

Pipeline Leak Detection—Program Management

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Introduction

Background

This Recommended Practice (RP) provides guidance to operators of hazardous liquid pipeline systems regarding a risk-based pipeline LDP management process.

This RP is designed to provide operators with a description of industry practices in risk-based pipeline LDP management and to provide the framework to develop sound program management practices within an operator's individual companies.

It is recognized that this RP creates requirements and practices that may take time to fully implement.

Objectives

This RP is written to provide guidance to operators for developing and maintaining management of pipeline LDPs. The elements of this RP are written to conform to current pipeline regulations and to encourage operators to “go beyond” and, in so doing, to promote the advancement or stronger utilization of LDPs in hazardous liquid pipelines.

This RP builds on and augments existing requirements and is not intended to duplicate requirements of any other consensus standards or regulations.

Each operator is expected to tailor their LDP to their requirements.

The goal of an operator is to operate their pipelines safely and reliably so that there are no adverse effects on the public, employees, the environment, or the pipeline assets. This pipeline LDP management RP aids in this primary goal by the following:

- Providing hazardous liquid operators with guidance on development, implementation, and management of a sustainable LDP to minimize the size and consequences of leak events.
- Providing operators with enhanced guidance on selection of leak detection systems (LDSs) using a risk-based approach and on establishing performance measures for the capabilities of LDSs unique to each pipeline to meet or exceed the requirements of 49 *CFR* Part 195, such as in 195.452(i)(3), pertaining to leak detection related preventive and mitigative measures an operator shall take to protect a sensitive area.
- Addressing identified gaps and incorporating guidance into a comprehensive program document.

The LDP decisions rely on a thorough assessment and analysis of risk and threats as they apply to leak detection and should integrate with the operator's acceptable risk level. An LDP may reduce the consequence of a leak and contribute to the development from a “thinking to knowing” leak detection culture.

This RP does not include the following:

- detailed technical design of LDSs (as this is operator, LDSs, and infrastructure dependent);
- SCADA system design (as this is already covered in other API documents, for example API RP 1113 ¹, API RP 1165, or API RP 1167);
- specific performance metrics (an individual operator's risk-based approach and engineering evaluation covers this);

¹ This is a historical document and is no longer supported by API.

- field response (as this is covered in an operator's emergency response plan);
- presentation of information to controllers (covered in RP 1165);
- equipment selection criteria (as these are specific to an operator, LDS, and vendor selection);
- a universal metric for pipeline leak detection performance (it is not a practical objective); or
- a definition of the relationship between emergency flow restriction devices (EFRDs) and leak detection (EFRDs and leak detection are two different mitigation systems).

Pipeline Leak Detection—Program Management

1 Scope

API Recommended Practice (RP) 1175 establishes a framework for Leak Detection Program (LDP) management for hazardous liquid pipelines that are jurisdictional to the U.S. Department of Transportation. This RP is an industry consensus document revised by hazardous liquid pipeline operators, leak detection manufacturers, consultants, and others. API RP 1175 focuses on using a risk-based approach to each operator's LDP. Reviewing the main body of this document and following the guidance set forth assists in creating an inherently risk mitigating LDP management system. API RP 1175 represents industry best practices in managing an LDP.

All leak detection systems (LDSs) used by a pipeline operator should be managed in a coordinated manner. The goal of the LDP is to detect leaks quickly and with certainty, thus facilitating quicker shutdown and therefore minimizing negative consequences. This RP focuses on management of LDPs, not the design of LDSs, and therefore contains relatively little technical detail. As with API RP 1130, API RP 1175 is intended for single-phase pipelines only; however, the approach may be applicable to pipelines that are not single phase.

Leak detection reduces the consequences of a LOC but does not reduce the likelihood of a leak. An appreciation and evaluation of leak event likelihoods, threats, and vulnerabilities drives the design of the LDP.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Recommended Practice 1130, *Computational Pipeline Monitoring for Liquids*

API Technical Report 1149, *Pipeline Variable Uncertainties and Their Effects on Leak Detection Sensitivity*

API Recommended Practice 1160, *Managing System Integrity for Hazardous Liquid Pipelines*

API Recommended Practice 1167, *Pipeline SCADA Alarm Management*

API Recommended Practice 1173, *Pipeline Safety Management Systems*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

continuous leak detection

Leak detection system that is operating in real time or near real time.

3.1.2

consequence level

Ranking of the possible consequences of a leak based on a calculated value or a relative value of the consequences.

3.1.3

dynamic leak volume

Amount of hazardous liquid that is leaked after the onset of a leak prior to the shutdown of the pipeline or other appropriate operational response is initiated.

3.1.4

escalation barrier

Functional group of safeguards, such as primary containment processes, equipment, engineered systems, operational procedures, management system elements, or worker capabilities designed to prevent loss of containment (LOC) and other types of asset integrity or process safety events and mitigate any potential consequences of such events.

3.1.5

externally based leak detection systems

leak detectors

Applications that use sensors to directly detect the presence of a hydrocarbon or physical changes in environment due to a leak.

