

Computational Pipeline Monitoring for Liquids

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Computational Pipeline Monitoring for Liquids

1 Scope

This recommended practice (RP) focuses on the design, implementation, testing, and operation of CPM systems that use an algorithmic approach to detect hydraulic anomalies in liquid pipelines. The primary purpose of these systems is to provide tools that assist Pipeline Controllers in detecting commodity releases that are within the sensitivity of an algorithm. It is intended that the CPM system provide an alarm and display other related data to the Pipeline Controllers to aid in decision-making. The Pipeline Controllers would undertake an immediate investigation, confirm the reason for the alarm and initiate an operational response to the hydraulic anomaly when the alarm represents an irregular operating condition or abnormal operating condition or a commodity release.

The purpose of this recommended practice is to assist the Pipeline Operator in identifying issues relevant to the design, implementation, testing, and operation of a CPM system. This RP is intended for pipeline controllers and operators, CPM system developers and engineers, and others interested in CPM system design, implementation, and operation.

This RP includes definitions, source and reference documents, concepts of data acquisition, discussion of design and operation of a pipeline as related to CPM, field instrumentation for CPM purposes, alarm credibility, Pipeline Controller response, incident analysis, records retention, maintenance, system testing, training, considerations for setting alarm limits, trending, and recommendations for data presentation. The relationship between the Pipeline Controller and the CPM system is also discussed.

This recommended practice is written for liquid onshore or offshore trunkline systems. CPM systems have typically been applied to steel pipeline systems. CPM applicability and performance may be limited by the characteristics of non-steel pipelines.

This recommended practice was written considering single phase, liquid pipelines. Many of the principles apply to liquid pipelines in intermittent slack line flow or liquid pipelines that may have permanent slack line flow. This RP may not apply to the special case of determining leaks during shut-in conditions that occur when the line is shutdown (sometimes called static conditions) unless shut-in leak detection is part of the deployed CPM solution.

It is recognized that no single CPM methodology or technology is suitable for all pipelines because each pipeline system is unique in design and operation.

This recommended practice complements but does not replace other procedures for monitoring the integrity of the line. CPM systems are one part of an operator's leak detection program. For further information on leak detection programs, see API RP 1175.

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 RP 551, *Process Measurement Instrumentation*

API TR 1149, *Pipeline Variable Uncertainties and Their Effects on Leak Detectability*

API RP 1175, *Pipeline Leak Detection—Program Management*

Code of Federal Regulations, 49 CFR Part 195, *Transportation of Hazardous Liquids by Pipeline*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

abnormal operating condition

A condition identified by the Operator that may indicate a malfunction of a component or deviation from normal operations that may:

- a) Indicate a condition exceeding design limits; or
- b) Result in a hazard(s) to persons, property, or the environment.

3.1.2

accumulator data

A SCADA data value that represents an accumulated quantity, usually volume in liquid pipeline service.

3.1.3

accumulator freeze

A feature of some SCADA protocols that allow all volumetric data to be captured at virtually the same time.

3.1.4

alarm

A visible and/or audible means of indicating to the controller an equipment malfunction, an analog or accumulation process deviation, or other condition requiring a controller's response.

3.1.5

alert algorithm

A part of a CPM system that evaluates the inferred measurements, compares against the thresholds, and issues a CPM alarm.

3.1.6

analog data

A SCADA data value that represents some measured quantity, such as temperature or pressure.

3.1.7

analog deadband

A parameter that defines the increment of change in a value that is significant.

NOTE See 5.2.3 for further information.

3.1.8

calibration

For this document, the activities in which instrumentation and measurement are proved.

3.1.9

communication failure

An interrupt in data exchange between the CPM system and the RTU, PLC, or Flow Computer.

3.1.10

commodity release

leak

An unintended loss of fluid from the pipeline.

3.1.11**computational pipeline monitoring
CPM**

An algorithmic monitoring tool that alerts the Pipeline Controller to respond to a detectable pipeline hydraulic anomaly (perhaps both while the pipeline is operating or shut-in) which may be indicative of a commodity release and includes an Inference Engine and an Alert Algorithm.

3.1.12**conservation of mass**

The principle as applied to liquid flow in pipelines, that states that the time rate of mass inflow to a pipe segment minus the time rate of mass outflow equals the time rate of mass increase (decrease is considered as a negative increase) in the pipe segment.

3.1.13**data archiving**

A SCADA system feature that records data in an historical database under some pre-defined data management process.

