The leak detectives

Dr. Olaf Stawicki, Carlos Sabido and Dieter Meendermann, ROSEN Technology & Research Center, Germany, discuss the most effective methods for the detection and localisation of leaks in liquid pipelines.

There is a strong demand in the industry for systems capable of detecting and localising leaks in pipelines. The operation of such systems is expected to be straightforward, i.e., they must be user-friendly and provide short turnaround times for inspection results.

ROSEN offers several options for detecting leaks in pipelines. Among those are leak detection and localisation systems based on measurements of the flowrate through, and the differential pressure across, the inspection tool. These are currently the two most common leak detection methods available in the market. A more sophisticated approach evaluates the acoustic signals generated by leak-induced turbulence in liquid media.

This article discusses how ROSEN has addressed the need for leak detection and localisation and the basic principles to be taken into consideration in the development of these three approaches.

Figure 1. Flow-type leak detection tool.

Figure 2. Differential pressure leak detection tool.

Flow-type leak detection

Measuring medium flowrate and direction represents one of the most commonly used approaches to the detection and localisation of leaks in pipelines. Information on product flowrate and direction at strategic points in the pipeline enables operators to obtain results within a short time.

This system essentially consists of a bi-directional tool with a disc set-up and is commonly referred to as a flowrate leak detection tool. In order to achieve pressure equalisation between the upstream and downstream sections of the tool, the medium is allowed to flow through its hollow body and to bypass the tool to a certain degree. For the purpose of measuring flowrate and direction, a flow meter is mounted inside the tool's body. This device takes in-situ measurements of the flowrate and direction at the pipeline position where the tool is located.

The tool is equipped with electronic systems allowing storage of flowrate and direction data as well as the precise position of their measurement within the pipeline. The data is then transmitted to the surface receiver/analyser unit by means of an onboard transmitter. The same transmitter is also used for tool tracking purposes.

The sealing capabilities of the discs are not critical in this approach because there is no differential pressure build-up across the tool, except where substantial leaks are present. In this case, the tool starts moving towards the leak, which can then be detected with the tool tracking system.

The operation principle of the flow-type leak detection system is based on a bi-sectional method. The tool divides the leaking pipeline into two sections: a positive and negative flow direction. Positive flow direction means that the product enters the tool at its rear and leaves through its nose, whereas negative direction is defined as medium flow in the opposite direction. The presence of at least

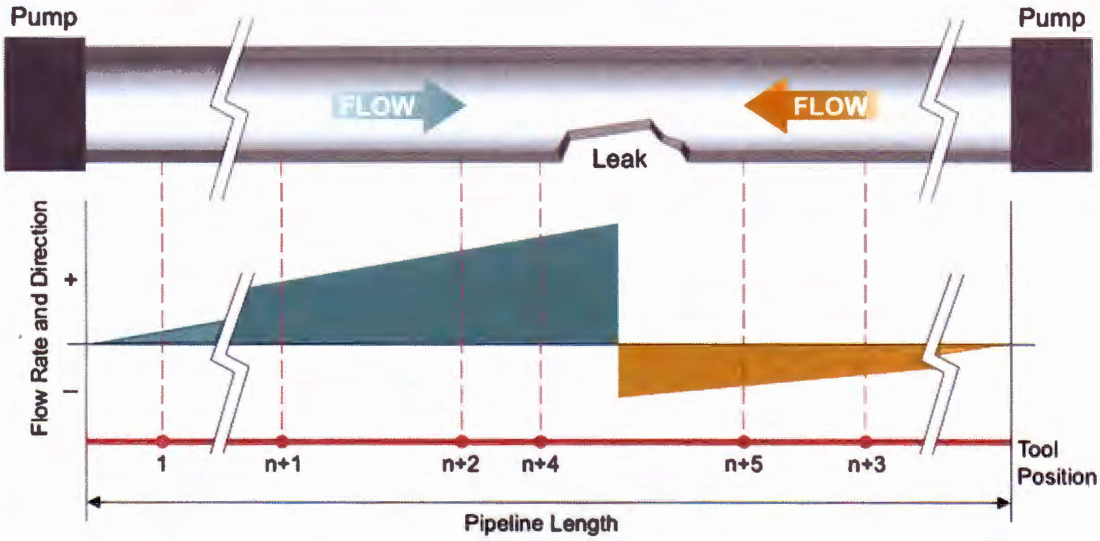

Figure 3. Flow-based leak detection and localisation: since even a single leak causes irregularities in product flow, measurements of flow patterns permit reliable detection and accurate localisation of leaks within the pipeline.