NOTE These sensors are generally placed on or near the external surface of the pipe or, in the case of cameras for instance, within sensing range of the pipeline.

3.1.6

groupthink

Psychological phenomenon that occurs within a group of people in which the desire for harmony or conformity in the group results in an irrational or dysfunctional decision-making outcome.

NOTE NTSB has several publications related to this phenomenon under the topic Crew Resource Management.

3.1.7

independent means

That which may be a separate or complementary leak detection system that uses another technique, some verification method, separate calculations, leak detection specialists' involvement, or other procedure or process.

3.1.8

internally based leak detection systems

Applications that are internally based using field sensor data that monitor internal (and perhaps related external) pipeline parameters but are not actually detecting the presence of hydrocarbons.

NOTE Since these systems do not actually contact leaked hazardous liquid, internally based leak detection systems may be regarded as inferential systems (see API RP 1130).

3.1.9

leak detection

a) leak detection method

Classification of leak detection operation as being continuous or non-continuous.

b) leak detection principle

Classification of leak detection by categories that are externally based or internally based.

c) leak detection program (LDP)

Top-level term that encompasses all the various LDSs (which may include multiple techniques) employed by the operator and identifies all strategies and methods used to detect leaks and the policies, processes, and the human element.

d) leak detection technique

Individual technology applications (e.g. real time transient model, wetted cable, fiber optical cable, or other technologies) used to detect or indicate a leak.

e) leak detection system (LDS)

End-to-end application of one technique that may be internally based or externally based and continuous or non-continuous.

3.1.10

leak indication

Alarm or other notifying event that suggests that present conditions indicate the possibility of a leak.

NOTE 1 The possibility of a leak is stronger if there is more than one indication.

NOTE 2 Industry also uses the word “triggers” for leak indications.

3.1.11

leak monitoring

Form of pipeline leak detection that is intended to detect the occurrence of a leak smaller than a rupture.

3.1.12

leak verification

Analysis of pipeline operation and/or pipeline conditions triggered by the suspicion of the existence of a leak intended to provide sufficient confidence to make a formal determination of whether or not a leak exists.

NOTE It may involve onsite investigation.

3.1.13

loss of containment

LOC

Unplanned or uncontrolled release of hazardous liquid to the environment.

NOTE 1 The words leak, spill, release, fluid release, or commodity release are sometimes used for a LOC.

NOTE 2 Sometimes this is called loss of primary containment or LOPC.

3.1.14

metrics

performance metrics

Performance category that is quantified by Key Performance Indicators (KPIs).

NOTE Leak detection metrics are described in API RP 1130, Annex C, and are grouped into four categories, or metrics, that determine a system's reliability, sensitivity, accuracy, and robustness.

3.1.15

non-continuous monitoring

Type of leak detection that is periodic but not in real time.

3.1.16

overall leak volume

Total leak volume that occurs from the time the pipeline leak begins until all leakage is stopped.

NOTE It includes dynamic leak volume plus static leak volume.

3.1.17

risk tolerance

acceptable risk

Amount of risk that the operator is willing to assume.

NOTE When the level of risk is above an acceptable level or is not tolerable it exceeds the risk tolerance.

3.1.18**risk-based approach**

Decision-making process that prioritizes the leak detection work based on the calculated risk, evaluates it against a level of risk tolerance, and then takes action to reduce the risk to a tolerable level.

3.1.19**rupture monitoring**

Form of pipeline leak detection that is intended to swiftly detect the occurrence of a rupture.

NOTE What constitutes a rupture is determined on a pipeline-by-pipeline basis and is defined by an operator.

3.1.20**sensitive area**

Specific locales and areas, not limited to HCAs or USAs, in or by the pipeline ROW where a leak may have significant adverse consequences to any or all nearby people, the environment, and community assets.

NOTE See 49 *CFR* Part 195 for definition and description of HCAs and USAs

3.1.21**static leak volume**

Amount of hazardous liquid that is leaked after the shutdown of the pipeline (or other appropriate operational response if applicable) is initiated.

NOTE This is also known as drain-down volume.

3.1.22**tuning**

Process where the function of the leak detection technique is adjusted for more precise functioning.

3.2 Acronyms and Abbreviations

For the purpose of this standard, the following abbreviated terms apply.

CMMS	computerized maintenance management system
CPM	computational pipeline monitoring
CRM	control room management
DOT	Department of Transportation
FAQ	frequently asked question
FMEA	Failure Mode Effects Analysis
HCA	high-consequence area
IMP	integrity management program
KPI	key performance indicator
LDP	leak detection program
LDS	leak detection system
LOC	loss of containment
MMS	maintenance management system
MOC	management of change
OJT	on-the-job training
PHMSA	U.S. DOT Pipeline and Hazardous Materials Safety Administration



PSDTS	Pipeline Strategic Data Tracking System
RACI	Responsible, Accountable, Consulted, Informed
RAM	Reliability, Availability, and Maintainability
RCM	Reliability-Centered Maintenance
ROW	right of way
RP	recommended practice
SME	subject matter expert
USA	unusually sensitive areas

