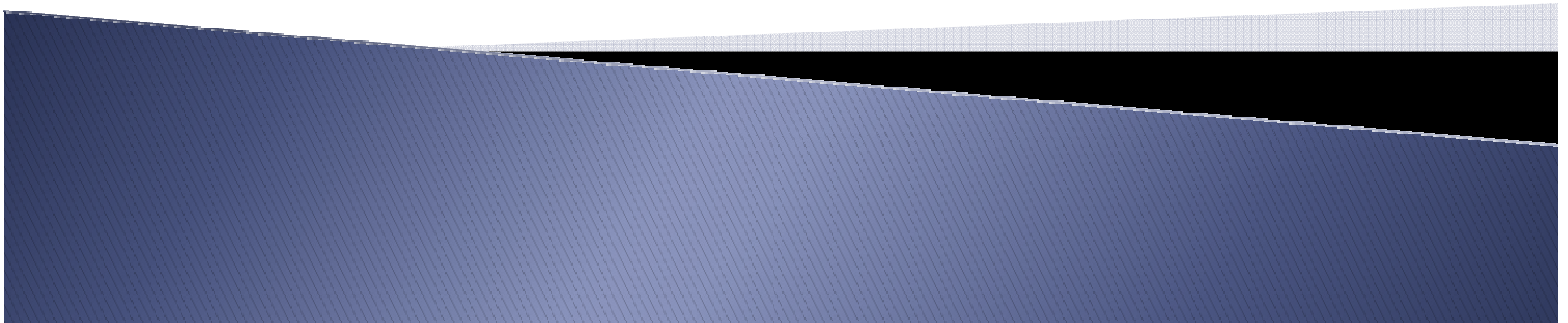




Pipeline Leak Detection Operational Improvements

An Overview of Currently Available Leak Detection Technologies & US Regulations/Standards

Presented at the Pipeline Technology Conference 2012
Hannover, Germany
April 4-5, 2012





Presentation Agenda



Introduction

Recent Pipeline Leak Detection History in the US

- Inspection Finding and Enforcement Actions

Overview of US Regulations & Standards

Current Pipeline Leak Detection Technologies

- Visual Inspection/Observation

- Instrumented Monitoring of Internal Pipeline System Conditions

- External Instrumentation for Detecting Spilled Hydrocarbons

Key Considerations for Evaluating Adequacy of Pipeline Leak detection Systems

Current Pipeline Leak Detection Capabilities

- Capabilities of Visual Leak Detection

- Capabilities of Internally Instrumented Leak Monitoring Systems

- Capabilities of Current External Leak Detection Technologies

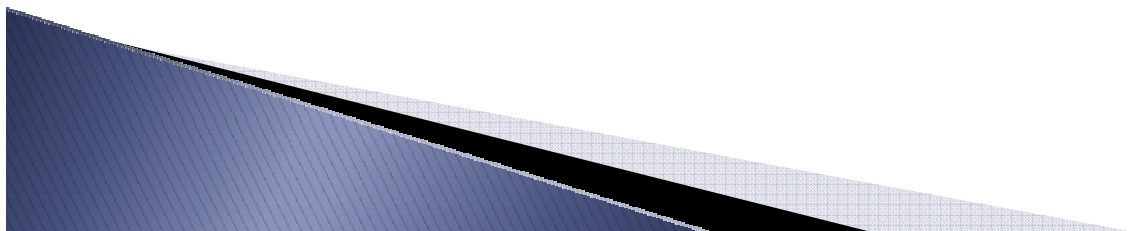
Integrity Management Program

PHMSA & Industry Research & Development

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Future & Conclusions

Recommendations





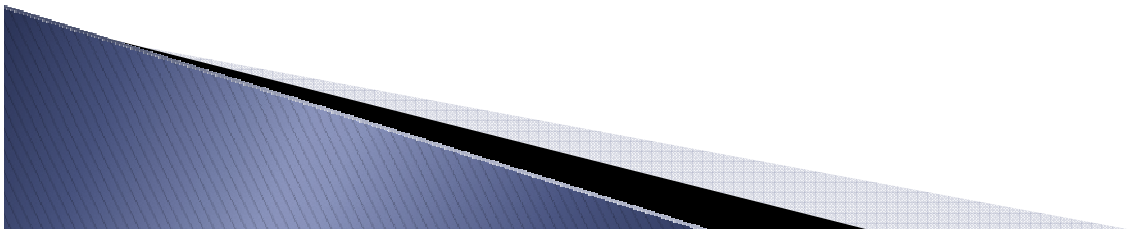
Introduction

Qualifications of Technical Toolboxes & strategic partner the Pipeline Research Council International (PRCI)

Presentation based on US DOT PHMSA Pipeline Leak Detection Technology Study Report to Congress as required by Section 21 of the Pipeline Inspection, Protection, Enforcement, and Safety (PIPES) Act of 2006, Public Law 109-468

Supplemented by the PRCI current 2011 pending research report & US DOT PHMSA "Advance Notice of Proposed Rulemaking (ANPRM) closed in February 2011 and formal comments/recommendations to the ANPRM by American Petroleum Institute (API) and Association of Oil Pipelines (AOPL)

The energy transportation pipeline network of the United States consists of over two million miles of pipelines.



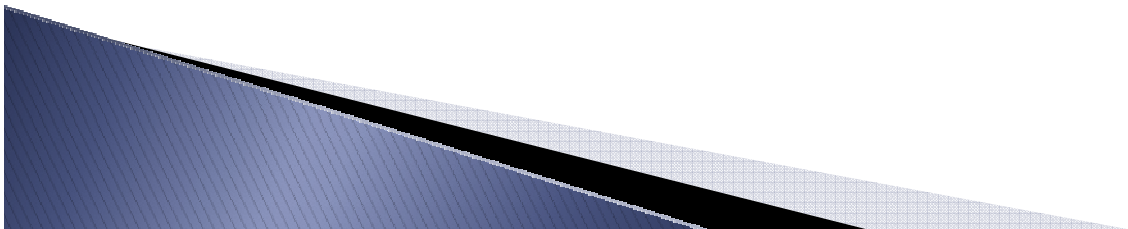


Introduction (Continued)

A dependable leak detection system is important to promptly identify when a leak is occurring in order to shut down the line, isolate the leak, initiate response actions, reduce the volume of the spill, and mitigate safety, environmental, and economic consequences of the release.

