The Use of Ultrasonic Meters in Pipeline Leak Detection Systems

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The Use of Ultrasonic Meters in Pipeline Leak Detection Systems

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Imagination at work.
Agenda

The Importance of Pipeline Leak Detection

Overview of Leak Detection Systems

Why Ultrasonic Meters?

Application Considerations

Conclusions
Keystone XL Pipeline Debate
Environmental Impact

100,000 Barrels Per Year Average leaks from Hazardous Liquid Pipelines
Public and Personnel Safety

Fatalities by Year

*US Only, Data taken from PHMSA; Gas and Liquid Pipelines Combined
Incident Causality

Significant Incident Cause Breakdown 20 Year Totals (1995-2014)
System Type: ALL  State: ALL

- ALL OTHER CAUSES: 21.45%
- CORROSION: 19.54%
- EXCAVATION DAMAGE: 16.43%
- INCORRECT OPERATION: 7.84%
- MATERIAL/WELD/EQUIP FAILURE: 6.88%
- NATURAL FORCE DAMAGE: 6.64%
- OTHER OUTSIDE FORCE DAMAGE: 21.22%

# of Incidents
Types of Leak Detection Systems

Non-Permanent
- Visual Inspection
- Aircraft Flyover
- Vehicle, etc.

External Permanent LDS
- Fiber Optics
- Vapor and Liquid Sensing
- Acoustic Sensing
- Infrared

Internal Permanent LDS
- Flow and Pressure Change
- Volume Balance
- RTTM
- Statistical Model
- Negative Pressure Wave
Future Look – Redundancy Throughout Network

Internal Leak Detection System with Integrated Diagnostics

100% Predictive
Internal Leak Detection Systems

Volume Balance
• Essentially Measures Volumetric Flow In / Out of a pipeline section
• Operates well in Theory – ie. Under steady conditions
• Very sensitive to transient conditions

Sequential Probability Ratio Test (SPRT)
• Based on Hypothesis testing method to identify leaks using inventory compensated volume balance
• Calculates the ratio of probability between a leak / no leak situation
• Identifies leak location and leak size using flow meters and pressure transmitters
• Can be applied on single and multi-phase lines

Negative Pressure Wave
• Relies on high speed pressure reading (>60 Hz)
• Specialized high speed equipment used for data acquisition
• Identifies leak when a pressure drop occurs
• Fast response; can detect very small leaks and thefts
• Cost Effective
SPRT Leak Detection System

Advantages
• Cost effective
• Low false alarm rate
• Works effectively under transient and steady state operations
• Leak size and location can be estimated
• Largely insensitive to fluid properties
• Unaffected by ambient conditions

Disadvantages
• Dependent on the quality of flow meters, SCADA and telecom system
SPRT Leak Detection System

Pipeline Inlets  | Intermediate Pump Station  | Block valves  | Pipeline Outlets

200 m - 200 km

Logger/Controller
Logger/Controller
Logger/Controller
Logger/Controller

Server

Legend:
- **FT**: Flow metering
- **DT**: Density meter or interface detector
- **PT**: Pressure sensor
- **Logger/Controller**: Flow computer (custody txr) or RTU (non-custody txr)
- **OPC**: Translates data into standard OPC format (OPC - open process control)
Principles of ATMOS SPRT

SPRT: Sequential Probability Ratio Test

Testing \( H_1 \) against \( H_0 \) at sample time \( t \),

\[
\lambda(t) = \lambda(t-1) + \frac{\Delta m}{\sigma^2} \left( \mathcal{T}(t) - M - \frac{\Delta m}{2} \right)
\]

\( \mathcal{T}(t) \) = The Corrected Flow Difference = Inlet Flow - Outlet Flow - Pressure Compensation

\( M \) = The mean corrected flow difference (normal Flow Diff for the pipeline)

\( \Delta m \) = The leak size that we are seeking

The Apparent Leak Size = The current corrected flow difference – the mean corrected flow difference

The apparent leak size = \( \mathcal{T}(t) - M \)
SPRT – Working Example
SPRT – Working Example

Transient
Leak
Steady State
Outlet Flow
Inlet Flow
Transient
Outlet Flow
Lambda

Data Tags Time QuickSql
Start Me 05 October 2004

Server: JUNIAP/40
Database: NAVO_Data
Data Table: Data20_11_2002
Refresh Mode: Manual
End Time: 20/November/2002 21:59:56
Refresh Rate: NA
Negative Pressure Wave Flow