4 Leak Detection Program

The operator shall develop and implement a leak detection program. The LDP shall be documented, and that documentation should cover all aspects of the LDP, define the goals of the LDP, and outline how the LDP will meet those goals. This document should be viewed as a listing of best practices to be employed when planning, selecting, designing, analyzing, implementing, maintaining, and empowering a culture within an operator's pipeline Leak Detection Program (LDP). While this document addresses hazardous liquid pipelines regulated under 49 CFR Part 195, the philosophy may be applied to non-regulated pipelines as well. In adopting this RP, operators should progressively implement changes and establish a timeline for the associated work. Pipeline leak detection should be managed by structuring the various elements of leak detection into an LDP. An LDP should promote a strong leak detection culture, which is critical in managing the human component of an LDP.

4.1 Details of the Elements of the Leak Detection Program

The elements of a leak detection program can include:

- a) Management commitment and leadership. A written document should clearly show management is engaged and has a commitment to a comprehensive LDP. Management should demonstrate its commitment through resources allocation, visibility, and leadership. Management should review and endorse a periodic report on the LDP. This is discussed in detail in Section 5.
- b) Operator's requirements and goals. Overall or broad goals for the LDP should be established and endorsed by management. The operator should require that dependent and interrelated functions within the organization are sharing information and working as a team to achieve the goals. The operator should ensure there is a clear connection between goals and day-to-day work activities. Management may set targets for performance aspects of the LDP. The strategy may set limits for non-leak alarms so the confidence in the LDS is not eroded by too many alarms. The strategy may specify a worst-case leak from a corporate point of view that may not be a rupture or large leak volume, or a target may specify an improvement in the leak detection performance metrics (for examples: an annual reduction in detection alarm thresholds by x % or improvement in localization, accuracy, and/or time to detect). The strategy may note what the operator wants to achieve in the future.
- c) How requirements and goals may be satisfied. The selection of LDSs chosen for the LDP shall cover regulatory requirements and should cover operator requirements and goals. The LDSs should be implemented and maintained so the users have confidence in leak alarms. The strategy should always emphasize the adherence to approved procedures and processes. The operator should use the overall operating experience of their pipelines, and of their individual pipelines to maximize the capability of the LDP. In some cases, the strategy may outline types of equipment that may be used with the LDSs (e.g. types of meters). The LDP should include continued awareness of developing technologies and the output of industry led initiatives to validate new technologies and approaches.
- d) Employing risk management. The framework of the LDP shall be based on a detailed risk assessment. The assessment should cover the leak detection required performance and reduction in risk level provided by an LDP. The LDP may work with the integrity management program (IMP) to ensure factors related to leak

detection are in the risk assessments for each pipeline. Aspects of the LDP (e.g. selection of LDSs) may be dependent on the acceptable risk that the operator is willing to assume. Risk assessment may be used to change the level of application of the LDSs based on short-term increased risks. A primary criterion within an operator's risk management program is LDP performance. Also to be evaluated are mitigating factors such as the operational response and emergency response in the event of a leak along the pipeline.

- e) Selection of LDSs. The leak detection strategy document should cover all aspects of pipeline operations that affect the LDSs and the principles, methods, and techniques that are or will be used. The selection may focus on proven and industry common LDSs. Some aspects of leak detection are prescribed in regulations (i.e. visual surveillance and landowner awareness); however, the detailed application of these LDSs should be determined by each operator. The leak detection strategy document should address leak detection requirements during design of new or significant changes to existing pipelines. The selection should outline why particular LDSs are chosen. The operator may implement multiple LDSs that complement one another. The focus of selection should be on methods that provide continuous leak detection. Selection should cover issues such as increased risk in some areas, using industry best practices, employing LDSs that may be tested and may have well defined KPIs or because no other LDS is possible. Selection should establish performance expectations that may be used for benchmarks for ongoing testing.
- f) Integration of all forms of leak detection employed. Whenever possible, the outputs of all LDSs that are employed should be integrated. All LDSs should be coordinated so they support the goal of detecting leaks on the pipeline.
- g) Regulatory requirements and industry standards. The strategy should list or refer to a list of regulatory references and any industry standards that apply to the LDP. The strategy document should outline how these regulatory and industry standards are applied and perhaps which parts do not apply and why.
- h) Ongoing measurement of performance of the LDP. The overall LDP performance should be evaluated annually, not to exceed 18 months. The LDP document should emphasize the importance of having methods to measure performance using measurable KPIs.
- i) Reporting. Reports to levels of management may be on a periodic basis but there should be a periodic report on the LDP to management, not to exceed 18 months. Changes based on these reports should be passed to an improvement process.
- j) Training, testing, and operations/procedures. The strategy should make a commitment to rigorous training of employees and appropriate level of training for other stakeholders. A training program should be developed to not only train employees and stakeholder in the technical aspects of their work, but also their roles and responsibilities as a part of the leak detection team. The strategy should outline a requirement for testing of the LDSs or evaluation of LDSs to ensure that design performance is maintained. The strategy shall outline the requirements for procedures and the application of procedures during operation.
- k) Review and approvals. The operator should periodically review their LDP to ensure it is up-to-date. The LDP should be modified as needed and reaffirmed with management of the operator.
- l) Management of change. The strategy shall outline the requirements for management of change because operation of the LDP involves many functional areas of pipeline operation. Subtle operational or equipment changes may have an adverse direct impact on leak detection unless they are tightly controlled and managed.
- m) Ongoing improvement of the LDP. Continual improvement requirements in the LDP should be outlined in the strategy. The LDS should indicate the importance of and support for an improvement process to address gaps if the targets are not met and to accommodate changes to regulations, pipeline operations, assets, stakeholder expectations, and overall improvement of the LDP. The operator may indicate a goal of improvement by, for example, evaluating industry best practices and lessons learned. Improvements should help move toward training improvement and strengthening of the culture. The strategy may indicate the desire to evaluate new technologies and the output of industry led initiatives to validate new technologies or be involved in leak detection R&D to improve the leak detection capabilities.

