Liquids Pipeline Leak Detection and Simulation Training

Best practices enhance savings and security

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Pipeline companies deal with stiff governmental regulation and environmental and economic constraints to ensure the safety of the population and environment where pipelines run. These policies, which also help protect the assets of the operating company, often dictate operator training requirements and integrity management – including technology and applications – that assure operational safety.

Computer-based leak detection is a common industry application that supports the safety of the general population and environment and helps sustain efficient operations and facilities management. This paper provides an overview of liquids pipeline leak detection best practices based on SCADA systems with Computational Pipeline Monitoring (CPM) software applications.

These best practices follow dictates of governmental regulations in place or proposed worldwide, as well as recommendations from leading industry agencies. Focus is on real-time leak detection through pipeline simulation, which not only complies with regulations and industry operations standards but also supports sound business procedures.

**CPM methods for pipeline leak detection**

The most common technology for detecting pipeline leaks is the Computational Pipeline Monitoring (CPM) system, which uses real-time information from the field to estimate the hydraulic behavior of the product being transported. An example of a hydraulic profile display is shown in Figure 1 on page 3. Calculated results are then compared to field references to identify an unexpected anomaly that might signal a leak – whether an accidental rupture or an unlawful tap. An example of leak detection using CPM is shown in Figure 2 on page 4.
The American Petroleum Institute (API) publication 1130 defines CPM systems as systems that are internally based, utilizing field sensor outputs that monitor internal pipeline parameters such as pressure, temperature, viscosity, density, flow rate, product sonic velocity, and product interface locations. Which parameters are considered and how they are interpreted depends on the CPM method being applied. The following is a brief description of the common CPM methods in use on pipelines today.

- **Line balance** – measures the imbalance between the receipt and delivery meters
- **Volume balance** – similar to the Line Balance but also includes a limited volume adjustment. An overall pipeline density is calculated based on pipeline boundary pressure and temperature.
- **Modified volume balance** – similar to Volume Balance except a different volume adjustment is used for each product in the pipeline

"Operator choices about methods of leak detection will be as varied as the types of pipelines they operate."

— Kelly Doran, liquids solution manager at Telvent
• **Real-time transient model** – all the fluid dynamic characteristics are modeled, including linepack, under all pipeline flow conditions, slack, shut-in, and transients

• **Statistical leak detection** – pressure and flow inputs that define the perimeter of the pipeline are statistically evaluated in real time for the presence of patterns associated with a leak

Figure 2. Leak Flows and Alarm Summary (Telvent SimSuite)

Once a leak event is detected, an alarm is generated and presented on the leak alarm summary page. The milepost and leak rate are indicated in the fields as shown. From this screen the controller can proceed to a set of detailed screens providing information needed to analyze the leak event.

**How to choose or evaluate a leak detection system**

A comprehensive analysis is necessary to identify which CPM technologies and methods are best suited for the pipeline assets in question. A simple A-to-B pipeline route might have simpler calculations than a pipeline with many active route connections and elevation changes, multiple receipt and delivery points, and reversible flow. As the complexity increases, the CPM to be applied needs to be flexible enough to handle all operational scenarios possible in the operation of the pipeline.

“The whole point of leak detection is enabling the controller to interpret and react.”

— Kelly Doran, liquids solution manager at Telvent
Below is a listing of key factors to be considered when evaluating a new or legacy CPM for its leak detection capability. Factors should be weighted according to their importance to any particular operation (see Table 1):