3.1.14**data quality**

A SCADA system feature that creates status bits that are attached to reflect the validity of process data.

3.1.15**drag reduction agent****DRA**

An additive used in liquid pipelines to reduce friction loss.

3.1.16**event log**

A SCADA system feature that creates a permanent record of changes to the pipeline and the system's state in chronological order.

3.1.17**false alarm**

A commodity release alarm which, after investigation, was not caused by an actual commodity release.

3.1.18**filter**

A device or algorithm to remove unwanted components from a process signal. Also called signal conditioning.

3.1.19**fluid properties**

The characteristics of the fluid that describe its hydraulic behavior including density; viscosity, compressibility (or bulk modulus); coefficient of thermal expansion; thermal capacity.

3.1.20**historical data**

Data that have been retained for later retrieval, typically maintained by a SCADA system's data archival subsystem.

3.1.21**hydraulic anomaly**

An irregular operating condition on the pipeline or abnormal operating condition that is explainable through the systems hydraulics.

3.1.22**inference engine**

A part of the CPM system that accumulates data, performs calculation, and provides outputs to the alert algorithm.

NOTE Additional description is offered in Annex B.

3.1.23

irregular operating condition

An infrequent event during which the pipeline may be operated in a way that is not normal and may require re-tuning the CPM.

3.1.24

leak declaration

The declaration that is made if a Pipeline Controller has reasons to suspect that a commodity release is occurring on the pipeline.

3.1.25

line balance

Comparison of the measured volume or mass entering the system to the measured volume or mass exiting the system or meter-to-meter reading comparison using conservation principles.

NOTE 1 Certain types of line balance are commonly referred to as mass balance or material balance.

NOTE 2 Additional description is offered in Annex B.

3.1.26

manual data override

When manual entries are input in lieu of actual field data values.

3.1.27

negative pressure wave CPM

A CPM system that senses the pressure wave signal that occurs when the pipe wall is compromised and the product escapes through the hole in the pipe.

3.1.28

noise

An unwanted component in a process signal.

3.1.29

pipeline controller controller

A person who is responsible for the monitoring or monitoring and direct control of a pipeline.

3.1.30

pressure/flow monitoring CPM

A CPM system which examines the relationship between pressure and or flow changes and applies an algorithm to determine if they indicate an anomaly.

NOTE Additional description is offered in Annex B.

3.1.31

protocol

The specifications of the message structure between RTU or PLC and Control Center Computer are collectively referred to as the communications protocol.

3.1.32

rate of change ROC

A calculated value that reflects the change in an analog data value per unit time.

3.1.33**real time transient model (RTTM) CPM**

A CPM system which monitors instrument data and physical characteristics of the pipeline and fluids transported, then employs hydraulic calculations to determine the in/out balance, inventory, and instantaneous flow or pressure in segments of the pipeline, or both.

NOTE Additional description is offered in Annex B.

3.1.34**return to normal**

The transition from alarm to normal state that signifies that an alarm condition has ended.

3.1.35**remote terminal unit****RTU**

A SCADA system component, typically installed at a field site, that gathers process data from sensors for transmission to the Control Center Computer.

3.1.36**report-by-exception**

A feature of some SCADA communication protocols that intends to improve communication efficiency by reporting only the data that has changed since the previous poll.

3.1.37**supervisory control and data acquisition****SCADA**

The technology that makes it possible to remotely monitor and control pipeline facilities.

3.1.38**scan time**

The time interval between two consecutive polls to Data Acquisition Devices on a SCADA communication channel.

3.1.39**segments**

A shorter part of a pipeline section often bounded by instrumentation or other physical features of the pipeline.

3.1.40**sensitivity**

A composite measure of the size of a leak that a CPM system is capable of detecting and the time required for the system to issue an alarm in the event that a commodity release of that size should occur.

NOTE This term is fully defined and discussed in Annex C.

3.1.41**shut-in**

The pipeline hydraulic condition that exists when fluid is not entering or leaving the pipe but may be contained within.

3.1.42**single phase**

A fluid state, either liquid or gaseous, based upon commodity, vapor pressure, pipeline pressure and temperature.

3.1.43**slack line**

The condition where a pipeline segment is not entirely filled with liquid or is partly void. May also be called column separation.

3.1.44**statistical analysis CPM**

A mathematical method of handling the CPM related instrument outputs from the pipeline. Statistical analysis CPM systems can use either Conservation of Mass techniques or Signature Recognition techniques or both techniques.