This presentation describes the capabilities and limitations of leak detection systems used by operators of hazardous liquid pipelines as required by Section 21 of PIPES. Topics discussed include:

- The capabilities and limitations of current leak detection systems;
- The results of the IM program as it relates to pipeline leak detection systems;
- Inspection findings and enforcement actions;
- Regulatory requirements for pipeline leak detection; and,
- Advancements in leak detection technology.





Recent Pipeline Leak Detection History in the US

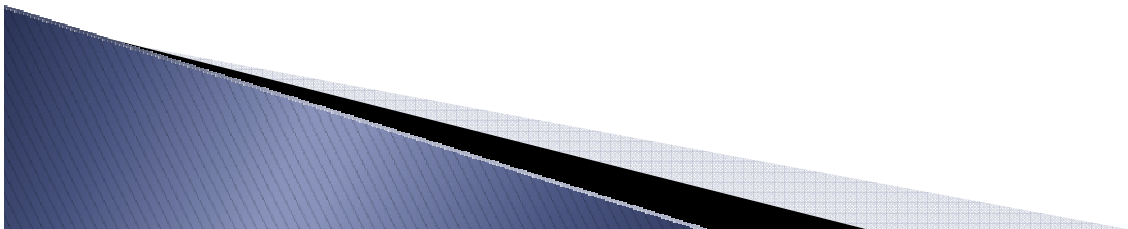
Pipelines are historically a very safe means of transporting large quantities of oil, natural gas, fuels, and other hazardous materials. However, since 2002, there has been an average of two serious pipeline incidents per year and 123 significant pipeline incidents per year.

Several high-profile ruptures and explosions:

Olympic, Alyeska, Colonial, El Paso, PG&E San Bruno...

By 2008 PHMSA completed inspections on all of the hazardous liquid pipeline operator's integrity programs.

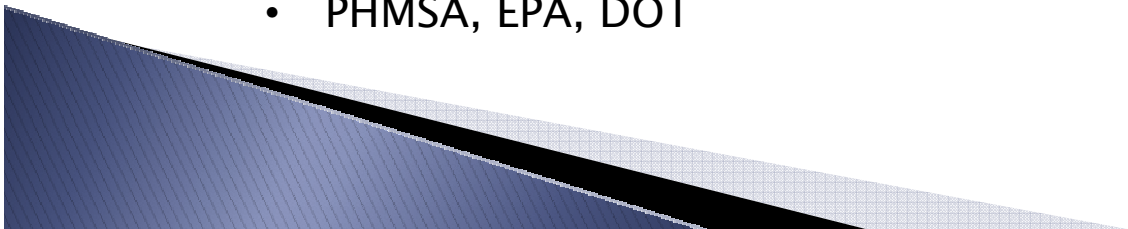
In response to the leak detection issues, PHMSA has initiated enforcement actions, or formally documented its concerns, for approximately 40 percent of hazardous liquid pipeline operators to date. Slow leaks of petroleum products from aging infrastructure have also forced stricter regulations.





Overview of US Regulations & Standards Regulatory Framework

- Federal Regulations, PHMSA, the PIPES Act and EPA
 - U.S. Department of Transportation (DOT) Safety Codes
 - Pipeline and Hazardous Materials Safety Administration (PHMSA) of DOT
 - Pipeline Inspection. Protection. Enforcement. and Safety (PIPES) Act
 - Environmental Protection Agency (EPA) spillage standards
 - These Agencies have Inspection and Enforcement powers, and resources
- State Regulations
 - Vary very widely – lax and unsupervised in Texas, through strict and enforced in Alaska
- Recommended Best Practices
 - American Petroleum Institute (API)
 - American Gas Association (AGA)
 - Pipeline Research Council International (PRCI)
 - Association of Oil Pipelines (AOPL)
 - PHMSA, EPA, DOT





Overview of US Regulations & Standards – Continued

Leak Detection Standards – When a CPM system is used, PHMSA requires that it conform to the requirements of the national consensus standard published by the API 1130. For Leak Detection System “Audits” API 1149 “Pipeline Variable Uncertainties and Their Effect on Leak Detection” must be followed.

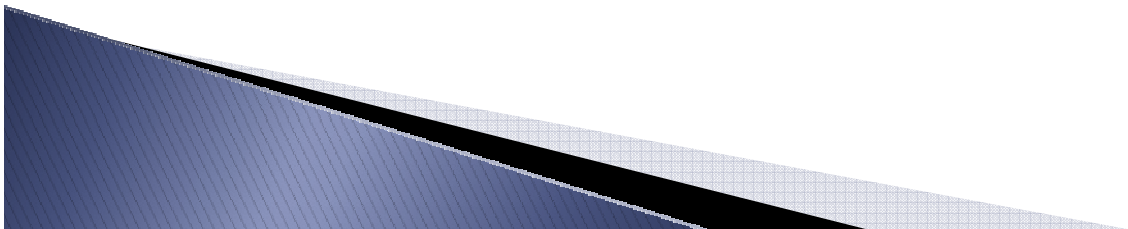
Pipeline ROW Inspections – Pipeline safety regulations (CFR 192/195) require hazardous liquid pipeline operators in the United States to perform periodic visual inspections of their pipeline ROW at least 26 times per calendar year.

Corrosion Control – Regular monitoring, testing, and inspection of pipeline corrosion is required under pipeline safety regulations.

Public Awareness – Federal pipeline regulations require that pipeline operators develop and implement a public education program in accordance with API Recommended Practice 1162, which is unique to the characteristics and attributes of each operator's pipeline system.

Damage Prevention Program – Pipeline operators are required to have a damage prevention program to prevent pipeline damage caused by excavation activities.

Procedures/or Investigating Abnormal Operating Conditions – Federal pipeline regulations require that operators have procedures to investigate abnormal conditions.



