The need for a system for liquids and gases that would reliably detect and locate a leak even under ramp up, ramp down and transient conditions led to the development of PipePatrol, E-RTTM from KROHNE.

Under any conditions
Zero false alarms

TRADITIONAL LEAK DETECTION systems usually trade off the minimum detectable leak rate for a maximum allowed number of false alarms per year. While this can reduce the number of false alarms to an acceptable level, it makes it impossible for the leak detection system to quickly and positively detect small leaks - if it detects them at all.

Modern, RTTM (Real Time Transient Model) based, systems have overcome these restrictions, by effectively combining sensitive leak detection with a low number of false alarms per year. Extending the system by "Leak Pattern Recognition" has reduced the number of false alarm to virtually zero per year. This system is known as E-RTTM (Extended Real Time Transient Model). This article takes the most difficult scenario, a transiently operated gas pipeline, to show that PipePatrol, KROHNE's E-RTTM based pipeline leak detection system, does what it is supposed to do: fast detection of small leaks without false alarms.

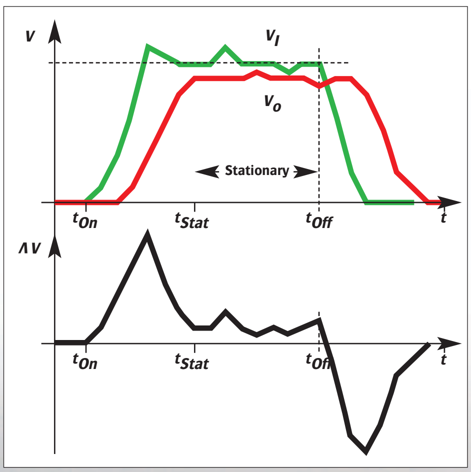

Figure 1: Flow in (green curve), flow out (red curve) and difference between inlet and outlet flow (black curve) during start-up, stationary operation and shutdown of a pipeline.

Pipeline theft and transient flow

Leak detection is more then just measuring inlet and outlet flow. As shown in figure 1 the inlet and outlet flow differ significantly during start-up and shutdown of the pump. This is however exactly the period where most of the leaks occur when the pressure in the pipeline changes. Even during a period of 'stationary' operation the difference between inlet and outlet flow will not be zero due to omnipresent transients in the pipeline.

To avoid false alarms in case of a traditional system the minimum detectable leak rate should of course be higher than the difference between inlet and outlet flow that is seen during normal operation. Keeping in mind that transient can be significant, it means the minimum detectable leak rate has to be relatively high. This then means that small leaks, e.g. caused by theft, will not trigger off 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 calculated flow is then compared to the measured flow (from a flowmeter at inlet and outlet). This difference between calculated and measured values for the inlet (or for the outlet) is around zero. As the system ramps up, for example, the flow changes, as does the pressure; but the difference between calculated and measured flow will not change and hovers around zero. Transients are present along the pipeline, yet the system is not affected by them. The difference in calculated and measured flow only appears when there is a leak. In this case, the pressure (and therefore the calculated flow) will shift due to the leak, while the measured flow remains constant. Such a difference is much easier to identify and is more reliable as an indicator. It permits a lower minimum detectable leak rate and therefore a low number of false alarms per year.

Leak Pattern Recognition

Building on the advantages of RTTM, KROHNE went one step further and combined RTTM with Leak Pattern Recognition to allow differentiation between a true leak and a sensor drift. This resulted in PipePatrol, KROHNE's leak detection and localisation system (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 described here.

Leak Detection on a transiently operated gas pipeline

As described an E-RTTM (Extended Real Time Transient Model) is used to calculate flow from just P and T at inlet and outlet. Since this model describes a pipeline without leaks, the

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inlet calculated values for inlet and outlet, should match the measured values for inlet and outlet under no leak conditions. In figure 3 a total of four curves are shown:

- measured inlet flow from flowmeter (blue),
- calculated inlet flow form P and T (green),
- measured outlet flow from flowmeter (cyan)
- calculated outlet flow form P and T (turquoise)

Under no leak conditions the measured and calculated values match almost perfectly, the minor deviations that show are caused by inaccuracies of the measurement devices. When a leak is created (in the first case a 2.5% leak) the calculated and measured values at inlet suddenly started to shift. This is logical; the model describes a pipeline without leaks, now that a leak is created the model calculates a flow that deviates from the measured flow! The reason why the difference between calculated and measured flow only manifests at the inlet side is because the leak was created close to the inlet as the gas had to be led back to the flare installation, rather than letting it escape into the atmosphere.

Leaks of 0.5% and 1% were also created. The leak of 0.5% is close to the inaccuracy of the applied field instrumentation, meaning it is close to the minimal detectable leak rate. The leak of 1% is easy visible again. See towards the end of the article for more details on the minimal detectable leak rate for this application.