Figure 1 provides a flowchart outline of the LDP management process. It shows the aspects of LDP management that are outlined in this RP and the relationship of the various aspects. This figure represents the process for most operators, but it is not intended that the aspects shown are followed explicitly.

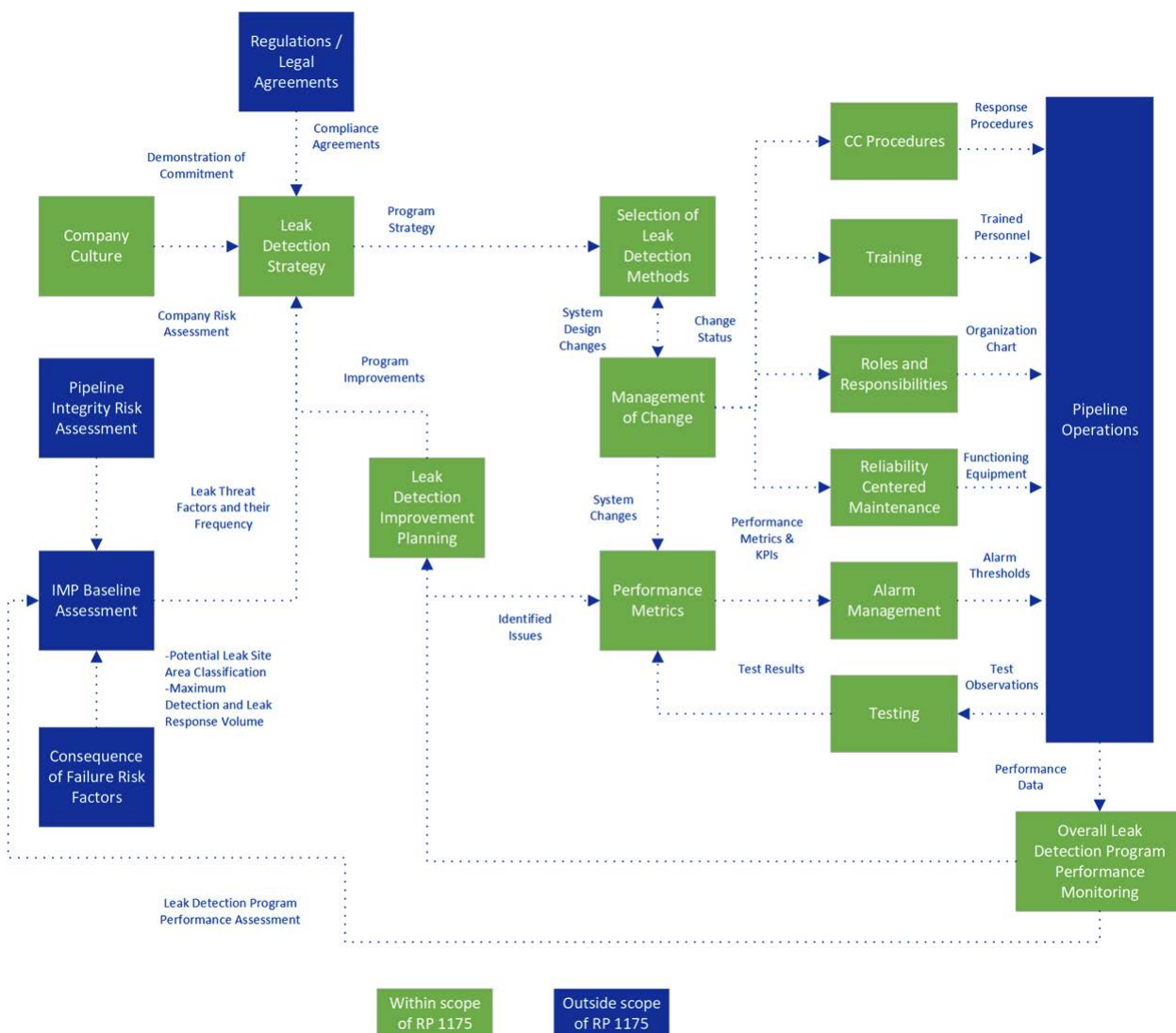


Figure 1—Leak Detection Program Flow Diagram

5 Management Commitment and Leadership

5.1 General

Top management shall establish goals and objectives for an operator's leak detection program. The objectives shall be measurable and consistent with overall leak detection policies. Top management shall also create a culture within the organization that encourages openness and two-way dialog so learnings from incidents and events can ultimately reduce the risk of recurrence. The health of this culture should be assessed, and leadership commitment needs to be visible to address areas of concern and opportunity.