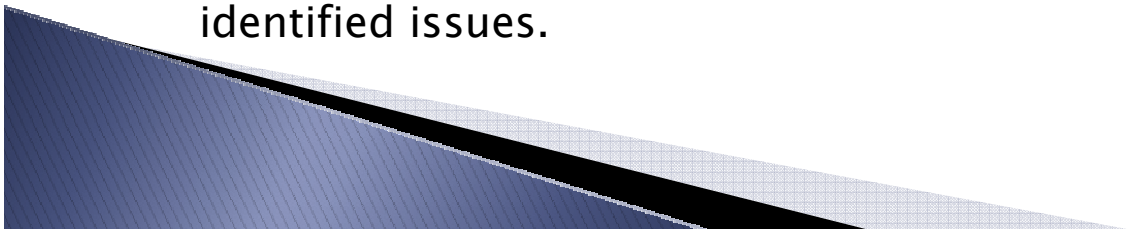


Inspection Findings and Enforcement Actions

Most hazardous liquid operators have some form of instrumented leak detection capability in place. However, PHMSA inspections identified a number of issues related to the operator's evaluation of its leak detection capabilities. Most issues fall into one of the following two categories:

- The operator's IM procedures did not adequately require or specify that a leak detection evaluation be conducted.
- The operator's IM procedures required that a leak detection evaluation be conducted, but the procedure or process by which the evaluation would be conducted was inadequate in some respect.

In response to the enforcement actions, operators are required to submit revised procedures to correct inadequacies related to leak detection evaluations. Operators must then evaluate (or reevaluate) their leak detection capabilities in accordance with these corrected procedures. Before a case is closed, PHMSA reviews the revised procedures, and determines that the revisions satisfactorily address identified issues.

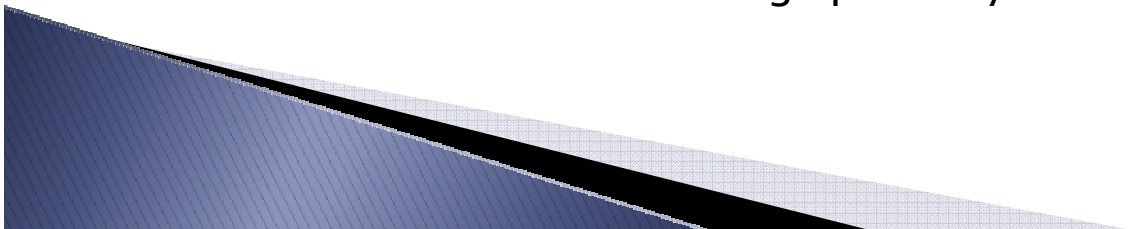




Current Pipeline Leak Detection Technologies

The methods used for leak detection cover a wide spectrum of technologies and are based on a number of different detection principles. They vary from intermittent aerial inspections to hydrocarbon sensors to Supervisory Control and Data Acquisition (SCADA) based, real-time monitoring. Each approach has its strengths and weaknesses. The operational principle, data and equipment requirements, strengths, weaknesses, and the realistic performance limits (size, response time, location, false alarm, etc.) for the leak detection methods listed above are addressed in this presentation.

Leak detection systems are varied and uniquely designed for each pipeline application. However, for discussion purposes, leak detection technologies can be classified according to the physical principles involved in the leak detection. Using this type of classification, general categories of leak detection technologies can be divided into the following three groups: visual inspection/observation, instrumented monitoring of internal pipeline system conditions, and external instrumentation for detecting spilled hydrocarbons.

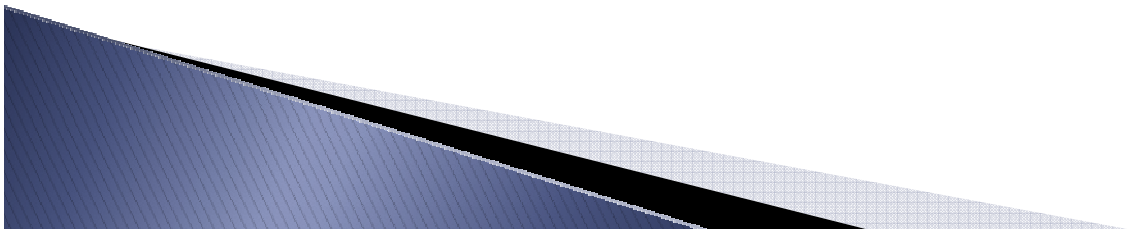




Visual Inspection/Observation

Simple visual observation is reliable and is part of every pipeline ROW patrolling and monitoring program, as mandated by Federal regulations. However, it cannot assure timely detection of leaks.

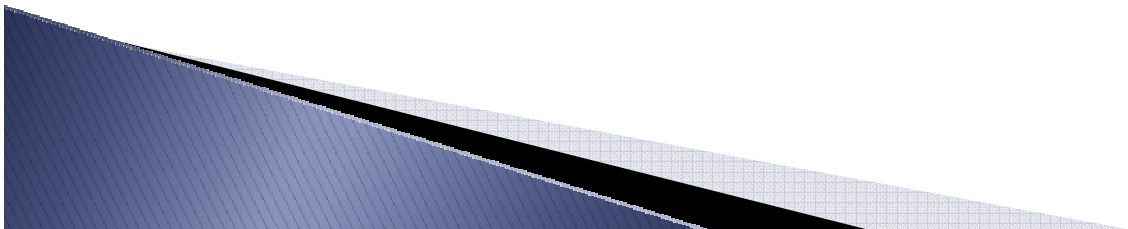
In addition to Visual Inspection/Observation the following list addresses the most commonly used leak detection approaches:



Instrumented Monitoring of Internal Pipeline System Conditions

The following list addresses the most commonly used approaches:

- 1) Regular or Periodic Monitoring of Operational Data
 - a) Volume balance (over/short comparison)
 - b) Rate of pressure/flow change
 - c) Pressure point analysis
 - d) Negative pressure wave method
- 2) Computational Pipeline Monitoring (CPM)
 - a) Mass balance with line pack correction
 - b) Real time transient modeling
- 3) Data Analysis Methods
 - a) Statistical methods
 - b) Digital signal analysis

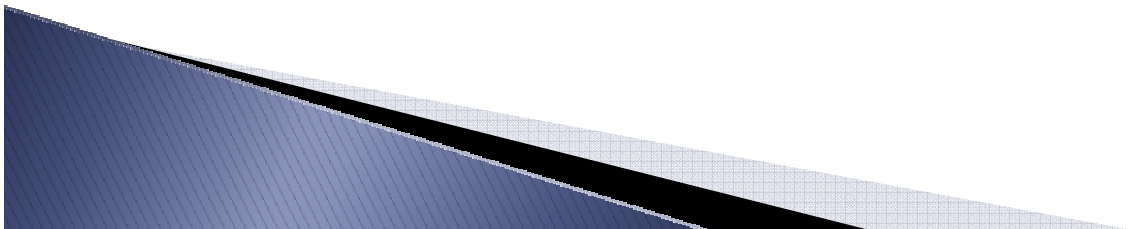




External Instrumentation for Detecting Spilled Hydrocarbons

The following list addresses the most commonly used approaches:

