Newsline

OIL & GAS

Leak Detection and Localisation and the Human Factor

Extract from a paper presented by Hilko den Hollander at the 2006 Pipeline Technology Congress

'Leak detection systems do not work and only generate false alarms' is still heard quite frequently. This is unfortunate since just the opposite is true. Modern state-of-the-art systems are highly reliable while permitting sensitive leak detection and accurate leak localisation.

Start with the basics: why install a leak detection system and how to choose a system that suits your application. Let's focus on the Human Factor. What is important for the people working with such a system? For example: No false alarms might be preferred above looking for the ultimate sensitivity and thereby increasing the opportunity for false alarms.

Typical leak detection specifications, such as sensitivity and accuracy, are also considered. Are these specifications relevant to real life situations or do they only refer to fully stationary pipeline conditions that are only encountered in theory?
We describe the E-RTTM technique used for PipePatrol, Leak Detection and Localisation System.Field test results from an ethylene sub-critical gas pipeline demonstrate that PipePatrol does work and does so without false alarms.

Discussing leak detection system immediately leads to the first basic question; 'Why a leak detection system'? A familiar reason is, of course, legislation. In Germany all new pipelines that transport polluting, toxic, or combustible gasses or liquids may only be operated if two independently continuously working leak detection systems are in place. The requirements for leak detection systems are laid down in the TRFL (Technical rules for Pipelines).

Legislation is, however, not the only reason for implementing a leak detection system. Items such as safety and protection of the environment are obvious. Loss of image is also an important issue. A company's image can be seriously damaged if this company comes in the news as 'not having done everything to prevent a leak'. Less known is that modern leak detection systems can provide relevant pipeline information, such as pressure and flow profiles along the pipeline that can improve pipeline opex drastically. Finally, the quicker and more reliably a leak can be detected, the quicker it can be repaired, and monetary losses can be minimised.

Finding the correct system

Once a decision is made to implement a leak detection system, the optimum system has to be selected. Because the available systems from different suppliers are based on different techniques this process can be time-consuming. Let us consider a number of decision criteria. We shall not focus on the technical details of each system, but rather on the human aspect, 'what is important for the operator'?

Reliability is of major importance for all operators. After two false alarms there is the danger the operator will ignore further leak alarms or will even switch the system off. The bottom line is that leak detection system should not give false alarms under any circumstances.

A second decision criterion is sensitivity: the system should be able to detect the smallest possible leak. The time required to detect this leak and the operational mode of the pipeline are also important: A leak detection system that can detect small leaks (e.g. 1% of nominal flow) sounds promising, but if it takes 24 hours before it detects the leak the system is of little use. Since pipeline operations almost always show transient behaviour, due to operational changes such as changing pumping capacity or opening or closing valves, sensitivity figures should be interpreted carefully. Does a figure refer to stationary or transient conditions and how much time is required to detect a leak?

Performance figures are only meaningful if they refer to the pipeline conditions (transient or stationary) and the time required to detect a leak.

If a sensor fails, the system needs to be robust and should definitely not give a false alarm. Ideally, it remains in operation. Redundant sensors might be a solution to overcome a reduction in sensitivity due to a sensor failure.
A final decision criterion is accuracy of the leak localisation. When a leak is detected, the localisation should be accurate enough to access the location with limited effort and within a reasonable time.

A theoretical or practical approach?

A comparison of different types of systems shows that most systems promise impressive sensitivity and accuracy figures. But, do these figures refer to stationary or transient pipeline operation and how long does it take to detect a leak. Secondly do the figures come from a purely technical calculation or can they be backed-up with field test data.

Field test results from similar applications are the best recommendation.

A simple example can be given for leak localisation. Leak localisation is typically done by analyzing pressure waves. Since pressure waves travel with the velocity of sound, their typical velocity in a liquid hydrocarbon is 1300 m/s. When a leak localisation of ± 10 meters is specified, this means the refresh rate of the pressure reading should be 10/1300 = 7 ms (milliseconds). In a purely mathematical approach, ignoring all transients in the line, this localisation is possible. In an industrial application, however, this scenario is unrealistic since refresh rates are typically between 0.5 and 30 seconds. Even a refresh rate of 0.5 seconds physically restricts the minimum achievable accuracy to 1300*0.5 = ± 650 meter.

A second example can be given for sensitivity. In fully stationary pipeline conditions the sensitivity of a leak detection system can go down to the accuracy, or in some systems even the repeatability, of the installed flowmeters. Unfortunately fully stationary pipeline conditions are a purely theoretical exercise, and even if they do occur, the system needs a virtually unlimited long detection time to reach such a state of sensitivity.

