Measuring in buckets... ...not barrels

Fast, reliable leak detection and location of small amounts of hydrocarbons

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A 10 inch pipeline carries refined hydrocarbon products from a refinery to a tank farm in Northern Germany – a distance of 31 km. The need for a system that would reliably detect and locate a leak along the route, even under transient conditions, led the Oil&Gas division of Krohne to develop the PipePatrol. This leak detection system is capable of detecting a leak of just 35 litres/30 sec (35 litres are only 3½ buckets). The unit locates the leak to within ± 0.5 percent of the length of the pipeline. ■ Hilko den Hollander

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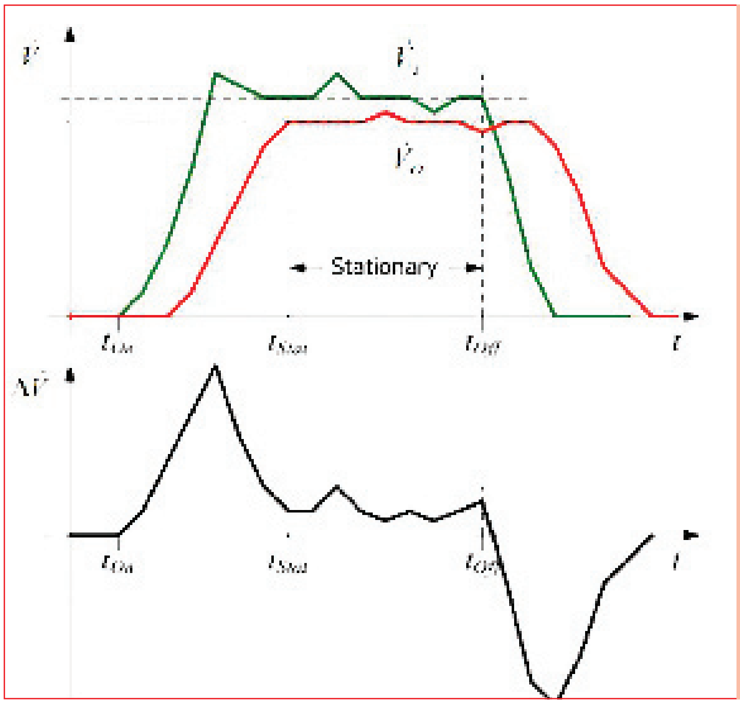
Traditional leak detection systems usually trade off the minimum detectable leak rate for a maximum allowed number of false alarms. While this can reduce the number of false alarms to an acceptable level, it is impossible for the leak detection system to quickly and reliably detect small leaks - if at all.

Modern Real Time Transient Model (RTTM) systems have overcome these restrictions by effectively combining sensitive leak detection with a low number of false alarms. The Extended Real Time Transient Model or E-RTTM has been augmented using "Leak Pattern Recognition" and has reduced the number of false alarms to virtually zero. This article has taken the most difficult scenario, a transiently operated gas pipeline in order to show that PipePatrol, Krohne‘s E-RTTM-based pipeline leak detection system, does what it is designed to do: fast detection of small leaks without false alarms.

Pipeline theft and transient flow

Leak detection is more than just measuring inlet and outlet flow. As shown in Figure 1, the inlet and outlet flows differ significantly during start-up and shutdown of the pump. Most of the leaks occur due to these pressure changes in the pipeline. Even during a period of ‚stationary‘ operation, the difference between inlet and



Flow inlet (green), flow outlet (red) and the difference between inlet and outlet (black) during start-up, stationary operation and shutdown of a pipeline.

outlet flow will not be zero due to omnipresent transients in the pipeline.

To avoid false alarms in a traditional system, the minimum detectable leak rate should, of course, be higher than the difference between the inlet and outlet flows during normal operation. Knowing that such transients can be significant means that the minimum detectable leakage has to be relatively high. This, then, implies that small leaks, e.g. caused by theft, will not trigger a leak alarm.

Real Time Transient Modelling

To overcome the limitations described above, modern RTTM based systems calculate the flow in the pipeline from the pressure and temperature at the inlet and outlet. This theoretical flow is then compared with the actual flow readings from flowmeters at both the inlet and outlet. This difference between the theoretical and actual values should be zero under "no leak" conditions. As the system ramps up, for example, the flowrate changes, as does the pressure; but the difference between theoretical and actual flows will not change and remain around zero.

The system is unaffected by any transients present in the pipeline and the difference between theoretical and actual flows only becomes apparent when there is a leak. In this case, the pressure, and therefore the theoretical flow, will change while the actual flow remains constant. Such a difference is much easier to identify and is more reliable than a flow indicator. This results in a lower minimum detectable leak rate and therefore a lower number of false alarms.

Leak Pattern Recognition

Building on the advantages of RTTM, Krohne went one step further and extended RTTM by Leak Pattern Recognition in order to differentiate between true leaks and sensor drift. This resulted in PipePatrol, the leak detection and localisation system developed by Krohne (see Figure 2). Today, PipePatrol is installed on many gas, liquid and LPG lines. One of the most difficult applications, a transiently operated gas pipeline, is illustrated here.