5.1.1 Responsibilities of Leadership

Operators should consult Sections 5.4, 5.5, and 5.6 of API RP 1173, First Edition, for guidance on leak detection.

5.2 Leak Detection Culture

Operators should develop a strong leak detection culture. An LDP includes not only the technology, but the people involved in applying the technology. Improving an organization's culture moves its people from thinking about safety and integrity to practicing safety and integrity.

Leak detection culture is visible by the level of commitment of employees, particularly an organization's management.

Leak detection is an integrating discipline that relies on major functions of an organization working together to be successful. A strong leak detection culture that promotes prompt and appropriate actions throughout the organization's hierarchy is essential to the success of a leak detection program.

5.2.1 Culture Indicators

The following are examples of behaviors which indicate a strong leak detection culture:

- Ongoing support toward continuously improving pipeline leak detection, even if the operator is meeting current leak detection goals.
- Coordination and collaboration between the different entities involved in the LDP.
- Ongoing training of relevant staff regarding how each person supports the leak detection program.

NOTE API RP 1168 describes control room management practices, including training for controllers.

- A focus on safe and reliable operation of the pipeline with no negative repercussions on the staff who take actions in response to leak indications. This includes:
 - Shutdown when there is a leak indication. When in doubt, shut down and then assess;
 - Policies and training on Stop-Work-Authority (SWA) or Stop-Work-Responsibility (SWR).

6 Stakeholder Engagement

6.1 General

Stakeholder engagement plans should be developed using the guidance in API RP 1173.

Stakeholder engagement plans should include information on leak detection and its relevance to particular stakeholder audiences.

7 Risk Assessment

7.1 General

The LDP strategy should be driven by the results of a risk assessment. An example of a risk assessment is included in Annex A.

7.2 Risk Assessment Factors

The risk assessment should be developed with consideration of the pipeline's integrity management program (IMP) to ensure that factors included in the IMP are built into the leak detection risk assessment. All aspects of the LDP, including selection of LDSs, is dependent on the acceptable risk that the operator is willing to assume.

Refer to API RP 1160 for further information on integrity risk assessments.

The risk assessment should evaluate the existing operational LDP elements as they relate to mitigating the consequences of a leak. Integrity management activities should be evaluated along with the pipeline segment's characteristics to determine the likelihood and consequence of a failure occurring. The risks associated with LOC differ for various pipelines, hazardous liquids being transported, and their location. A specific risk analysis and evaluation may be performed for LDSs on each individual pipeline system or segment; typically called a leak detection capability evaluation.

7.2.1 LOC Risk Factors

Elements for inclusion in the risk assessment pertaining to the probability and consequence of an LOC include:

- Review of the IMP, particularly the integrity risk assessment results:
 - IMP risk reduction initiatives.
- Review of the existing pipeline infrastructure, possibly including:
 - age of pipe,
 - history of pipe,
 - operating pressure-to-hydro test ratio (i.e. the safety margin),
 - diameter,
 - length,
 - size,
 - type of hazardous liquid carried,
 - pipeline profile,
 - high-consequence areas,
 - ignition sources,
 - specific terrain between the pipeline and the high-consequence area.
- Review of known leaks and their causes,
- Isolation capability (pumps, number of valves, and the types and their locations).
- Emergency response/leak response capability, including nearest locations of response personnel and time to respond.
- Environmental factors.
- Other considerations.

Risk assessments may be used to change the application and tolerances of LDSs based on short-term increased risks, which can include, for example, nearby construction, natural hazards, or operational changes. The risk assessment should evaluate mitigating factors such as the operational response and emergency response in the event of a leak along the pipeline.

A risk-based approach should be applied to the evaluation of an operator's LDP and should list factors fundamental to the selection process. Since the risk-based approach should evaluate overall risk, consequences, and likelihoods, the operator may look at all three of these items during the selection process.

7.2.2 Factors Affecting Risk Mitigation

Some mitigation factors are within the scope of a leak detection program and should be included in the risk assessment. These factors can include:

- Leak detection capability of the existing LDSs:
 - performance metrics: reliability, sensitivity, robustness, and accuracy;
 - KPIs and evaluations of the LDSs;
 - primary, complementary, alternative LDSs in place and their coverage.
- Leak detection capability of the existing LDP:
 - strength of the leak detection culture;
 - strength and completeness of the strategy.