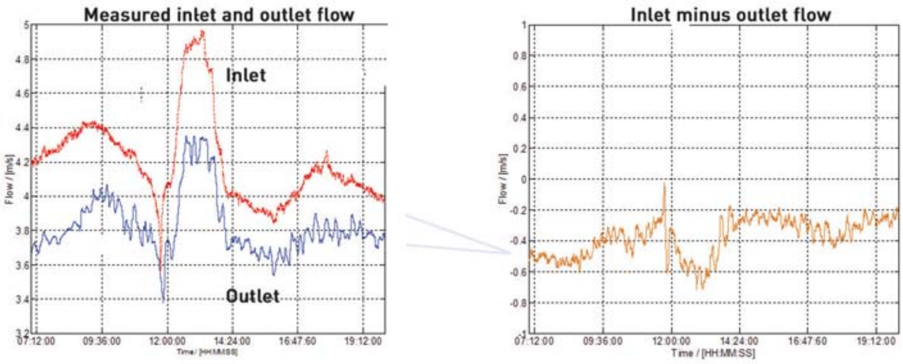


Fig. 1: A simple line balance. The left-hand graph shows inlet and outlet measured by a flowmeter. The right graph shows inlet minus outlet flow.

PipePatrol in 4 easy steps

1. Conventional systems track measured flow, comparing inlet and outlet.
2. PipePatrol compares measured flow with calculated flow to check if there is a difference, to detect true (compensated) flow differences.
3. PipePatrol compare inlet and outlet true (compensated)flow to check for leaks
4. PipePatrol applies algorithms for Leak Pattern Recognition.

The result is no false alarms

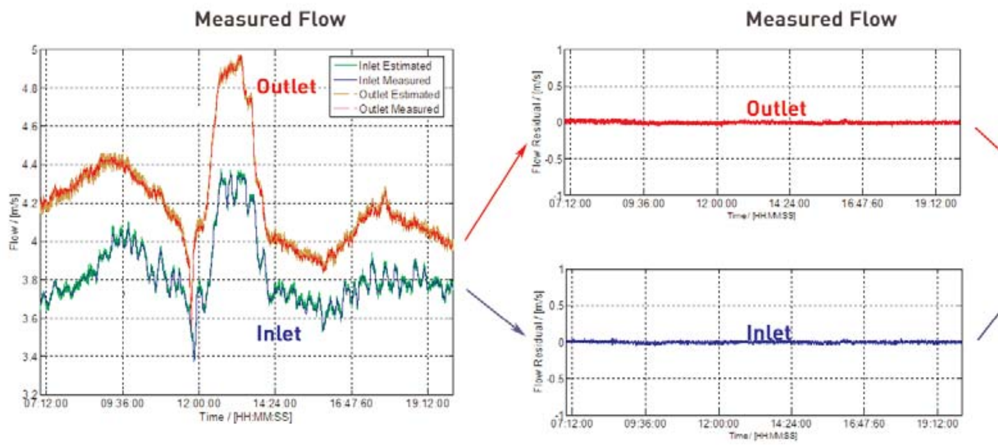


Fig. 2: The RTTM approach: The graph on the left shows measured and calculated flow at the inlet and outlet . The graphs on the right show the difference between measured and calculated flow at the inlet (blue line) and outlet (red line).

PipePatrol, KROHNE's Leak Detection and Localisation System

During the development of PipePatrol, reliability was one of the key design elements.
To overcome the limited performance of traditional systems in transient conditions, KROHNE decided to base PipePatrol on RTTM technology (Real Time Transient Model). To avoid false leak alarms a Leak Pattern Recognition algorithm was incorporated and as a result the model behind PipePatrol is called an E-RTTM (Extended Real Time Transient Model). The following paragraph explaining E-RTTM focuses on basics, and minimises the explanation of the underlying algorithms. More technical information, including the underlying algorithms, is available on request but is not required to understand the basics of the RTTM technique.