Leak Detection on a transiently operated gas pipeline

As previously discussed, an E-RTTM (Extended Real Time Transient Model) was used to calculate flow from just P and T at the inlet and outlet. Since this model describes a pipeline without leaks, the theoretical flows for the inlet and outlet should match the actual flows for the inlet and outlet under no leak conditions. Figure 3 depicts a total of four curves:
Bottom curves

- actual inlet flow from flowmeter (blue),
- theoretical inlet flow from P and T (green),Top curves
- actual outlet flow from flowmeter (red)
- theoretical outlet flow from P and T

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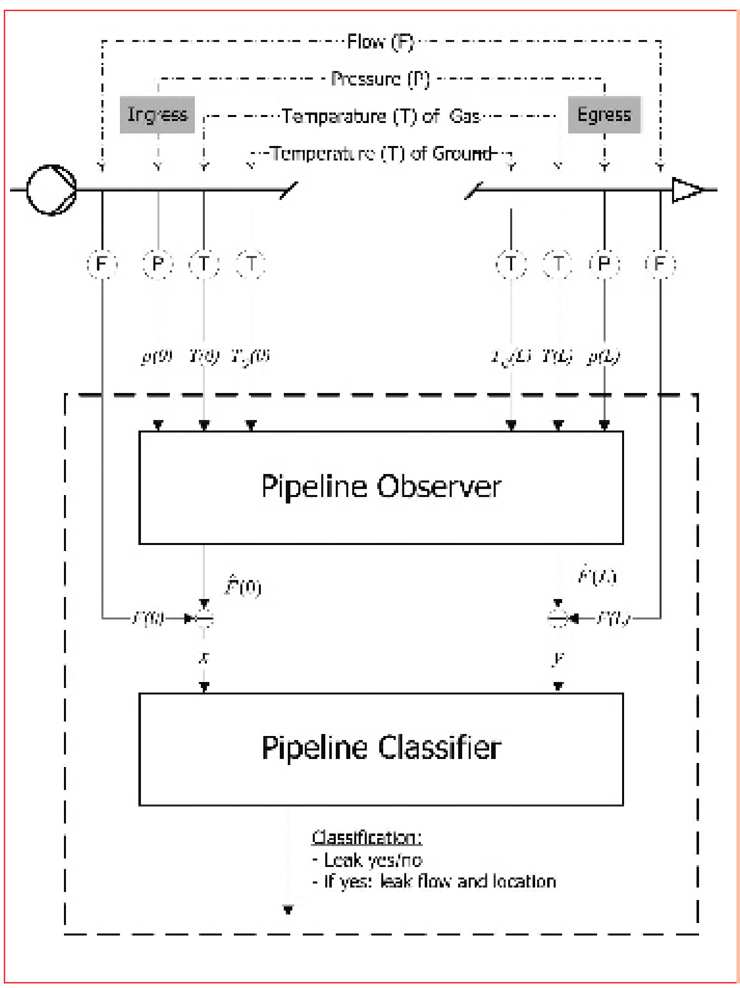
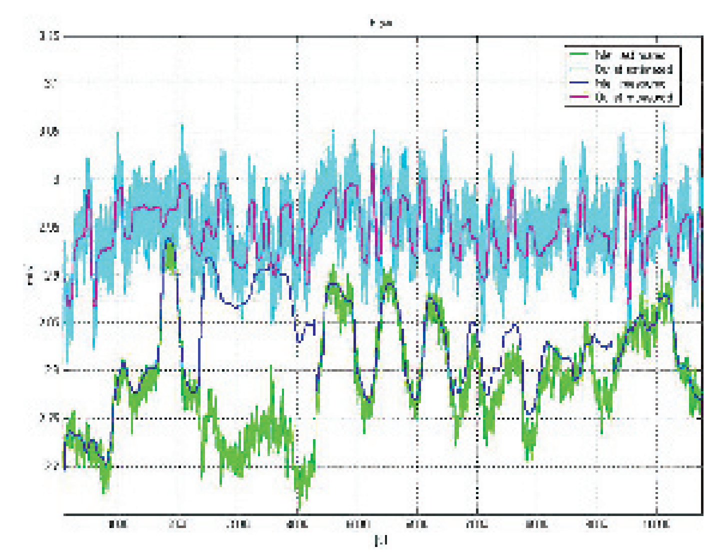
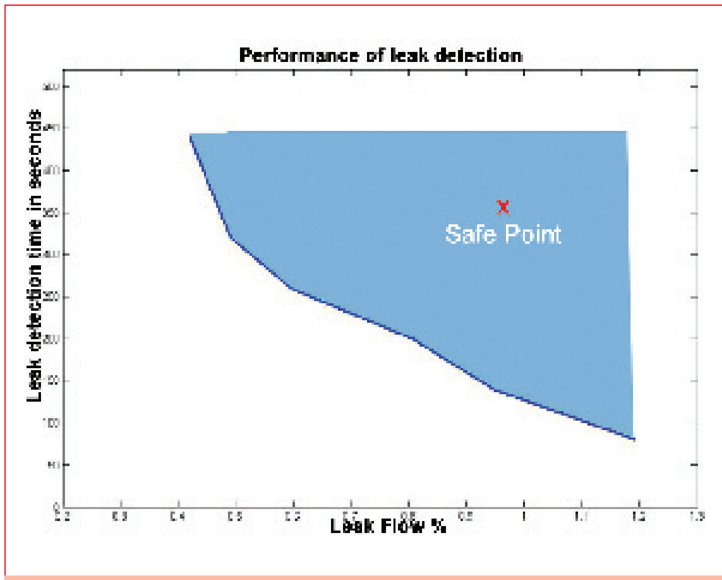