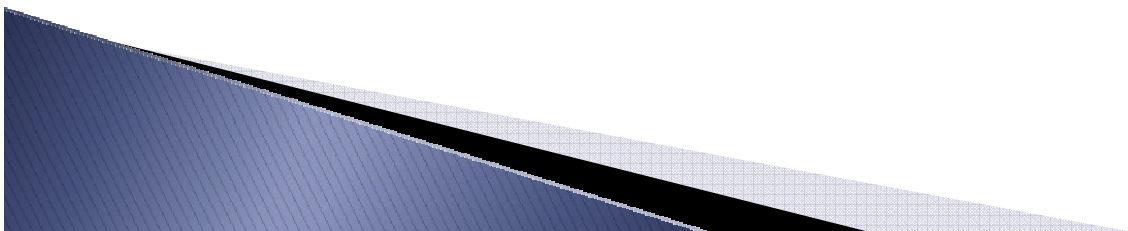
- 1) Liquid Sensing Cables
- 2) Fiber Optic Cables
- 3) Vapor Sensing Tubes
- 4) Acoustic Emissions





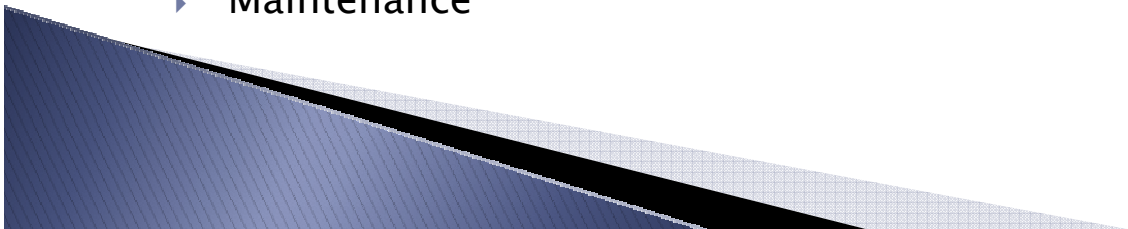
Key Considerations for Evaluating Adequacy of Pipeline Leak detection Systems

Each leak detection system is unique based on the pipeline on which it is used. As such, the capabilities of the system and the degree to which it mitigates risk must be evaluated for each pipeline system. Pipeline size, length, operating parameters and instrumentation design will affect the detection time. Key considerations that should be taken into account include, but are not limited to, the following:



Key Considerations for Evaluating Adequacy of Pipeline Leak detection Systems

- ▶ Rate of False Alarms and Misses
- ▶ Personnel Training and Qualification
- ▶ System Size and Complexity (Including Batch Line Factors)
- ▶ Leak Size or Leak Flow Rate
- ▶ Response Time
- ▶ Leak Location Estimation
- ▶ Release Volume Estimation
- ▶ Detecting Pre-Existing Leaks
- ▶ Detecting a Leak in Shut-in Pipeline Segments
- ▶ Detecting a Leak in Pipelines under a Slack Condition During Transients
- ▶ Sensitivity to Flow Conditions
- ▶ Multiphase Flow
- ▶ Robustness
- ▶ Availability
- ▶ Retrofit Feasibility
- ▶ Testing
- ▶ Cost
- ▶ Maintenance





Current Pipeline Leak Detection Capabilities

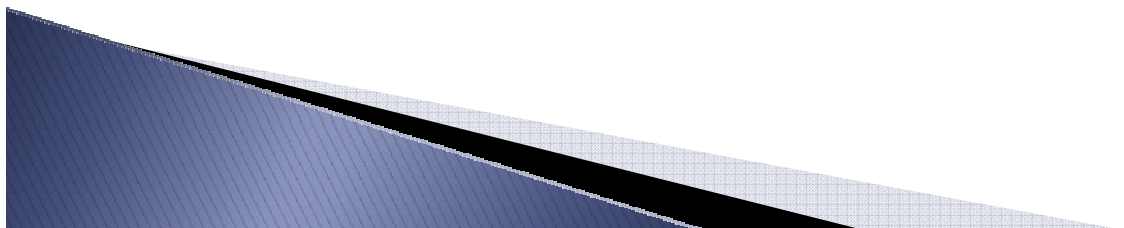
Capabilities of Visual Leak Detection

Visual leak detection is the oldest and most widely used method of leak detection. All operators of hazardous liquid pipelines within the United States that are regulated by the DOT are required to perform visual inspection of their system for leaks. Specifically, 49 CFR 195.412 requires that:

Each operator shall, at intervals not exceeding 3 weeks, but at least 26 times each calendar year, inspect the surface conditions on or adjacent to each pipeline ROW. Methods of inspection include walking, driving, flying or other appropriate means of traversing the ROW.

Capabilities and Limitations of Visual Leak Detection

Capabilities	Limitations
Requires no tools or equipment	Up to three-week detection time
Location of leak is immediately known in most cases	Small leaks may not be readily apparent at ground level
	Dependent on the diligence of personnel inspecting the ROW
	Aerial inspection might miss some evidence of small leaks

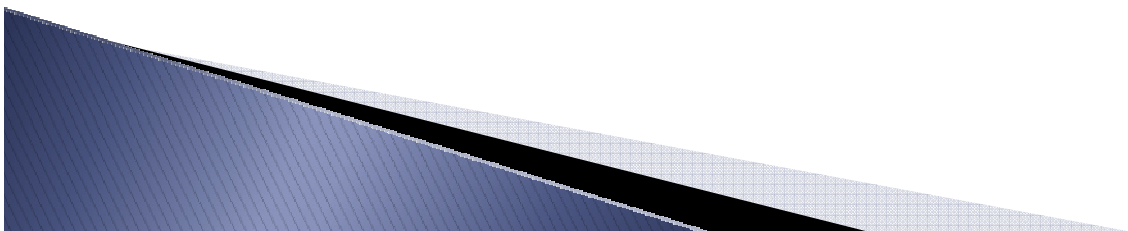




Capabilities of Internally Instrumented Leak Monitoring Systems

Internally based leak monitoring systems use pipeline operational data to calculate predicted operational parameters under normal conditions. The predictions are compared to measured parameters to identify differences that could indicate a leak. Geographically-distant field sensors on the pipeline are constantly polled and data is transmitted to a control center through a SCADA system. In the control center, the SCADA system then provides the needed data to a monitoring computer running the leak detection algorithm. (In some simple applications of volume balance method, the controller manually reads the instruments and performs the calculations, sometimes locally.) The quality of the data affects the system's ability to detect a leak and the pipeline size, length and operating parameters affect leak detection time.