Table 1. Leak Detection Capabilities of CPM Methods*

<table>
<thead>
<tr>
<th></th>
<th>Line Balance</th>
<th>Volume Balance</th>
<th>Modified Volume Balance</th>
<th>Real-Time Transient Model (RTTM)</th>
<th>Statistical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Size**</td>
<td>1 to 5 percent</td>
<td>1 to 5 percent</td>
<td>1 percent</td>
<td>1 percent</td>
<td>1 percent</td>
</tr>
<tr>
<td>Response time</td>
<td>Minutes to hour</td>
<td>Minutes to hour</td>
<td>Minutes to hour</td>
<td>Seconds</td>
<td>Second to minutes</td>
</tr>
<tr>
<td>Leak Location</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Existing Leaks</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>False Alarms</td>
<td>Frequent</td>
<td>Frequent</td>
<td>Less frequent</td>
<td>More frequent</td>
<td>Less frequent</td>
</tr>
<tr>
<td>Transients</td>
<td>No tolerance</td>
<td>Some tolerance</td>
<td>Better tolerance</td>
<td>Best tolerance</td>
<td>Best tolerance</td>
</tr>
<tr>
<td>Ease of Maintenance</td>
<td>Easier</td>
<td>Easier</td>
<td>More difficult</td>
<td>Difficult</td>
<td>Easier</td>
</tr>
<tr>
<td>Cost</td>
<td>Lower</td>
<td>Lower</td>
<td>Higher</td>
<td>Highest</td>
<td>Higher</td>
</tr>
</tbody>
</table>

* Source: Table 2-8 Comparison of Internally Instrumented Leak Detection Methods – Leak Detection Technology Study for Pipes Act HR 5782, December 31, 2008

** Approximate percent of throughput in ideal conditions

- Rate of false alarms and misses
- Sensitivity to pipeline flow conditions such as transients, shut-ins, starts, and stops
- The impact of instrument accuracy and configuration accuracy
- Personnel training and qualification requirements
- Required response time
- Leak location estimation and release volume estimation precision
- Ability to detect pre-existing leaks
- Robustness/high availability
- Initial cost/tuning costs/maintenance costs

Different leak detection solutions target different needs

Kelly Doran, liquids solution manager at Telvent, identified the integrated Telvent SCADA applications that help meet multiple leak detection requirements.

“Telvent approaches leak detection with a multi-tier solution for monitoring pipeline leaks:

- Monitoring of shut-in pipelines can be accomplished by trending pressure and temperatures and correlating pressure drop with an associated temperature drop.
- Pressure/Flow Rate Monitoring, associating configured pressure telemetry with related flow meters that would be affected if a leak was to occur.
- Pipeline Monitoring (PLM), a steady-state CPM application with tools for line balance, volume balance, and modified volume balance. PLM has dynamic alarm thresholds to reduce false alarms while increasing the sensitivity of the leak detection capabilities.
- SimSuite Pipeline – Telvent’s high fidelity real time transient model (RTTM) is a highly accurate, real-time, two-phase flow simulation for crude oil and refined products pipelines that handles two phase flow, drag reducing agent (DRA) injections, shut-in monitoring, and pipeline transients.”
If the pipeline network is a large and complex network with diverse operating parameters and products – or if it has locations close to or in high consequence areas (HCAs) – more than one leak detection system might be warranted. A multi-tiered approach might be necessary to satisfy specific requirements.

**CPM system implementation**

**System configuration and testing**

**Initial configuration.** Pressure to commission pipelines on a tight schedule can necessitate vendors and operators to accept less than 100 percent accuracy in pipeline survey data. When this happens, estimated data and a non-accurate leak detection solution might result. The leak detection solution must be flexible enough to accommodate corrections and expansions.

**Changing configuration.** Changing SCADA configuration can mimic values representative of a leak condition and provide a test of the theoretical capabilities of the system. To do this, SCADA administrators can adjust the scale of input points, manipulate correction factors on meters, and alter other parameters. However, it is difficult to adjust all the parameters with the corresponding values representative of a real leak. Caution must be taken to ensure all manipulated values are returned to their original settings and controllers be advised of the changes.

**Product withdrawal.** A live leak test is a testing alternative to configuration adjustment that tests both system detection capability and personnel response. In this test, product is removed from the pipeline to a receiving vessel. The logistics involved often make product withdrawal tests difficult to execute practically. Also, it is possible that a real leak could occur during the test, complicating detection of the real leak. Spillage that occurs as a result of the withdrawal test is another risk to be considered.

