operators considerable benefits. It complies with current and upcoming global safety standards according to SIL 3. It ensures maximum functional safety and extremely high reliability by automatically shutting down any affected areas during critical situations. As a result, it cuts the operating costs of pipelines, significantly reduces false alarms, and increases the profitability of installations. At the same time, the closed HIMA system with integrated cybersecurity provides a strong line of defense against cyberattacks.

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