RTTM, the Real Time Transient Model

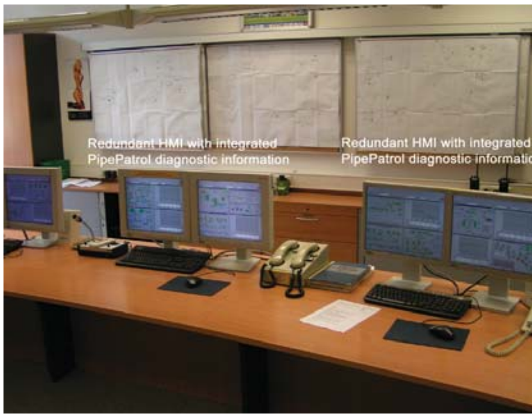
RTTM uses measurements of flow, temperature, and pressure at the inlet and outlet of a pipeline. The flow is measured by flowmeters and simultaneously calculated from the pressure and temperature readings. A simple (albeit limited) analogy can be made to a differential pressure or orifice flowmeter, where the flow is calculated from two pressures.

Comparing the calculated flow (from P and T readings) with the measured flow (from the flowmeters) gives the flow residuals at inlet and outlet. In the graph below, Figure 1 represents a simple line balance situation where only flow at the inlet (upper curve) and outlet (lower curve) is measured. Subtracting the outlet from the inlet flow gives the flow imbalance as shown in the right-hand graph.

Figure 2 shows what happens with the RTTM approach. The left-hand graph (no leak present yet) now shows 4 lines, the upper lines shows the measured flow at the inlet, and the corresponding calculated (estimated) flow at inlet. The lower lines are for the outlet. Subtracting the measured flow from the calculated flow at the inlet gives the flow residual for the inlet in the top right-hand graph. The flow residual for the outlet is given in the graph below.

The two graphs on the right show the 'true' leak (or compensated) flow at the inlet and outlet. Both lines are around zero since there is no leak in this line. A leak near the inlet will create a significant shift from zero in the top line. A leak near the outlet will have a similar effect on the bottom line; leaks in between will show in both graphs. For example, if the pipeline is 10 km long and there is a leak at 8 km, the leak effect will show to 80% in the outlet graph and 20% at the inlet graph. Using RTTM therefore not only allows leak detection, but also leak localization.

Figure 3 summarizes the RTTM technique. The lower erratic line represents inlet minus outlet flow, based on a simple line balance where only flowmeters are used. The smooth line around zero represents compensated inlet flow (i.e. calculated minus measured inlet flow, the blue line in the right top graph from figure 2) minus compensated outlet flow (the red line in the right bottom graph from figure 2). The blue line thus represents the actual leak flow where compensation is made for the transient pipeline behaviour.



Control room at major German chemical plant

Introducing a leak recognition algorithm - differentiating between a sensor failure warning, and a true leak alarm

KROHNE decided to extend the RTTM model with a leak recognition algorithm. If a predefined threshold is exceeded, PipePatrol first analyzes the leak pattern. A spontaneous leak will always show a specific leak pattern (see figure 4). A sensor drift will not show this specific pattern

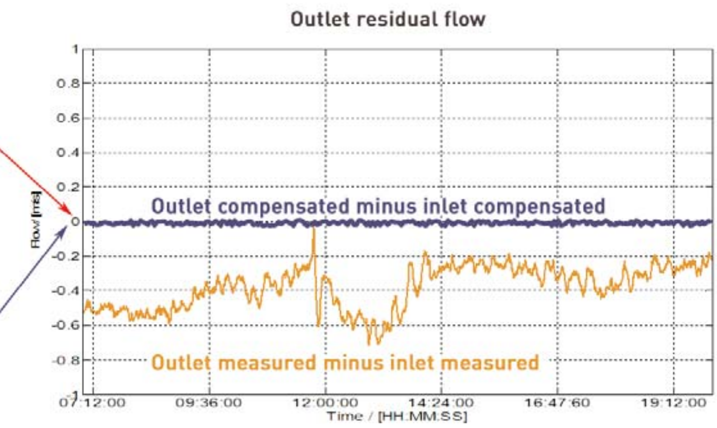


Fig. 3: The difference between inlet and outlet flow using a simple line balance method (orange line) and using an RTTM model (blue line). The RTTM technique compensates for all transients.