NOTE Additional description is offered in Annex B.

3.1.45**status data**

A SCADA data value that represents the operational state of an item of field equipment.

3.1.46**steady state conditions**

The pipeline hydraulic condition that exists when all the pipeline operating parameters remain nearly constant over a period.

3.1.47**system**

An entire entity such as a complete pipeline. Segments are a subset of a system.

3.1.48**threshold**

An upper or lower established value for a parameter which may be fixed or dynamic.

3.1.49**time skew**

The variation in reporting times from one Data Acquisition Devices to another in a polled SCADA communications protocol.

3.1.50**time tag**

A SCADA system feature that records the time that a measurement or event occurs along with the data.

3.1.51**transient conditions****transient**

The pipeline hydraulic condition that exists when pipeline operating parameters change meaningfully over a period.

3.2 Abbreviations and Acronyms

For the purposes of this document, the following abbreviations and acronyms apply.

CPM	Computational Pipeline Monitoring
DRA	Drag Reduction Agent
PLC	Programmable Logic Controllers
ROC	Rate of Change
RTTM	Real-time Transient Model
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition

4 Technical Overview

This section discusses the generic types of CPM technologies and applications, provides a list of desirable CPM features, and mentions important issues concerning the fluids transported.

4.1 Selection Consideration

Each CPM methodology contains different combinations of features with varying degrees of capability and sophistication. Under appropriate circumstances, commodity release detection can benefit by employing multiple CPM techniques or applications for validation or redundancy. The independence of techniques used in some methodologies potentially allows for independent validation or redundancy.

CPM systems are installed to detect pipeline leaks. Before installing a CPM system, the following should be considered:

- instrumentation capabilities
- communications reliability
- pipeline operating condition
- pipeline physical constraints and characteristics
- product type
- commodity fluid/thermodynamic properties
- technical maturity level

4.2 CPM System Features

The following is a list of desirable CPM features and functionalities that improve performance or add utility, or both.

The CPM features listed below are not in any order nor is there any attempt to weight the importance of each. No one methodology or application possesses all these features and certain features may be more appropriate for specific pipeline systems.

The CPM system may:

- Be able to perform its CPM functions with existing sensors and instruments (or does not have special or additional requirements for instrumentation).
- Be minimally impacted by communication outages or by data failures, however, provide alarming based on a degraded mode of operation and during an abnormal operating condition (see 6.1.1).
- Accommodate complex operating conditions and be configurable to complex pipeline networks.
- Be available and reliable during transients.
- Perform an imbalance calculation on meters over a configurable set of time constants.
- Possess dynamic alarm thresholds.
- Possess dynamic liquid pack.

- Accommodate commodity blending.
- Account for heat transfer.
- Provide the pipeline system's real time hydraulic pressure profile, recognizing MAOP and elevation violations.
- Be able to handle slack line conditions.
- Be available during shut-ins
- Accommodate all liquid hydrocarbons.
- Can identify the location of a release.
- Can display pressure trends.
- Allow provisions to substitute manual override to specific status or values during periods when input data may be unavailable (e.g. communication outage, measurement failure, maintenance, etc.).
- Provide data attributes associated with supporting field inputs and calculated data.
- Identify the leak rate.
- Accommodate commodity measurement and inventory compensation for various correction factors (temperature, pressure, density, meter factor).
- Provide batch tracking including interface and anomaly markers. Compute bulk modulus and perform inventory compensation.
- Validate commodity release alarms using redundant analysis within the same method or redundant analysis between methods, or both.
- Account for effects of drag reducing additive.
- Provide the necessary documentation and training to support self-guided navigation, maintenance, alarm definition, and theory of operation.
- Vendor-provided technical support
- Provide tools to support a controller's decision-making.
- Provide an interface to allow alarming of a stand-alone CPM application to be integrated into the Pipeline Controller's primary alarm processing system.
- Provide audit trails of CPM actions taken by Pipeline Controllers and system developers.
- Allows self-testing without affecting performance while the test is underway.
- Allows for system health monitoring.

Different CPM systems have different features, not all of which are listed here. Operators are advised to do research and compare systems based on their needs.

4.2.1 Performance Metrics

Selection of a CPM system for a given pipeline involves evaluation of the required and expected (or estimated) performance of the system. Other aspects such as commercial considerations (e.g. use of a common system)