Schematic overview of PipePatrol. The Pipeline observer uses RTTM to calculate flow from pressure and temperature at inlet and outlet.



Actual results from PipePatrol installed on a gas pipeline. The 2.5 percent leak trial can be seen clearly, measured and calculated flow at inlet differ significantly.



Maximum deviation between calculated and measured flow vs. allowed detection time.

(blue/green)

Under no leak conditions, the actual and theoretical flows match each other almost perfectly with the minor deviations caused by inaccuracies in the measurement devices. When a leak occurs (in the first case a 2.5 percent leak) the theoretical and actual values at the inlet suddenly alter.

This is logical as the model describes a pipeline without leaks. Once a leak is created, the theoretical flow calculated by the model deviates from the actual flow! The reason for this only becomes apparent at inlet as the leak occurs close to the inlet. This was because the gas has to be led back to the flare installation, rather than letting it escape into the atmosphere.

Leaks of 0.5 percent and 1 percent were also created. The leak of 0.5 percent is close to the inaccuracy of the field instrumentation used. This means that it is close to the minimum detectable leak rate. The leak of 1 percent is easy visible again. More details on the minimal detectable leak rate for this application are described at the end of the article

Using existing instrumentation

PipePatrol is principally a software program that uses P and T inputs from the Scada system to calculate flow. This theoretical flow is compared to an actual flow (also provided by the Scada system) The visualisation of the information that the operator requires is either provided by the Scada system or else shown on a separate desk-top PC. In the case study described in this article, PipePatrol used existing pressure, temperature and flow instrumentation and interfaced with the existing Scada system. The only hardware installation that the operator requested was a visualisation PC in the control room.

Minimum detectable leak rate and time required to detect a leak

An important, but often overlooked, parameter for leak detection systems is the time required to detect a leak. If, for example, a system is capable of detecting a leak of 1 percent, but needs several hours to detect it, then the system is of little practical use. In general, a longer detection time will allow smaller leaks to be detected due to the statistics used for interpreting the signals.

For the gas pipeline mentioned above, the blue curve in Figure 4 indicates the maximum difference between theoretical and actual flow recorded over several months under no leak conditions. In cooperation with the customer, a `safe reference point‘ was chosen: a 1 percent leak to be detected within 5 minutes. A 1 percent deviation between theoretical and actual flow with a detection time of 5 minutes will never occur during normal operation and therefore is a very safe point with regards to avoiding false leak alarms. On the other hand, detecting a 1 percent leak in a transiently operated gas pipeline is an impressive achievement!

System reliability and false alarms

The system described above went live in October 2002 and since this time only one false leak alarm has occurred which can be attributed to the E-RTTM system. This leak alarm, however, was caused by abnormal pipeline conditions during emergency shutdown tests. Breakdown of the inlet turbine flowmeter caused a sensor alarm but did not lead to a leak alarm. After investigation the meter was replaced by a Coriolis mass flowmeter and no more instrument errors have been indicated since. The operator thus obtained real-life proof that PipePatrol truly differentiates between leaks and sensor failures.

Hilko den Hollander, Product Manager, Leak Detection Systems, Krohne Oil & Gas says:

„State-of-the-art E-RTTM systems have overcome the limitations that more traditional systems have under constant, but especially under transient, pipeline conditions. Krohne's PipePatrol E-RTTM has been in use on one of our gas pipelines since 2002. The gas pipeline is used for both transport and storage. Despite these almost permanently heavy transient conditions, a 1 percent leak was easily detected within just 5 minutes. Since start-up in 2002, this application has been up-and running with only one false leak alarm caused by the E-RTTM algorithms during an emergency shutdown scenario set up at short notice.
PipePatrol is also used for liquid pipelines with similarly good results. A 1.5 percent leak was purposely created along the 31 km long pipeline described here. It was detected within 30 seconds. This far exceeded customer requirements. The velocity of sound from the ultrasonic flowmeters is also an ideal method for batch identification."

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In 2001, the leader in flow metering KROHNE in Duisburg, grouped together all its experts and established a specialist company at their main manufacturing site in the Netherlands. The company has grown continuously since then. The need for more space while retaining access to a qualified workforce brought KROHNE Oil & Gas to custom-designed premises in Breda.

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