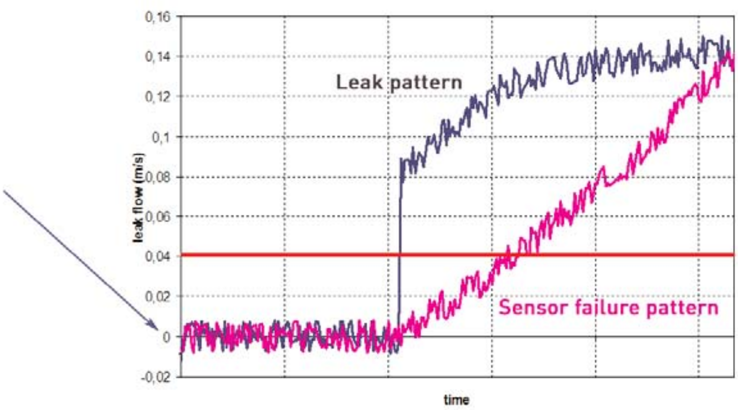


Fig. 4: The red line indicates a predefined threshold. Both the magenta and the blue flow imbalance lines exceed this threshold; however, only the blue line shows a typical leak pattern and will set off a leak alarm. The magenta line is typical for a sensor drift and will raise a sensor failure warning - not a leak alarm.

and will manifest with a slowly increasing leak rate. After the leak pattern has been analyzed, the E-RTTM model will either set off a leak alarm or a sensor warning. The system makes a clear and unmistakable difference between a warning that a sensor needs attention and an alarm for a true leak.

PipePatrol, a dedicated LDS system

To maximise reliability PipePatrol is installed on a dedicated industrial PC. If requested, redundant components are included. This PC is called the PipePatrol Monitoring Station and runs completely autonomously. The HMI (Human Machine Interface) runs on a separate Operator Station or can be included in the existing SCADA system.

PipePatrol can be divided into two kernels; the Pipeline Observer and the Pipeline Classifier (see figure 5). The Pipeline Observer runs the RTTM algorithms that calculate flow from pressure and temperature readings. The Pipeline Classifier analyzes the difference between the measured flow (coming from the flow meter) and the calculated flow (coming from the Pipeline Observer). In case a predefined threshold is exceeded, the Pipeline Classifier will first analyse whether this is caused by a sensor drift or by a spontaneous leak and a sensor warning or a leak alarm will be given. The Pipeline Classifier subsequently calculates the leak location and the leak rate.

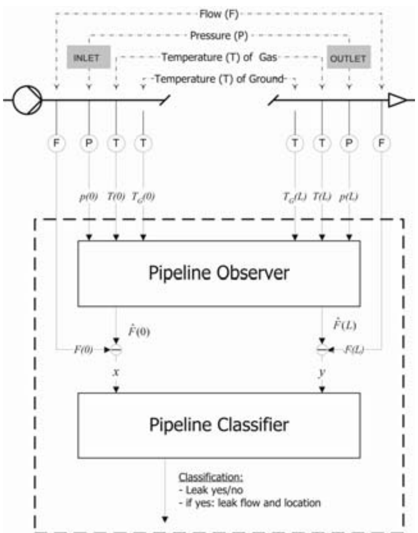


Fig. 5: PipePatrol runs two kernels. The Pipeline Observer supports the RTTM algorithms. The Pipeline Classifier supports the leak pattern recognition, therewith improving PipePatrol to an E-RTTM based system.

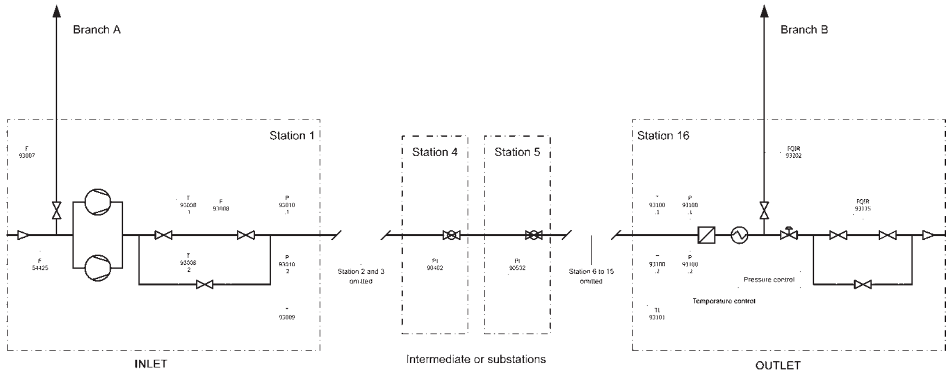


Fig. 6: Overview of the 112 km long Ethylene pipeline. Flow is measured at inlet and outlet, additional pressure measurements are made on twelve of the fourteen valve stations

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Leak detection on an ethylene gas pipeline

Leak testing was done on a 112 km long sub-critical ethylene gas pipeline. The pipeline has two branches at inlet and outlet (see figure 6) and therefore can be seen as a small pipeline network. Due to the high compressibility and non-ideal behaviour of ethylene gas the pipeline is in constant transient operation. Although this application places high demands on a leak detection system, E-RTTM makes reliable leak detection possible.