7.3 Risk Tolerance

Selection of leak detection strategy for each pipeline or pipeline segment should consider the practicality of implementing the strategy in relation to the risk mitigation benefit. The risk level for a pipeline or pipeline segment can be scored with a qualitative or quantitative risk assessment. The LDP shall be appropriate for the level of risk assessed.

The risk score for various pipelines or pipe segments may influence the selection and application of LDSs within operator's leak detection strategy. An example is shown in Annex G.

8 Selection of Leak Detection Methods

8.1 Selection Process Overview

LDSs are implemented to provide early notification of loss of containment (LOC), so action may be taken to mitigate the consequence of the leak. An LDS is intended to decrease the spill volume by shortening the time required to detect a leak within its detectable range and assisting in identifying the leak location. Once a leak is detected, an operator can initiate actions to manage the leak.

This section is intended to help operators select which LDSs and associated leak detection principles, methods, and techniques to include in their LDP. This selection process may be used for the selection of new applications, to add additional LDSs, or to re-examine existing LDSs.

The selection of LDSs, leak detection principles, methods, and techniques are a multifaceted, multi-step, iterative process that may include the following elements:

- performing a risk assessment (see Section 7 for further details);
- considering the LDS selection to cover particular constraints of individual pipelines and individual threats;
- evaluating gaps in the LDS for operating modes;
- incorporating regulatory requirements;

- evaluating industry knowledge;
- integrating the operator's requirements;
- aligning the selection with the operator's leak detection culture and strategy;
- evaluating the available technology for leak detection;
- linking the operator's performance metrics, KPIs, and targets;
- considering primary, complementary, and perhaps alternative LDSs.

If an LDP is already in place, this selection process may be applied to validate the selection. The selection process should be documented.

8.2 Incorporating Regulatory Requirements

In the U.S., the primary regulatory requirements for liquids pipelines are outlined in 49 *CFR* Part 195. In Canada, the primary standard for liquids pipelines are outlined in CSA Z662.

8.3 Evaluating Industry Knowledge

There are several related RPs, standards, and publications related to leak detection. Those necessary to implement this RP are noted in Section 2. Sources of additional information that may be useful are listed in the bibliography. Additional research in leak detection is ongoing and continual improvements to an LDP should incorporate improved technologies and methodologies following a review approved by the operator.

8.4 Integrating Operator Requirements

In addition to ensuring LDSs satisfy all regulatory requirements, an operator should identify LDSs which meets their own internal requirements. While it is typical for larger operators to have additional internal requirements, it is not intended to imply that every operator needs to have their own set of requirements. The decision whether to evaluate LDSs against operator requirements resides solely with each operator and should be a needs-based decision driven by the results of their risk assessment. These requirements, where applicable, can be as specific or general as an operator chooses and can be based on functionality (i.e. the presence of a user interface or leak location capability), methodology (i.e. using a specific detection technique), historical experience (i.e. a system or technique an operator is familiar with), or some other criterion the operator deems vital to their selection process. Due to the list of potential requirements being as varied as the principles, methods, and techniques available, this section cannot provide an all-encompassing list, nor can it recommend elevating one requirement over another.

8.5 Leak Detection Strategy Requirements

The leak detection strategy may be satisfied in part by selection of leak detection systems (LDSs) that best fit the requirements of the strategy. The strategy may for example set several goals and targets. These should be understood and accommodated during the process of selecting LDSs. For example, the strategy may require primary and complementary LDSs.

The leak detection design and selection aspects should be aligned with the operator's KPIs (which are discussed in Section 15). The overall goal of a pipeline leak detection strategy is to provide the resources required to positively identify an LOC from a hazardous liquid pipeline within a time period that is commensurate with the associated level of risk. These resources should encompass the technology, processes, and trained personnel to monitor the pipelines to ensure indications supporting a possible LOC are rapidly acknowledged and acted on.

The operator may implement complementary and alternative LDSs as a part of the LDP. The main LDS may be called the primary LDS by the operator. However, the designation "primary LDS" is not simply defined. An LDS that is primary during operation may not be primary on a shut-in pipeline when another LDS may be more reliable.

Most often, a continuous method is chosen as a primary. On many pipelines, a CPM technique is commonly the primary; however, an externally based LDS may satisfy the leak detection strategy.

A complementary LDS may be continuous, use a different technique, have different metrics, and may be independent of the inputs for the primary technique. In some cases, depending on risk, more than one complementary LDS may be implemented throughout the pipeline system or just in specific segments if it is not practical to implement across the entire pipeline system.

An alternative LDS may be chosen that may be used if the primary LDS is out of service. Usually, an alternative LDS is used under closely supervised leak detection monitoring of the pipeline operation.

There may be other LDSs that are designated as redundant (i.e. have the same function as another LDS and exist so that LDP does not fail if the primary or complementary LDS fails). The redundant LDS may be running and mirroring the system to which it is redundant so fail-over is automatic; or there may be a backup LDS used to replace an LDS that fails. The backup may be made active when it is required.

Table 1 is a visual example of an LDP that shows leak size classifications, the LDS that may be used for leak detection, and an unspecific factor of time to detect LOC. Information on the definition of the various leak sizes is found in API RP 1130, Annex B.

