Real-Time Pipeline Leak Detection And Location Using Volume Balancing

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For companies transporting valuable oil through thousands of kilometers of pipeline, a leak, no matter how insignificant it might seem, can cause major problems. For this reason, it is crucial that leaks are detected and located as soon as the problem arises. By using the correct Leak Detection System (LDS), it is possible to detect even the smallest leaks. This can aid petroleum companies in preserving their most valuable resource, saving millions of dollars and protecting the environment surrounding the pipelines.

There are three main methods of detecting and locating leaks: visual inspection, external instrumented systems, and instrumented internal pipeline systems. While visual inspection is dependent upon human resources to walk, drive, or fly the length of the pipeline, external instrumented systems rely on liquid-sensing cables, fiber-optic cables, vapor-sensing tubes and acoustic emissions installed external to the pipeline.

Instrumented internal pipeline systems on the other hand, work by measuring the balance in a pipeline, using varying types of process instrumentation to collect data. One such system is based on a compensated volume balancing method that uses ultrasonic flow meters and offers the operator continuous real-time monitoring of the pipeline.

**LDS Overview**

An LDS based on compensated volume balancing provides specific benefits that are considered crucial for the needs of the pipeline industry. These include real-time detection of small and large product releases under flow and no-flow conditions; accurate leak location; easily accessible pipeline performance data; operation unaffected by changes in liquid properties and product type, and quality identification.

The system consists of several non-intrusive ultrasonic flow meters, a master station and a software package that provides overall control of the system. A pipeline is divided into segments that consist of two flow meters — one at the beginning and one at the end of the segment. Each flow meter is called a site station. The number of site stations depends on the length of the pipeline, but typically two are required on a continuous pipeline 50-70 miles long and one every 50–70 miles thereafter. The master station, which consists of computer consoles and monitors, polls the site stations for data such as flow rate, temperature, liquid density, liquid viscosity and diagnostic information at regular intervals.

**Measurement Basics**

The core of this type of LDS is the non-intrusive ultrasonic flow meter, which inherently measures the speed of sound in a fluid. To determine the speed of sound, one pair of sensors is required although many ultrasonic flow meters are equipped with multiple pairs of sensors for higher accuracy. The system described here, however, uses the WideBeam measurement technology that allows two pairs of sensors to produce similar performance and data acquisition than four pairs of sensors used in other systems.
This process works well under steady state conditions and during normal flow variations. Since conditions in pipelines vary with pump starts, shutdowns and packing conditions, the LDS monitors the difference in the rate of change between two adjoining site stations under such conditions. This method monitors and accumulates the amount of additional volume that enters the pipeline less the amount leaving the pipeline, resulting in an increasing total volume. This routine allows the four integrators: 1-minute, 5-minute, 15-minute, and 60-minute. This function continues to operate for a preset period, typically two to six minutes, depending on the pipeline’s normal transient duration. Once the preset time expires, the system will automatically return to the normal volume-balancing function.

**Zero Flow Measurement**

The LDS must also function well under static, no-flow conditions and is frequently required to operate on bi-directional pipelines. The clamp-on ultrasonic meter is well suited for both scenarios because it is one of the few meter technologies that maintains accurate measurement and operation during static conditions and reverse flow. Should a leak occur during this time, the upstream flow meter will read a positive flow while the downstream meter will read a negative flow. Because the system monitors the difference between flow rates, a difference (delta) will exist that exceeds the leak threshold. Depending on the log size, this will activate a leak alarm during any of the four integration periods.

**Leak Location**

Another important factor in an LDS is leak location. The compensated volume balance system described here works under the same principle as pressure-based systems in which a pressure transient caused by a leak, propagates in both directions upstream and downstream of the leak. As pressure changes influence the liquid’s sonic velocity (VS) in a predictable way, a pressure change occurring at the measurement point will be reflected in the liquid’s measured sonic velocity. By interrogating the VS approximately 80 times per second the clamp-on ultrasonic flow meter looks for and compared against the known value of total volume the pipeline segment is capable of containing (or packing).

A leak alarm is triggered if the accumulated volume exceeds the threshold of maximum pipe volume. This function continues to operate for a preset period, typically two to six minutes, depending on the pipeline’s normal transient duration. Once the preset time expires, the system will automatically return to the normal volume-balancing function.

**Repeatability Vs. Accuracy**

Clamp-on ultrasonic flow meters that are optimized properly offer repeatability within the 0.05–0.1% range. Repeatability is important because the LDS described here is based on the balance between two adjoining flow meters. Although accuracy is desired and can be tuned, it is a secondary consideration for a volume balance LDS. While optimizing the system, focus is on maintaining balance of all meters under all operating conditions, and not on the accuracy of each individual meter.

**A Complete Solution**

As illustrated throughout this article, the compensated volume balance LDS meets the specifications that the pipeline industry requires. As it provides all components from one single supplier it is considered a complete solution. It can be optimized to fit the requirements of the customer by fully exploiting all of the benefits that ultrasonic flow meters offer, such as the use of enhanced diagnostics.

Its high sensitivity enables even very small leaks to be detected, it can accurately predict the location of a leak, it operates under zero flow conditions, and it is extremely repeatable. As such, it not only offers companies a solid pipeline surveillance and management system, it also assists them in complying with increased environmental regulations. By installing an effective LDS, oil pipeline companies can help avoid a huge expense that can result in millions of dollars while keeping the environment safe.

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