Because continuous pipeline operation is mandatory, the application is characterised by strong redundancy requirements. While this application describes a gas pipeline, similar application notes for liquid pipelines are available on request.

Application details

Ethylene (C2H4) is produced in the petrochemical industry by steam cracking and is used primarily as an intermediate in the manufacture of other chemicals. It is a raw material for polyethylene, polystyrene and PVC. Ethylene is highly inflammable, mixtures with air are explosive, and inhalation can lead to unconsciousness.

Figure 6 shows the pipeline configuration. Most of the field instrumentation was already present so the leak detection system could use measurement data from existing instruments. Flow is measured at inlet and outlet with a mixture of Coriolis mass flowmeters and orifice plates. Additional pressure measurements are available from 12 of the 14 intermediate valve stations. Density measurements are not required, since density is calculated from P and T readings at inlet and outlet. The pipeline has a length of 112 km (70 mile) and a diameter of DN 250 (10"). Inlet pressure is 34 bar (493 psi), outlet pressure is 24 bar (348 psi).

Data communication in this application is based on PLCs. To avoid any breakdown of the communication three different communication lines were installed, of which two lines for redundancy reasons (see figure 7 for details). The refresh rate for the reading from inlet and outlet instrumentation is about 1 second. The refresh rate for the intermediate pressure readings is about 30 seconds.

All instrument data readings are fed into a dedicated, stand-alone industrial PC (and a redundant second PC). The PipePatrol E-RTTM algorithms are run on this PC and the critical information is fed into the existing pipeline control system. PipePatrol's diagnostic information is integrated in the HMI and forms an additional module for the operator to the existing pipeline control system.

Leak testing

Various leak tests were carried out. The first test was a heavy transient operation test. Since the pipeline is operated continuously, a start-up or shutdown could not be carried out. For this reason the transients were introduced by temporarily closing the valve at branch A (see figure 6). A special transient operation day was organized for this. The results of this test are shown in figure 8.

A second test was carried out by introducing a leak. A valve at station B (bypassing the flowmeter, see figure 6) was opened for about 10 minutes at a leak rate of approximately 2 tons/hour. Figure 9 shows an overview of the measured and calculated flows during this period. The leak can clearly be identified here.

As can be seen from figure 8 the measured and calculated flows match each other closely. Note that the valve at the inlet side was opened at around 06:00 and the effect on the outlet side only showed by around 20:00 (14 hours later!)!

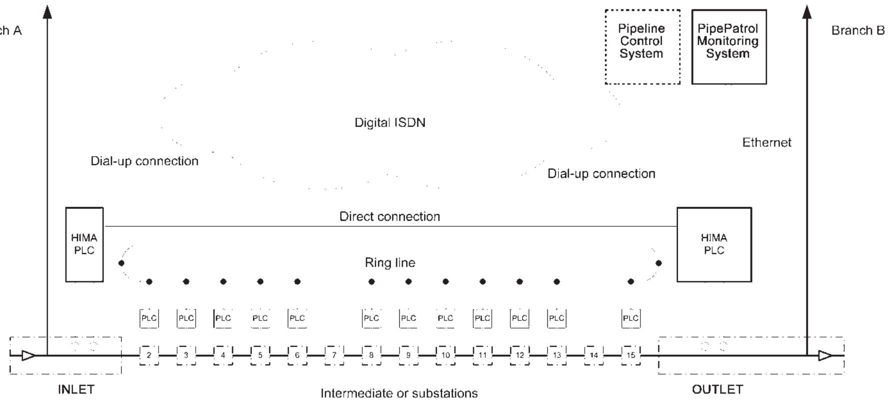

Fig. 7: Data communication system with redundant communication lines

Figure 10 shows the residual (i.e. the difference between calculated and measured flow at the inlet minus the difference between calculated and measured flow at the outlet). This figure shows that a leak is identified after only 100 seconds after it was created.

Results from the leak tests

Based on the above mentioned leak trials, the system has been configured such that it will detect any leaks which cause more than a 0.2 bar pressure loss (note that nominal pressure is 34 bar at the inlet and 24 bar at the outlet). By using a combination of different leak localization methods leak locating errors of less than 0.1% of the pipeline length are achievable. To date the system has not given any false alarms during normal operation.