The design, implementation, testing, and operation of these systems are addressed by API 1130.

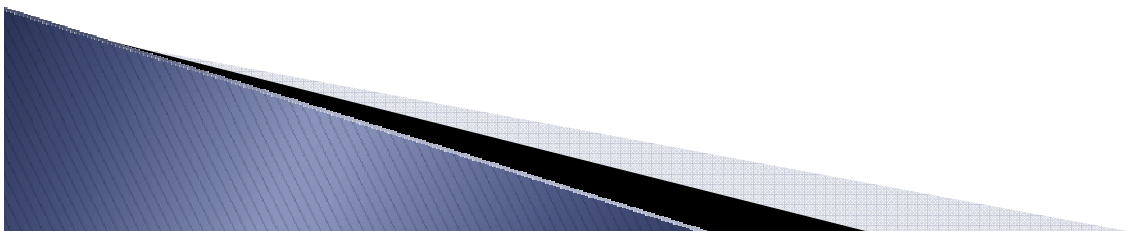




Volume Balance (Over/Short Comparisons)

Capabilities and Limitations of the Volume Balance

Capabilities	Limitations
Implementation or retrofitting on any Pipeline configuration is easy	Leaks cannot be detected during shut in and slack line conditions
This method is easy to learn and use	Leaks cannot be detected during transient conditions
Testing and maintenance are easy	Small leaks may have very long detection times
Costs are relatively low	The location of a leak cannot be determined
Detect less than 5 percent leak in minutes to hours	Long-term average of leak volume can only be roughly estimated
	False alarms are frequent unless thresholds are softened during transient states

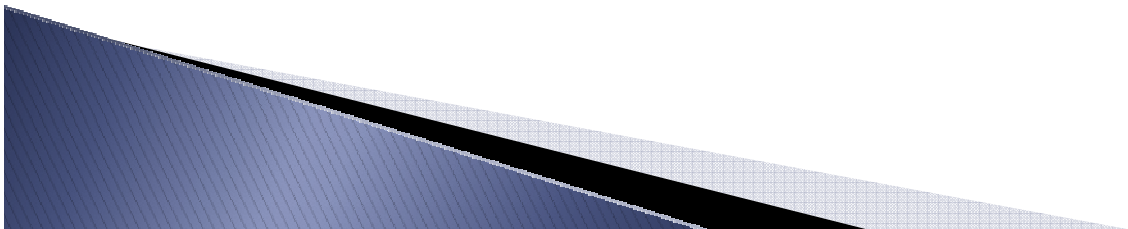




Rate of Pressure/Flow Change

Capabilities and Limitations of the Rate of Pressure/Flow Change

Capabilities	Limitations
Leaks can be detected in shut in conditions	Small leaks, existing leaks, and leaks during slack line conditions cannot be detected
This method can estimate the volume and location of large leaks	Implementation and testing are not easy
Retrofitting and maintenance are easy	The method is not easy to learn and use
Able to detect 5 percent leak in minutes	False alarms are frequent during transient conditions
	The method is less robust



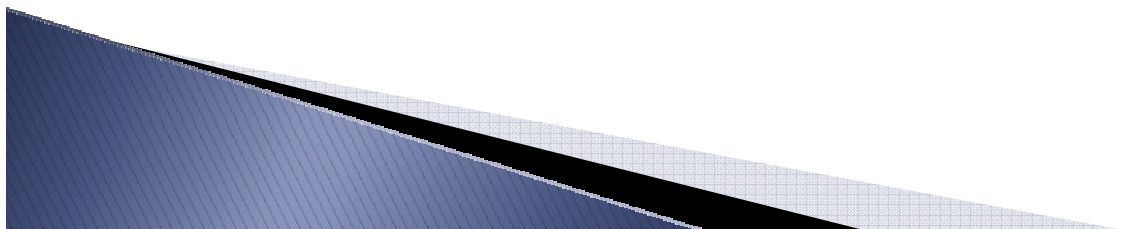


Computational Pipeline Monitoring (CPM)

Mass Balance with Line Pack Compensation

Capabilities and Limitations of the Mass Balance with Line Pack Correction

Capabilities	Limitations
Existing leaks and leaks for shut in and transient conditions can be detected	Leaks cannot be detected during slack line conditions
Able to detect 1 percent leaks in minutes	Implementation, retrofitting, and maintenance are not easy
Leak detection can be used during transient conditions with less frequent false alarms	The location of a leak cannot be determined.
The method is easy to learn and use	Cost is high
Testing is easy	
The method is adaptable to any pipeline configuration	

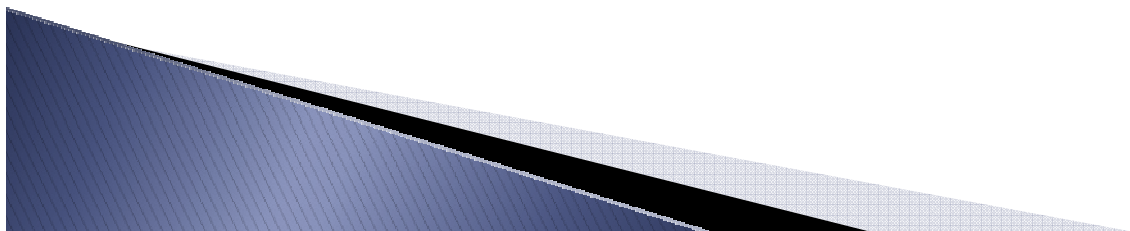




Real Time Transient Model (RTTM)

Capabilities and Limitations of RTTM

Capabilities	Limitations
Able to detect 1 percent leaks in seconds	Existing leaks cannot be detected
Leak flow rate and leak location can be estimated	The method is difficult to learn and use
Leaks can be detected for shut in, slack line and transient conditions	The model must be customized and tuned to each unique pipeline configuration
	Implementation, testing, and maintenance are difficult
	Costs are very high