Table 1—Visualization of an Example LDP

	Leak Type	SCADA Monitoring	CPM	Public Awareness	Aerial Surveillance	In-line Inspection
Leak Rate	Rupture	a	a	a	a	N/A
	Medium Leak	b	a	a	a	a
	Small Leak	c	b	b	a	a
	Seep	c	c	b	b	a
Time-to-Detect						
^a Detection Probable ^b Detection Possible ^c Detection Improbable						

8.6 List and Classification of LDSs

The LDSs that may be used to detect leaks cover a wide spectrum of techniques, principles, and methods. The techniques vary from surveillance to hydrocarbon sensors to real-time monitoring software. The principles employed may be externally or internally based. The methods may be continuous or non-continuous.

- non-continuous, externally based;
- non-continuous, internally based;
- continuous, externally based;
- continuous, internally based.

Table 2 provides an example list of the above-mentioned techniques and categorizes them. Table 2 is not intended to be a comprehensive list of leak detection techniques.

Each practical LDS has its strengths and weaknesses that are dependent on the characteristics of the LDS, the specific application, the leak detection technique, its maturity, and the complexity of the pipeline to which the LDS is applied. In combination with processes or procedures, applying the appropriately selected LDSs is the key to effective pipeline LDP.

It is important to note the following when investigating the various techniques for leak detection:

- additional instrumentation may need to be added to the pipeline to support a particular technique.
- additional maintenance, support, and testing may be required for some techniques.
- some existing techniques may be enhanced. For example, the visual aspect of surveillance may be enhanced by the addition of infrared sensors.

Not all the techniques listed in Table 2 are proven; some are still being evaluated for practicability in industry. Practical techniques are readily available, potentially operator deployed, and possess some form of adequate field-based installation. This list is not intended to be all inclusive; new techniques for leak detection are continuously under development by industry.

Table 2—Example LDS Techniques

	Externally Based		Internally Based	
	Physical Inspection	Sensor-Based Monitoring	Manual Observations	Computational Pipeline Monitoring
Non-continuous	Aerial Surveillance	Ground-Penetrating Radar	Volume or Line Balance Calculations	—
	Ground-Based Line Surveillance	Sniffer Tubes	Hydraulic Calculations	—
	Hydro Testing	Tracer Chemicals	—	—
	Satellite	Intelligent Pigs	Shut-in Testing/Stand-up Testing	—
	One Call System/ Public Awareness	Soil Sampling	—	—
	—	Sensing Cables	controller SCADA Monitoring	Conservation of Mass
Continuous	—	Acoustic Sensors	—	Pressure Monitoring
	—	Cameras	—	Line Balance
	—	Chemical Analyzers	—	Acoustic Negative Pressure Wave Monitoring
	—	—	—	Statistical Analysis
	—	—	—	Real-time Transient Modeling
	—	—	—	—

During LDS evaluation, it may be helpful to discuss the application and expected performance with the vendor and other users of the specific LDS. Each pipeline operation is unique, and the actual performance of the same LDS applied to different pipelines may vary significantly.

8.7 Leak Detection Technology

Applications that use sensors (or leak detectors) to directly detect a commodity release are called externally based systems. Applications that indirectly detect or infer commodity releases are called internal based systems.

8.7.1 Externally Based Leak Detection Systems

Externally based pipeline leak detection systems indicate evidence of a commodity's presence outside of the pipeline or its exiting the pipeline. In these systems, the detector may send an alarm signal to the control center for display and annunciation.

Common types of externally based systems or devices include:

- fiber optic leak detection cables.
- hydrocarbon sensing cables.
- acoustic emissions detectors.
- cameras.
- foot patrols.
- aerial inspection.
- hydrocarbon sensors (including those with vapor pick-up tubes).

8.7.2 Internally Based CPM Systems

CPM systems analyze real-time data to infer evidence of a leak and present that evidence and other calculated information for the controller to evaluate and take appropriate action. The degree of complexity in processing field data varies from simple comparisons of a parameter relative to a threshold limit to more extensive analysis of multiple parameters that may include pattern recognition, machine learning, statistical analysis, and other techniques.

Common types of internally based CPM techniques include:

- line balance methods (line balance, volume balance, modified volume balance, compensated mass balance).
- real time transient model.
- pressure/flow monitoring.
- acoustic/negative pressure wave.
- statistical analysis.

Refer to API RP 1130 for further discussion of CPM systems.

8.8 Evaluating and Selecting Suitable Technologies

After evaluation of risk, operator strategy, and regulatory requirements, the operator should develop a list of selection criteria and select LDSs. There are three key areas of inquiry: what features are needed, what performance is required, and the process of the selection criteria to evaluate a prospective LDS.

When selecting an LDS that is to be deployed in the LDP, the operator should be cognizant of its range of applicability and any potential limitations inherent to the LDS that could impact its ability to accurately detect leaks in the field. The performance should be quantified by use of metrics and related KPIs.