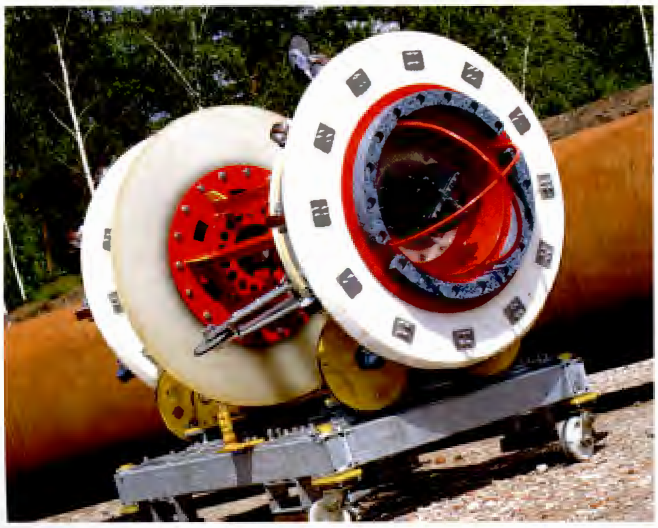

Figure 4. ROSEN's acoustic leak detection tool.

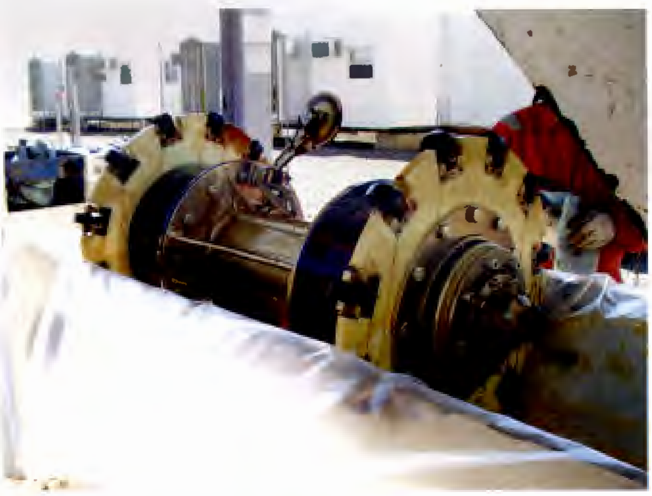

Figure 5. 20 in. acoustic leak detection tool after inspection run.

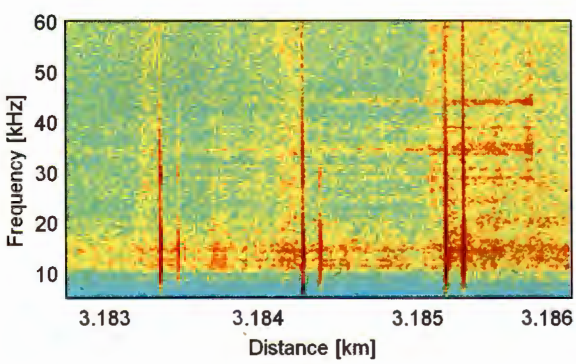

Figure 6. Measurement results obtained with the 46 in. acoustic leak detection tool during an inspection run. The recorded frequency spectrum vs. distance is shown. The regular vertical pattern results from girth welds. The two horizontal signals at ultrasonic frequencies around 35 kHz and 45 kHz, which increase gradually with increment in distance, indicate a leak at around 3.1857 km.

one leak in a pressurised liquid pipeline causes a flow with increased speed from both ends of the pipe towards the leak. In order to avoid misinterpretation of the flow measurements, both ends of the pipe have to be sealed.

In a leaking pipeline, the measurement-based leak detection tool identifies the flowrate and its direction at the current tool position in the line. As long as the flow direction is positive, the tool will be pumped from its initial position 1 towards the end of the line (positions n+1 and n+2 as indicated in Figure 3) and, therefore, closer to the leaking section. Typically, the measured flowrate increases when the tool approaches the leaking pipeline section, but the flow direction remains constant, i.e., positive. The flowrate not only depends on the relative tool position in relation to the leak but also on the dimensions of the leak, since a bigger leak results in higher flowrates.