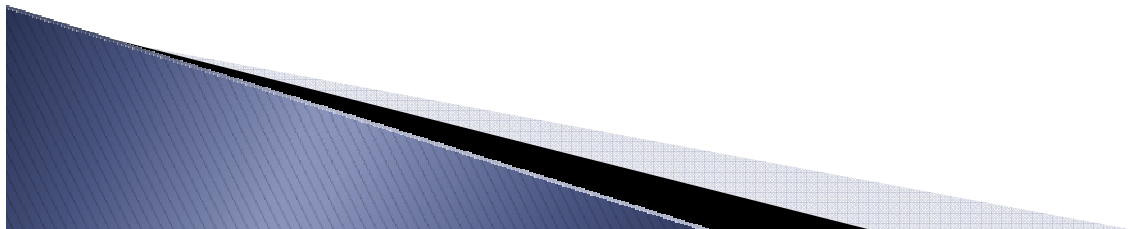


Data Analysis Methods

Statistical Analysis

Capabilities and Limitations of the Statistical Analysis Methods

Capabilities	Limitations
Able to detect 1 percent leaks in seconds to minutes	Existing leaks and leaks in slack line conditions cannot be detected
Leaks can be detected for shut in and transient conditions	Leak volume difficult to estimate
False alarms are less frequent	Implementation and testing are difficult
Leak location can be estimated	Costs are high
Retrofitting and maintenance are easy	
The method is easily adaptable to any pipeline configuration	
The method is robust	

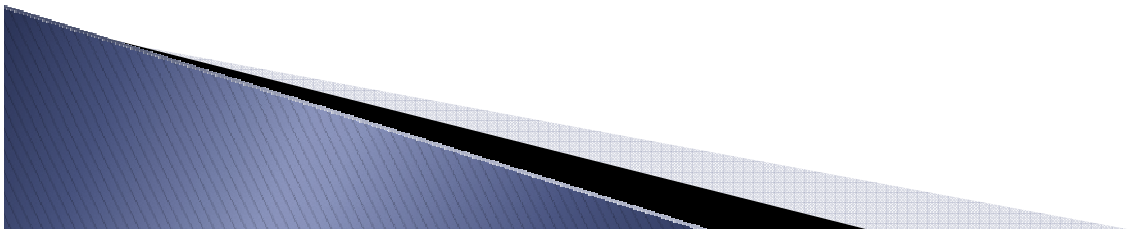




Digital Signal Processing

Capabilities and Limitations of the Digital Signal Processing Technique

Capabilities	Limitations
Able to detect 1 percent leaks in seconds to minutes	Existing leaks and leaks in slack line conditions cannot be detected
Leaks can be detected for shut in and transient conditions	Leak volume cannot be estimated
False alarms are less frequent	Implementation, retrofitting, and testing are difficult
Leak location can be estimated	Costs are high
The method is easy to learn and use	
Maintenance is easy	
The method is easily adaptable to any pipeline configuration	
The method is more robust	

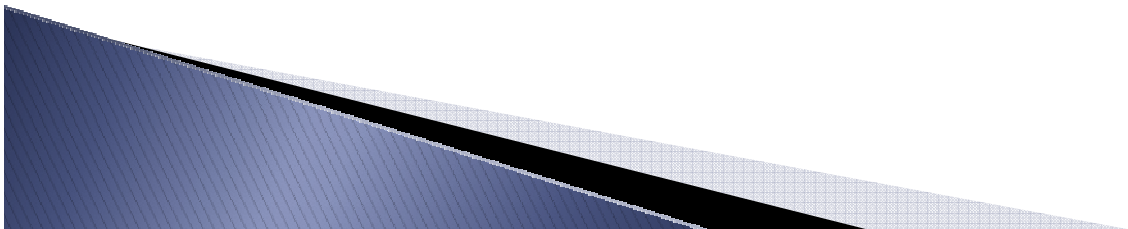


Uniqueness of Internally Instrumented Detection Methods

The single most important aspect of internally instrumented leak detection is each system is unique to the pipeline on which it is installed. The same system installed on two different pipelines will not have the same performance. The performance of the system is highly dependent on the pipeline on which it is installed. When evaluating the capability of a leak detection system one must consider the pipeline design and operation. Validation of leak detection systems is best accomplished by testing the installed system. This testing should follow the requirements of API 1130.

Comparison of Internally Instrumented Leak Detection Methods

The implementation of the various algorithms within this category varies considerably. As a result, the performance of a particular method may be significantly different from a similar system deployed on a different pipeline. Further compromising the boundary between categories are the many hybrid approaches that have been developed. For example, statistical analysis can be applied to volume balance, with pressure sensor-based line pack correction.

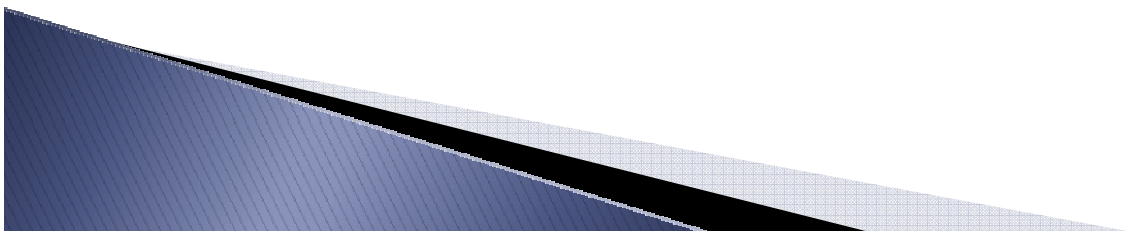




Capabilities of Current External Leak Detection Technologies

External leak detection methods are better suited for shorter pipeline segments due to the installation costs associated with installing either cables or vapor sensing tubes adjacent to the pipeline for the length of the pipeline to be instrumented. These types of sensors have proven results for underground storage tank applications. There are several factors that affect the performance of external leak detection systems (other than visual inspection) and should be considered as part of the selection process. A user guide developed by the Naval Facilities Engineering Service Center (UG-2028-ENV) describes selection criteria for the different methods, summarized as follows:

- Soil Conditions
- Water Table
- Continuous Monitoring
- Spacing of Sensors
- Leak Rate