Example

Pressure record over 1 hour 3 minutes
Pressure record of 68 seconds to be processed
Pressure output of 68 seconds processed by Algorithm 1
3-D pattern map by Algorithm 2
Leak identified by Algorithm 3 & circled in white

Wave direction confirms a leak within pipeline
Pressure Wave Flow – Accurate Theft Indication
Why Ultrasonics?
## Comparison of Flow Technologies in LDS

<table>
<thead>
<tr>
<th></th>
<th>Turbine</th>
<th>PD</th>
<th>Coriolis</th>
<th>Ultrasonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>No moving parts</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Measurement drift over time</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>No filters/strainers required</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Viscosity independent</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Flow profile independent</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>No Pressure drop</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Bi-directional measurement</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Advanced diagnostics</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Piggability</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Typical line sizes</td>
<td>≤ 12”</td>
<td>≤ 12”</td>
<td>≤ 12”</td>
<td>≤ 72”</td>
</tr>
<tr>
<td>Externally Mounted Solution</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
In-Line (Wetted) USMs

- Highest Level of Performance
- Calibrated for Application
- Permanent Measurement
- Serviceable Under Pressure
- Remote Access
- Multi-Path Diagnostics
Clamp-On USM

✓ Economical and Flexible Installation
✓ Serviceable under pressure
✓ Can be installed in Hard-to-Access Areas
✓ Extremely wide size range
✓ Best applied with Negative Pressure Wave Systems

Installation Uncertainty

Limited Diagnostics
Application Considerations

Types of Fluids

  Refined Products?
  Crudes?
  Multi-product line?

Check metering?

Custody Measurement?

Type of Leak Detection System
Meter Calibration

Water Calibration?
• Large meters >24” are often used
• Repeatability is most important, but viscosity changes impact system

Multi-Viscosity Calibration?
• Reynolds number for pipeline applications rarely can be matched using water
• Installations are rarely proved – so uncertainty of installation must be considered!
• Is the meter also serving as a check, allocation, or custody measurement?
Comparison of Clamp on and In-line Ultrasonic Flow Meters in SPRT Leak Detection System

<table>
<thead>
<tr>
<th></th>
<th>In-line</th>
<th>Clamp-on</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td>Very High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Custody transfer, control, leak detection</td>
<td>Leak detection</td>
</tr>
<tr>
<td><strong>Installation cost</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Retrofit</strong></td>
<td>Very difficult</td>
<td>Easy and cost effective</td>
</tr>
<tr>
<td><strong>Minimum leak detectable</strong></td>
<td>0.15%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Accuracy of leak size estimate</strong></td>
<td>Very high</td>
<td>Medium to high</td>
</tr>
<tr>
<td><strong>Reliability of leak detection system</strong></td>
<td>Very high</td>
<td>Medium to high</td>
</tr>
<tr>
<td><strong>Leak location accuracy using pressure profiling</strong></td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Leak location accuracy using Time of Flight</strong></td>
<td>Very high</td>
<td>Very high</td>
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</table>
### Comparison of 0.15% and 0.3% In-line Ultrasonic Flow Meters in SPRT Leak Detection System

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<td>Control, leak detection</td>
</tr>
<tr>
<td><strong>Minimum leak detectable</strong></td>
<td>0.15%</td>
<td>0.3% -0.5%</td>
</tr>
<tr>
<td><strong>Accuracy of leak size estimate</strong></td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td><strong>Reliability of leak detection system</strong></td>
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<tr>
<td><strong>Leak location accuracy using Time of Flight</strong></td>
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<td>Very high</td>
</tr>
<tr>
<td><strong>Theft detection</strong></td>
<td>Effective for nearly all thefts</td>
<td>Only effective for larger thefts</td>
</tr>
<tr>
<td><strong>Detection of corrosion leaks</strong></td>
<td>Effective</td>
<td>Not effective</td>
</tr>
</tbody>
</table>
Application Considerations

Line Size?

Existing Instrumentation?

New or Existing Pipeline?
Line Size Considerations

48” Diameter Gas Pipeline

8” Diameter Liquid Pipeline
Different Types of Flow Meters in One System
Additional Application Considerations

Pigging

Meter location

Remote Access!
Meter Diagnostics Dashboard
Meter Diagnostics Dashboard
Conclusions

• Proper Leak Detection Systems are of Increasing Importance

• Many types of Internal LDS – focus on less false alarms and fast, accurate Leak Detection

• Ultrasonic Flow Meters are the preferred flow measurement instrument for Leak Detection Applications…

• However – they must be correctly applied

• Luckily – many options are available – be sure to consider all parameters during design
Questions?