When the flow direction turns negative, as shown in Figure 3, for tool position n+3, it can be inferred that the leak is located between the tool's current position n+3 and its previous position n+2 where a positive flow direction was measured. In this case, the leak detection tool should be pumped back for a specific short distance to position n+4, i.e., until the flow direction is once more reversed. The leak is always in between two tool positions with different flow directions. Since the flowrate is measured at each tool location within the leaking pipeline, further information can be gathered on the leak rate and/or the likelihood of additional leaks being present.

By dividing the total and/or remaining pipeline length into equal halves, a total of 14 measurements are required to pinpoint the leak within ±1.5 m for a pipeline of 20 km in length. Using a flow-type leak detection tool, leaks with rates as low as 1 litre/hr can be detected. ROSEN offers the flow-type measurement system for pipelines with a diameter of 12 in. or more.

Leak detection based on differential pressure

The basic principle of the detection and localisation system based on differential pressure is the same as for the flow-type approach. However, instead of measuring the flowrate and direction through the tool, the pressure values at the tool's front and rear are obtained as a basis for determining the differential pressure across the device.

As part of the differential pressure system, a special bi-directional tool with high sealing capacity is used to divide the pipeline into two sections. The tool is equipped with a transponder that transmits the recorded differential pressure data to an above-ground receiver. Pressure measurements are taken on both pipeline ends with synchronised high-resolution pressure measurement equipment.

This system has a proven track record for offshore applications in particular, since the environmental conditions in terms of temperature changes are much more stable than in a land pipeline. Accurate flow measurement is vital for calculating the actual tool positions and movements. To determine the precise position of the tool, a standard transponder receiver can be used.

Similar to the flow-type leak detection approach, leaks are located on the basis of current versus previous tool position. By combining this bi-sectional method with the differential pressure measurement, a minimum detectable leak rate of 0.1 litre/hr can be achieved. The position of the leak can be pinpointed with an accuracy of ± 0.5 m. ROSEN offers the differential pressure-based leak detection system for pipelines with a diameter of 8 in. or greater.

Acoustic leak detection tool

In contrast to the detection systems based on flow type and differential pressure, the third approach uses acoustic signals. In the event of a leak in a pipeline, the liquid moves from a high to a low-pressure area. As it passes through the site of the leak, a turbulent flow is generated, which is associated with strong ultrasonic components. As ultrasound is a short-wave signal, these sound waves tend to be highly directional and localised; they are loudest at their source. ROSEN's acoustic leak detection tool senses high-frequency ultrasonic waves in the range of 20 - 40 kHz.

ROSEN's acoustic leak detection tool is based on a conventional bi-directional tool body supported by soft rubber wheels. They ensure a smooth and noiseless run through the pipeline. A hydrophone system located at the front of the tool is used for the detection of the ultrasonic waves; it has been adapted to meet the requirements of the ROSEN data acquisitions system. The tool converts the acoustic signals into an electronic signal in real-time, thereby allowing non-relevant surrounding noise to be filtered out for accurate leakage analysis. Only signals from a pipeline leak will be recorded. The leak signals depend on a variety of parameters, including operational parameters such as the pressure in the pipeline and the viscosity of the medium as well as the size and shape of the leak.

Three independent odometer wheels with a polyurethane surface take distance measurements. This information can be correlated with above-ground marker points for additional accuracy. To ensure reliable tool tracking, the inspection device can optionally be equipped with an electromagnetic transmitter. Since ROSEN's tool design is based on a modular approach, a Pipeline Data Logger can be attached as well enabling the user to record operational data during a pipeline run. This device generates time-dependent profiles of the temperature and the absolute and differential pressure in the pipeline.

ROSEN offers a modular electronic system that can be mounted in tools of various sizes covering a range of 10 – 48 in. with a minimum bend capability of 1.5 D. With the ultrasonic leak detection system, the minimum leakage rate detectable is 10 litres/hr with a leak localisation accuracy of 1 m.

Conclusion

ROSEN offers a variety of methods and technologies for the detection and localisation of leaks in pipelines, notably flow-type leak detection, differential pressure-based leak identification, and the ultrasonic leak detection device incorporating acoustic signal evaluation.

All leak detection systems combine their individual innovative approaches with ROSEN's established inspection technology to achieve high levels of reliability and accuracy in a multitude of different pipeline conditions. This compatibility with ROSEN's entire inspection fleet also means that a wide variety of tool sizes are available. Enabling focused short-term maintenance programmes, these different technological approaches to leak detection and localisation help pipeline operators to reduce the risk of ecological damage and its potentially devastating economic impact, thus offering invaluable environmental and financial benefits. **WP**