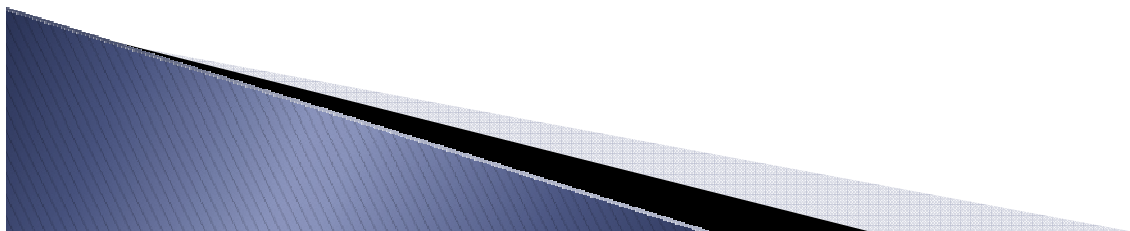




Liquid Sensing Cables

Capabilities and Limitations of Liquid Sensing Cables

Capabilities	Limitations
Operated in continuous mode and may be automated	Cannot estimate the size of the leak
Method can determine leak location	Retrofitting to existing pipelines would be very difficult and costly
A reasonably fast response time	Multiphase flow leak may not be detected if only gas escaped
Minimally affected by multi-component flow conditions	Costs are extremely high
More sensitive than computational methods and responds in seconds to minutes	

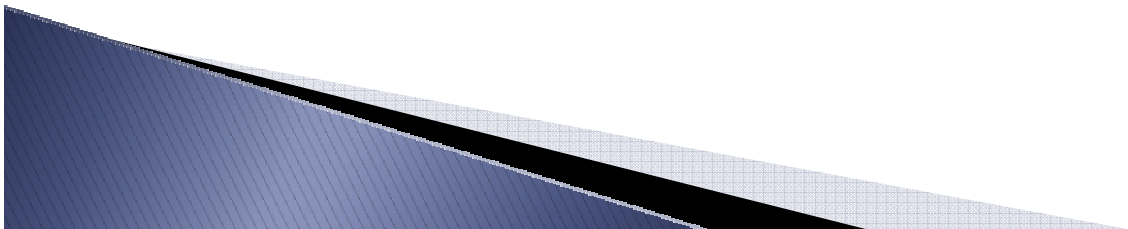




Fiber Optic Cables

Capabilities and Limitations of Fiber Optic Cables

Capabilities	Limitations
Operated in a continuous mode and may be automated	Retrofitting to existing piping system is difficult
Method can determine leak location	Multiphase flow is problematic for this technique
Method can estimate the concentration of the hydrocarbon and maybe the size of the leak	Stability of the chemical coating is an issue which could lead to missed leaks.
Fiber Optic is immune to electromagnetic interference (noise),	Costs are extremely high
Response time to a leak is reasonable	
Minimally affected by multi-component flow conditions	
More sensitive than computational methods and responds in seconds to minutes.	

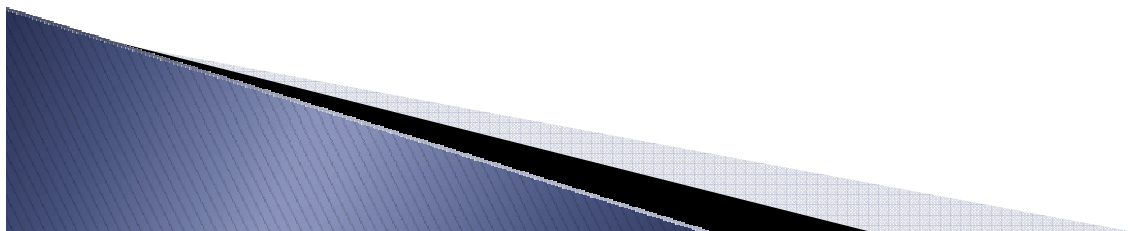




Vapor Sensing

Capabilities and Limitations of Vapor Sensing

Capabilities	Limitations
Operated in a continuous mode and may be automated	Response time is slower than most other continuous external measurement types.
Location of the leak can be estimated	Typically used for short piping runs
The size of the leak can be estimated by concentration measurements	This method is not effective for above ground pipelines.
Minimally affected by multi-component or multiphase flow conditions.	Costs are extremely high
More sensitive than computational methods and responds in minutes	

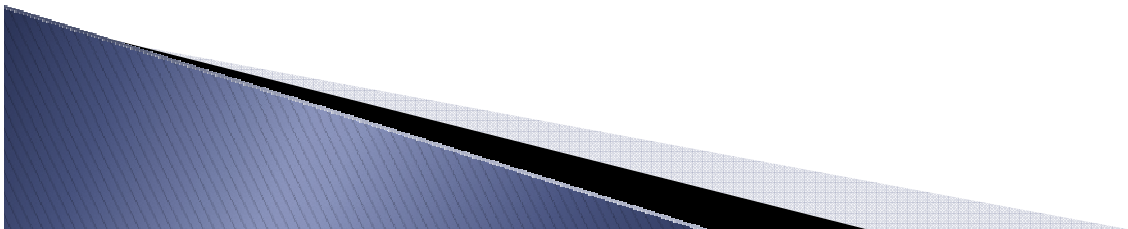




Acoustic Emissions

Capabilities and Limitations of Acoustic Emissions

Capabilities	Limitations
Operated in a continuous mode and may be automated	High flow noise conditions may mask the leak signal (valve or pump noise, multiphase flow).
Method can determine the location of the leak	Numerous sensors may be needed to monitor long pipelines.
Size of leak can be estimated	Costs are extremely high
Minimally affected by multi-component flow	
The acoustic emission method can be used on new or retrofitted to existing pipelines.	
More sensitive than computational methods and responds in essentially real-time.	



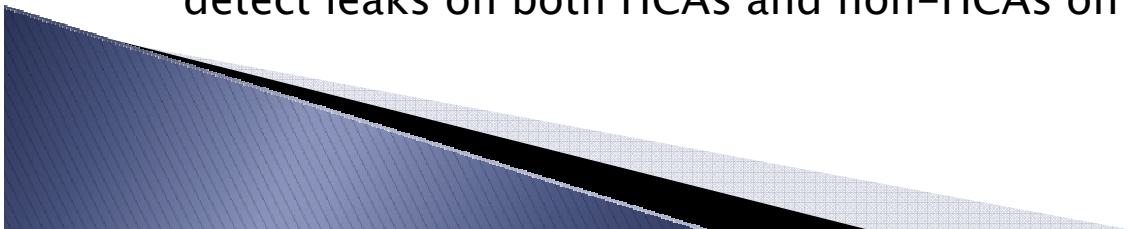


Integrity Management Program (IMP)

Operators are required, by the 1M rule, to have a means to detect leaks. Operators must also perform a critical, investigative, risk-based evaluation of their leak detection capabilities. The operator's evaluation of its leak detection capabilities must consider, at a minimum, the following factors:

1. Length and size of the pipeline:
2. Type of product carried:
3. The pipeline's proximity to the high consequence area:
4. The swiftness of leak detection:
5. Location of nearest response personnel:
6. Leak history; and,
7. Risk assessment results.