"Telvent’s leak detection system offers dynamic alarm thresholds that optimize alarm performance – reducing false alarms while increasing the sensitivity of leak detection. Today, operators can work more efficiently, being able to focus on real alarms."

— Kelly Doran, liquids solution manager at Telvent
Operational response to alarms

Validation. When the control room receives notification of a possible leak detected through CPM, it must validate that a true leak exists. This process is necessary because, with SCADA, there always is uncertainty based on poll cycle timing, meter errors, communications being interrupted, and calibration accuracy of the instrumentation being used. Operational activity, such as pigging and routing around meters, will affect calculations and could cause CPM alarms.

False alarms. The frequency of false alarms depends on the sophistication of the leak detection system technology, particularly in its capability to handle transients. False alarm frequency also hinges on how communication problems and instrumentation uncertainty are handled. Certainly, false alarm frequency should be reduced, so that controllers do not lose confidence in leak detection capability. Yet, false alarms can signal unexpected pipeline behavior; investigating the cause of the false alarm can improve the overall effectiveness of the leak detection system.

Training best practices

Even the best leak detection solution is only as good as the personnel who act on the information it provides.

Include engineering. Engineers should be fully trained along with controllers on the capabilities of the system, particularly on dynamic alarm thresholds. Training engineers to monitor alarm thresholds over time will help improve the sensitivity of the system while reducing the false alarms that reflect known operational activities.

Refresher training for modifications and expansions. As pipelines grow and companies acquire new assets, pipeline configuration data must be added to the CPM, and controllers must be informed and trained accordingly. It is a recommended best practice to schedule annual controller refresher training for leak detection that includes updated information and lessons learned; see Figure 3.

Training simulates reality

“The more valuable aspect of using pipeline simulators is to train controllers to recognize and respond to abnormal operations conditions (AOC) – including a commodity release. Today pipeline companies can train their teams in recognizing the conditions that may cause emergencies, verifying the quality of data, or simulating emergency shutdowns.

“It moves the training beyond theory and provides the controllers exposure to how system will behave in actual operation.”

— Kelly Doran, liquids solution manager at Telvent
Figure 3. XML-Based Project Configuration Tool (Telvent SimSuite)

Telvent’s SimSuite Pipeline helps assure system changes are part of operator training simulations. An XML-based project configuration and Excel® spreadsheet-based project data input allow easy, rapid, and accurate input of data. The user can organize, retrieve, edit, and add project data and the specifics of the pump stations in an efficient way.

**Qualification information system.** A QIS system documents all operations training received, results of testing, and all other relevant information used to manage a controller qualification. The QIS helps make training and testing fair and objective and clearly defines the scope and expiration of current qualifications.

**Use of simulation.** Training simulations are recognized as one of the best tools to maintain appropriate knowledge and skills for a specific pipeline. The U.S. Department of Transportation National Transportation Safety Board (NTSB) recommended in its “Safety
Recommendations” report to the U.S. Department of Transportation’s Pipeline Hazardous Materials Safety Association (DOT-PHMSA):

“Pipeline training coordinators who used simulators for training reported that the simulators were invaluable for leak detection training. In contrast, they found on-the-job training for leak detection to be difficult because such events are rare and may not occur during training.”

Coordinators further noted that oral or written tests might not be the most effective means of training controllers to recognize leak events. The Safety Board concluded that requiring controllers to train for leak detection tasks using simulators or non-computerized simulations will improve the probability of controllers finding and mitigating pipeline leaks. Figure 4 shows one of the simulation software user screens that make training practical and effective.

**Figure 4. Telvent SimSuite Trainer Scenario Navigator**

Telvent SimSuite Trainer Scenario Navigator allows the instructor to create scenarios for replay so that the students can have a consistent training environment. The actions of both instructor and students can be recorded and replayed.
Simulation lends high value to leak detection and prevention

Generic simulation – a reasonable alternative
Ideally, the training/simulations environment will be the same in every way as the production environment (displays, alarms, navigation). However due to the effort required to engineer and maintain a trainer that is an exact replica of the production system, generic pipeline simulators should be considered as a reasonable alternative. Generic pipelines models provide a realistic representation of the key skills required for the controllers to manage their operation.