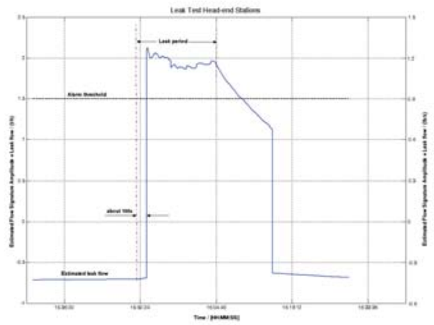

Figure 10: This line represents the difference between the inlet residuum (measured flow at the inlet - calculated flow at the inlet) and the outlet residuum. During the leak trials the pre-defined threshold of 1.5 tonnes / hour was exceeded. After 100 seconds (less then two minutes) this resulted in a true leak alarm!

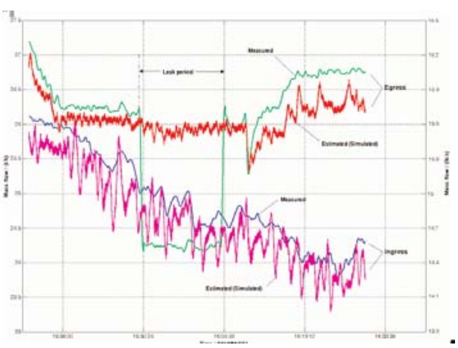

Fig. 8: The blue line represents the measured flow at the inlet, the magenta line the calculated (also from P and T readings) flow at the inlet. The green line represents measured flow at the outlet, the red line the calculated flow at the outlet.

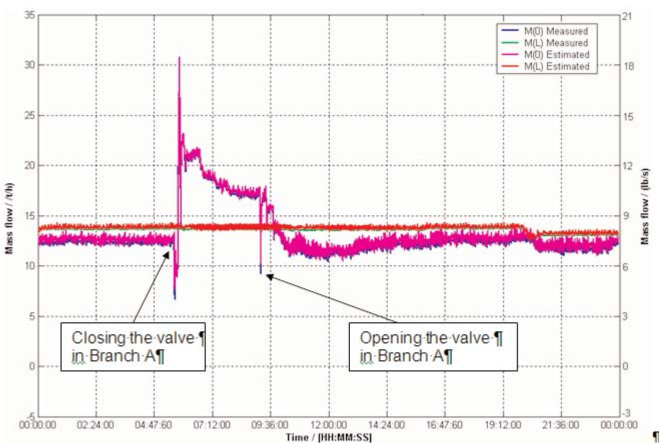

Fig. 9: The blue line represents the measured flow at the inlet, the magenta line the calculated (from P and T readings) flow at the inlet. The green line represents measured flow at the outlet, the red line the calculated flow at the outlet. The deviation between calculated and measured flow at the outlet can be clearly seen during the leak trials.

KROHNE

PipePatrol - Leak Detection and Localisation

Now there is a way to distinguish between a true leak and a sensor failure.
It's Leak Detection and Localisation from KROHNE's PipePatrol.

- Zero false alarms by Leak Pattern Recognition
- Highest sensitivity even under transient conditions through E-RTTM (Extended Real Time Transient Model)
- For liquids, gases and LPG
- Easy retrofit using existing field instrumentation
- Interfaces to all existing SCADA systems

For further information, visit our website

www.krohne-oilandgas.com

Conclusion

Modern leak detection systems work and do so without false alarms. State-of-the-art E-RTTM systems have overcome the limitations that more traditional systems have under transient pipeline conditions.

This paper describes the field test results of PipePatrol, an E-RTTM based leak detection system, on an ethylene gas pipeline. Although ethylene is a non-ideal compressible gas and the pipeline operates constantly under transient conditions, PipePatrol allows accurate and false alarm free operation.

- To ensure your leak detection system will work optimally, the correct system has to be selected.
- Care should be taken during this selection.
- Specified accuracy and sensitivity figures are often based on a theoretical approach, whereby factors such as data refresh rates and transient pipeline conditions are easily overlooked.
- Compare field test results from similar applications.

Choosing the right Leak Detection System will ensure no false alarms, operator trust and early recognition of leaks.

PipePatrol - the dependable choice

For questions contact us, we are experienced and in most cases have leak test results from an application similar to yours available.

KROHNE Oil & Gas Main Building housing General Management, Engineering, Project Management and Marketing. Software development and development are in adjacent buildings


Metering skid being taken out of the assembly halls for packaging and subsequent delivery to customer


KROHNE Oil & Gas engineer heading for platform for regular servicing of installed meters


KROHNE Oil & Gas engineering supervising installation of custody-transfer metering system, later to be included in leak detection system

PipePatrol Leakage Detection and Localisation

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