While the IM rule focuses on additional protections for HCAs, operators also have an obligation to detect and respond to leaks in non-HCAs. Typically, the same leak detection systems and procedures are used to detect leaks on both HCAs and non-HCAs on the same pipeline.





PHMSA & Industry Research & Development

Appendix A

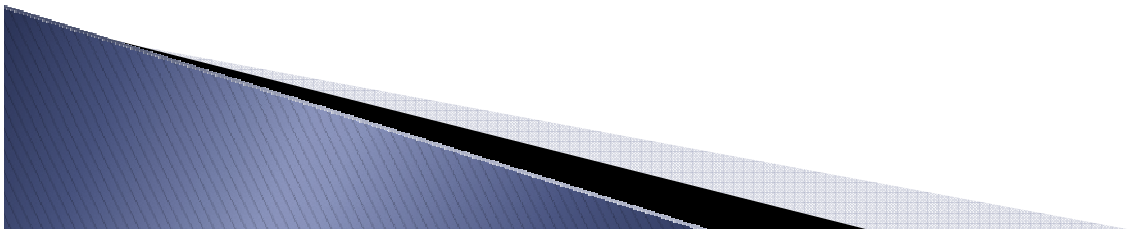
PHMSA Pipeline Safety Research
(Leak Detection Projects since 2002)

No.	Goal	Type	Location	Project ID	Contractor	Project Title	PHMSA	Co-Share	Pct Cmpl
1.	Safety	HazLiq GasTrans Dist-Steel Dist-Non-Metal	Onshore Alaska	DTPH56-05-T-0004	Electricore, Inc., Pipeline Research Council International, Inc.	"Use of Unmanned Air Vehicle (UAV) for Pipeline Surveillance to Improve Safety and Lower Cost"	\$457,361	\$625,416	100
2.	Environmental Stewardship	HazLiq GasTrans	Offshore	DTPH56-05-T-0004	Electricore, Inc., Pipeline Research Council International, Inc.	"Use of Unmanned Underwater Vehicle (UUAV) for Pipeline Surveillance to Improve Safety and Lower Cost"	\$405,358	\$285,000	100
3.	Environmental Stewardship	HazLiq GasTrans Dist-Steel Dist-Non-Metal	Onshore Offshore Alaska	DTRS56-04-T-0012	ITT Industries Space Systems, LLC	"Hazardous Liquids Airborne LIDAR Observation Study (HALOS)"	\$553,114	\$555,115	100
4.	Environmental Stewardship	GasTrans Dist-Steel Dist-Non-Metal	Onshore Alaska	DTRS56-01-X-0023	LaSen and U.S. Air Force Research Laboratory	"Airborne LIDAR Pipeline Inspection System (ALPIS) Mapping Tests"	\$2,245,204		100
5.	Environmental Stewardship	HazLiq GasTrans Dist-Steel Dist-Non-Metal	Onshore	DTRS57-04-C-10012	Prime Research	"Intrinsic Distributed Fiber Optic Leak Detection"	\$99,706		100
6.	Environmental Stewardship	GasTrans Dist-Steel Dist-Non-Metal	Onshore Alaska	DTRS57-04-C-10016	Midé Technology Corporation	"Piezo Structural Acoustic Pipeline Leak Detection System"	\$100,000		100
Total:							\$3,860,743	\$1,465,531	



Industry Confusion

- There are at least 80 External LDS vendors (DTS and Acoustic) in the US
- There are at least 18 Computational Pipeline Monitoring (CPM) LDS vendors in the US
- There is a very real, and self-confessed, lack of know-how on LDS at the pipeline operators
- PHMSA: Operators' choices about methods of leak detection will be as varied as the types of pipeline construction, operation, and the environments in which they operate.



Future & Conclusions

- PHMSA will soon propose additional measures designed to enhance the ability of control rooms and controllers to effectively detect and mitigate the consequences of a leak.
- A key component of the IM rule is continual improvement. Each operator's IM program is expected to mature and improve over time.
- LDS should always be selected to be fit-for-purpose. A major component of its cost is continuing training, maintenance, testing and improvement over time.
- Dual or more backup systems are preferred both for redundancy (no single point of failure) and also to extend the range of effectiveness of the LDS.
 - It is better to have two cheaper LDS that work in synergy, than a single expensive, badly maintained LDS
- Detailed engineering design of any LDS is needed to cover:
 - Suitability, sensitivity and requirements of CPM (API RP 1130 for CPM for liquids)
 - Selection of instrumentation LDS (API 1149 for variable uncertainties and their effects on LDS)
 - External Leak Detection Technology selection (Naval Facilities Engineering Service Center, UG-2028-ENV)

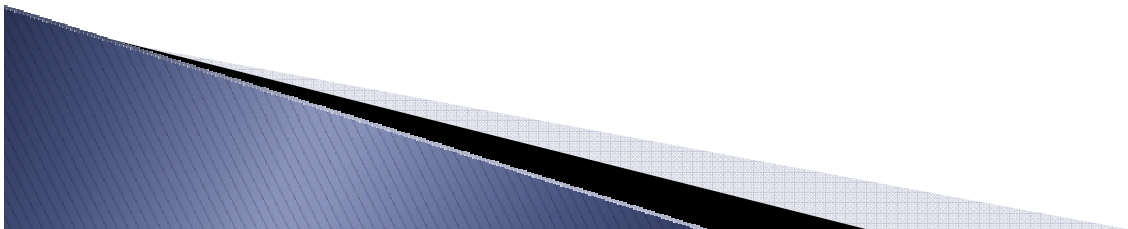




Recommendations

Pipeline owner/operators should conduct a comprehensive audit and leak detection system assessment at least once every 2 years

- The audit and system assessment should consider additions and/or modifications to the pipeline network as these changes can severely impact system performance.
- The audit and system assessment should include a review of new technologies that could be used to enhance performance.
- The audit and system assessment should include a comprehensive cost/benefit analysis





Thank You

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