There are several factors related to physical environment and hazardous liquids transported that may affect the leak detection method(s) selected. These include elevation profile, major thoroughfares, spans and bridges, fluid properties, limitations of the location, meteorology, radiant heat effects, and other factors.

The selection process may also evaluate additional functionality that may be obtained from LDS systems, such as the using fiber optic cable to support telemetry for pipeline communications, public address, and general alarm (PAGA) systems, closed-circuit television (CCTV), and private automatic branch exchange (PABX).

When designing an LDP, operators should maintain an overall system view and recognize that each component works with the others to provide the desired performance. Different components play different roles in mitigating the overall consequences of a release. Table 1 shows an example of different categories of LDSs defined by their relative time-to-detect.

The choice of an LDS(s) may be impacted by pipeline characteristics such as:

- non-regulated pipelines;
- pipelines that do not or cannot have all the required instrumentation;
- pipelines that pose challenges for effective leak detection, such as those operating with two-phase or multiphase flow;
- pipelines with a history of small (seepage) leaks;
- pipelines with a history of ruptures;
- pipelines with unique operating histories that characterize significant operational challenges.

As part of the evaluation process, operators may conduct pilot programs or have trial periods of a leak detection technology to ensure any additional leak detection system performs as intended prior to relying on it for leak indications. Operators should have a process to document which technologies or processes are in the R&D stage/pilot program. Operators should document when a new technology or process has become a formal part of a leak detection program and should follow internal training and MOC processes before controllers are expected to respond to leak indications.

8.9 Modifying Selection for Particular Requirements of Individual Pipelines or Pipeline Segments

LDSs are engineered systems, meaning that the same LDS applied to multiple pipelines may have different results or the LDS may not perform as well on some pipelines. Perhaps an additional LDS or modification to the LDS may be needed to accommodate leak detection on other pipelines or pipeline segments; or perhaps installation of additional instrumentation or changes to operation may be required.

8.10 Periodic Review of Selection

The operator may periodically evaluate the selection of LDSs to ensure they are meeting the requirements of the leak detection strategy. Possible reasons for the review may be:

- population or environmental changes that may have occurred around the pipeline,
- when technology or operating conditions warrant, or
- the periodic review may be performed on a timed cycle.

One potential approach to a timed cycle is to review the leak detection requirements based on a five-year cycle, similar to a baseline IMP. The review would look at the items outlined in regulation and use a team of leak detection and risk experts who would use a risk matrix or other ranking process. In particular, the team may look at SAs, leak detection alarms, and any other performance-related information. The purpose is to keep the LDP current with this information. The selection process outlined may then be re-applied to the new conditions.

Improvements or other changes to LDSs or the LDP may be triggered by new circumstances such as:

- program modified by field experience;
- application updates;

- availability of new LDSs or extensions, to be evaluated by selection criteria;
- technology review cycle;
- IMP evaluation review;
- re-evaluation of the leak detection methods based on an established cycle;
- new pipelines have been built or acquired;
- pipeline service is changed or there are significant instrumentation or measurement changes;
- change of regulatory requirements;
- leak detection strategy change;
- a requirement for enhanced leak detection.

9 Performance Targets, Metrics, and KPIs

9.1 General

Hazardous liquid operators should establish performance targets for their LDSs and define and track KPIs to ensure the performance targets are met. Typically, these performance targets are set as part of the operator's leak detection strategy, and the leak detection selection process attempts to select and implement the LDSs that will meet these targets.

In this RP, the terms "metric" and "KPI" are closely related. The metrics (e.g. reliability) are quantified by the KPIs (e.g. number of non-leak alarms) of the metric. KPIs and their targets should be specific and measurable quantities designed and implemented to facilitate the attainment of desirable overarching goals of an operator's LDP. These metrics are defined as sensitivity, reliability, accuracy, and robustness which are described below. These KPIs are quantified by the operator. The leak detection vendor may assist as well.

Performance targets and KPIs may exist at the LDP level for a specific LDS and for a specific instance of the LDS, i.e. its implementation on a particular pipeline or pipeline segment. The operator's performance monitoring of an overall LDP is discussed in Section 15 and covers KPIs at the program level.

Determination of the leak detection KPIs and performance targets are predicated by the goals of the operator's leak detection strategy.

The KPIs and performance targets in turn influence the selection of LDSs, both in terms of which LDSs are available in the LDP and which LDS or strategy is applied to specific assets. The leak detection targets are refined by the LDP's continual improvement process and by performance monitoring. The leak detection metrics and associated KPIs are designed to verify that performance targets are being met and to provide diagnostic information if they are not. The KPIs should be analyzed statistically to deduce appropriate performance targets.

An independent third party may be used to evaluate the LDS and management of KPIs.

9.2 Performance Metrics and Key Performance Indicators

9.2.1 Goal and Targets

Performance metrics and KPIs should be defined, computed, and tracked to establish that leak detection goals are being met. The corresponding performance targets are then refined and revised as part of the continual improvement process. KPIs should be designed to allow the operator to gauge the degree to which the goals are being met. The availability of KPIs should be evaluated when deciding on the leak detection goals. Goals that