Uses existing instrumentation

In essence PipePatrol is a software program that uses P and T inputs from the SCADA system to calculate a flow. This calculated flow is compared to a measured flow (also provided by the SCADA system) and the information that is required for the operator is either returned to the SCADA system or is shown on a separate desktop PC. In the case study described in this article, PipePatrol used existing instrumentation and interfaced with the existing SCADA system. The only hardware installation that was required was a 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 leaks of 1%, but it needs several hours to detect the leak, the system is of little practical use. In general a longer detection time will allow smaller leaks to be detected, due to the statistical analysis that is applied to interpret the signals.

For the aforementioned gas pipeline, the blue curve in figure 4 was plotted. It shows the maximum difference between calculated and measured flow under no leak conditions that was seen over a period of several months. In co-operation with the customer a 'safe reference point' was chosen; a 1% leak will be detected in 5 minutes. A 1% deviation between calculated and measured 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% leak in a transiently operated gas pipeline is quite impressive!

System reliability and false alarms

The system described above went live in February 2003 and since this time only one false leak alarm has been given. This leak alarm 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 seen.

Conclusion

State-of-the-art E-RTTM systems have overcome the limitations that more traditional systems have under transient pipeline conditions. This article describes KROHNE's PipePatrol E-RTTM in an actual application in a gas pipeline. Despite that fact that the gas pipeline is operated under (heavy) transient conditions, a 1% leak will be found within 5 minutes. Since February 2003 this application has been up-and running and only one forced false leak alarm was seen.

PipePatrol is also used for liquid pipelines with similarly good results. In many cases much better, liquid pipelines are not as severe in their behaviour as gas pipelines. ■

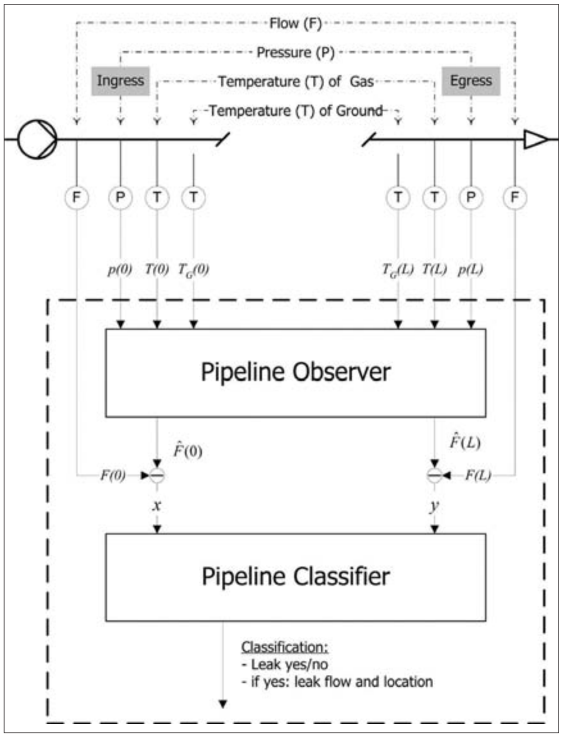

Figure 2: Schematic overview of PipePatrol. The Pipeline Observer uses RTTM to calculate flow from pressure and temperature at inlet and outlet. The Pipeline Classifier analyses the difference between calculated and measured flow and uses Leak Pattern Recognition to distinguish between a sensor failure and a true leak.

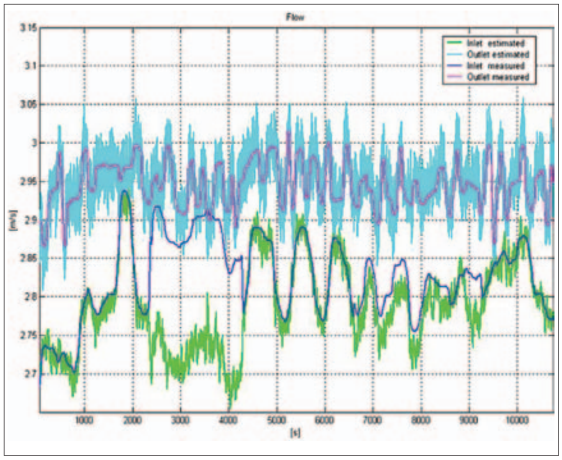

Figure 3: Actual results from PipePatrol installed on a gas pipeline. The 2,5% leak trial can be seen clearly, measured and calculated flow at inlet differ significantly.

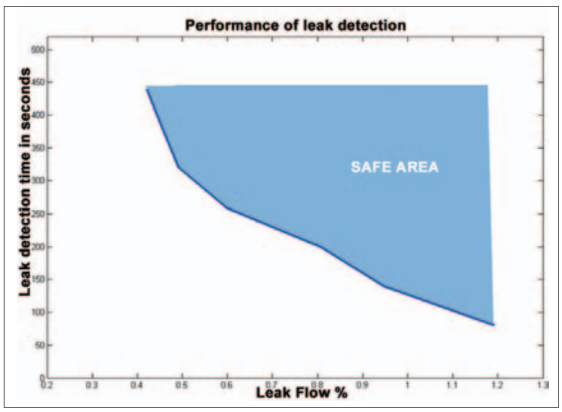

Figure 4 - Maximum deviation between calculated and measured flow vs. allowed detection time.