Simulation a powerful training tool
Generic pipeline simulators contribute to controller training by providing interaction with the pipeline. Generic pipelines enables representative modeling that yields a realistic pipeline behavior and develops the key controller skills required in the particular operation. Simulation provides the ideal training platform for skills relating to not only common operating conditions but also seldom-performed operational tasks, including:

- Starting/Stopping Pumps
- Changing set-points, controlling pressures and flows
- Reconfiguring of deliveries
- Back flushing of pipeline sections

A simulator provides a repeatable, unbiased assessment of all controllers’ skills and abilities and can be a highly valuable part of a comprehensive controller training/qualification program for not only leak detection procedures and practices but also other loss prevention systems.

Transient modeling
The transient model takes into account: pipeline start-up, pipeline shutdown, and pipeline transients. The virtual pipeline simulation created by a real-time transient model – identified as one of the

Main benefits and functionalities

Kelly Doran, liquids solution manager at Telvent, emphasizes, “SimSuite Pipeline, based on a real-time transient model, helps forecast and plan, increasing the efficiency of existing installations and allowing new system evaluation prior to installation and commissioning. It delivers leak detection capabilities, crucial to safety and environmental concerns, and is used for targeted training of operational staff.

“Merging SimSuite modeling capabilities with actual business information such as energy rate contracts, using Telvent’s information management and control system software, reduces pipeline operations cost.”
CPM options listed earlier in this paper – helps with the following engineering tasks, in addition to providing leak detection capabilities:

- Proving the performance of new pump stations, compressor stations, injection/delivery stations, tank farms, valves, and control logic before actual operation puts them to the test
- Identifying unexpected estimations of product hydraulic behavior during actual pipeline operations
- Accessing predictive analysis capabilities to create advanced planning and risk management strategies
- Obtaining flexible constraint definition functionality to perform advanced pipeline engineering and design analysis
- Serving as the platform for control center operator training and certification to assure controller recognition of leak events

Summary

No single leak detection solution is optimum for the diverse range of pipelines operating in widely ranging environments. More sophisticated leak detection that justifies additional effort to configure and maintain in a high consequence area often is not practical in other situations.

A multi-tiered approach using different leak detection methods is a recommended practice. Operators should look for vendors who can offer the appropriate solutions for the level of protection desired. This multi-layered approach should align with the operator’s leak detection strategies and operating philosophies.

Pipeline Training Simulators offer realistic operational sequence of events associated with normal and abnormal operational conditions. They provide a controlled environment needed to develop good judgment without the risks normally associated with other testing practices, particularly with abnormal operating situations such as a commodity release.
There’s more to complying with relevant regulations or best practices than simply implementing a SCADA and CPM leak detection system. Pipeline operators must update information on any new pipeline assets operated; communicate any configuration changes effectively to controllers; continually review the operational procedures in use; monitor the way controllers interact with leak detection tools provided; and implement scheduled refresher training with conscientious training documentation to ensure a full program compliance.

Leading pipeline operators know their best defense is a good offense: establish the best possible predictive, preventive, and protective measures and then assure there is a highly trained operations staff in place to implement those measures.

Want to know more?
Telvent’s SimSuite Pipeline, comprising leak detection and simulation trainer applications, is the most technically advanced and dependable pipeline simulation system in the industry. It is part of the company’s comprehensive Telvent Oil & Gas Pipeline Solutions are used by many of the largest, most progressive pipeline companies. These open-architecture applications, available individually or combined as an integrated system, all function on popular central operating systems and provide built-in redundancy and security for reliable performance. Contact us or visit our Web site for more information.

Our evolution to Schneider Electric, the global specialist in energy management, re-affirms our commitment to provide you with innovative solutions, best-in-class customer service, and exceptional quality in everything we do. We are proud to be your partner, and we are dedicated to helping you make the most of your energy.