



AMERICAN PETROLEUM INSTITUTE

API Technical Report 1149

Pipeline Variable Uncertainties and Their Effects on Leak Detectability

SECOND EDITION | SEPTEMBER 2015 | 160 PAGES | \$165.00 | PRODUCT NO. D11492

This document describes procedures for predicting uncertainties in the detection of leaks in pipelines using computational methods based upon physical hydraulic state measurements. This class of pipeline leak detection methods is commonly called computational pipeline monitoring (CPM). A large number of factors are known to contribute to the effectiveness of CPM and it is essential to understand the uncertainty in the prediction made by the CPM algorithm in use regarding the existence, or absence of leaks.

Generally, CPM methods take physical measurements from a pipeline as an input, and calculate a metric that is used to assess whether a leak is likely to have occurred. The uncertainty in the CPM method is a fundamentally statistical measure of how likely an alarm is to be valid; equivalently, how often an alarm may be due to routine operational conditions or lie within the realm of known input uncertainty.

For ordering information:

Online: www.api.org/pubs

Phone: 1-800-854-7179
(Toll-free in the U.S. and Canada)

(+1) 303-397-7056
(Local and International)

Fax: (+1) 303-397-2740

API members receive a 30% discount where applicable.

Contents

Page

1	Scope	1
2	Normative References	1
3	Terms, Definitions, Acronyms, Abbreviations, and Symbols	1
3.1	Terms and Definitions	1
3.2	Acronyms, Abbreviations, and Symbols	2
4	Background	4
4.1	General	4
4.2	Prediction vs. Evaluation	6
4.3	Performance Factors vs. Uncertainty	6
5	Engineering Summary	7
5.1	General	7
5.2	Process	9
6	Procedure	11
6.1	General	11
6.2	Uncertainty Framework/Measurement Model	12
6.3	The Reference Model (RM)	22
6.4	Metrics	26
6.5	Rate of False Alarms and Misses	26
6.6	Filtering	28
6.7	Outputs	28
6.8	Outline of the Document	30
7	Measurement Model	30
7.1	General	30
7.2	Instrument Uncertainty	31
7.3	Summary	36
8	Uncertainties Due to the Metric	36
8.1	General	36
8.2	General Approach	38
8.3	Algorithms	43
8.4	Particular Engineering Factors	43
8.5	Other Common Sources of Uncertainty	46
8.6	Summary of Model Uncertainties	46
8.7	Leak Detection Metrics and Techniques	46
8.8	Real-Time Transient Model (RTTM)	52
8.9	Leak Location Algorithms	53
8.10	Slack Line Flow (SLF)	56
8.11	Constant Threshold	57
8.12	Two Metrics	57
8.13	Root Mean Square	58
8.14	Student <i>t</i> -test	58
8.15	Sequential Probability Ratio Test	59
9	Filtering	60
9.1	General	60
9.2	Moving Average	61
9.3	High-pass Filter	61

Contents

	Page
9.4 Outlier Removal	61
9.5 Comment on Usage.	62
10 Uncertainty Model	62
10.1 General	62
10.2 Model Details	63
11 Reference Model	68
11.1 General	68
11.2 Model.	68
11.3 Calculation of Density.	69
11.4 Friction Factor	70
11.5 Parameters and Boundary Conditions	71
11.6 Transient Treatment of Boundary Condition Uncertainties	71
11.7 Treatment of Numerical Uncertainty	71
11.8 Extrapolation to Networks	73
12 Definition of Leak Detection Techniques	73
12.1 General	73
12.2 Summary	73
12.3 Metrics	74
12.4 Comparisons	77
12.5 Location Algorithms	79
12.6 Filtering.	80
13 Rate of False Alarms and Measurement Uncertainties.	80
13.1 General	80
13.2 Rate of False Alarms.	81
13.3 Uncertainties in Metering	86
14 Case Study: Using Manufacturer Specifications and Meter Proving Reports	87
14.1 General	87
14.2 Example Flow Meter	88
14.3 Example Pressure Transducer.	91
14.4 Example Temperature Transducer	91
15 Case Study: Worked Example Uncertainty Assessment	91
15.1 General	91
15.2 Assemble Data	91
15.3 Scenario 1: Steady-State.	98
15.4 Scenario 2: Transient Startup.	102
15.5 (Original, 1993) API 1149 Estimates.	106
Annex A (informative) Technical Report Summary	109
Annex B (informative) Worked Examples	112
Acknowledgment	157
Bibliography	158

Contents

Page

Figures

1	Example Summary Tornado Diagram	11
2	Example Summary Alarm Analysis	12
3	Basic Uncertainty Framework	13
4	Non-Gaussian Distribution	13
5	Multiple Uncertainty Assessments	15
6	Distribution of Bias and Precision	16
7	Typical Uncertainty Impact, Liquids Line	18
8	Typical Uncertainty Impact, Gas Line	19
9	Typical Tornado Diagram for Telemetry Uncertainties	22
10	General Form of the Uncertainty, Imbalance LDS Techniques	29
11	Measurement Uncertainty Table	37
12	Flowchart of Overall Process	39
13	Impact of Individual Parameters on CPM Metric	42
14	Volume or Mass Balance Uncertainty Behavior	49
15	Gradient Intersection Method	54
16	Flowchart for Numerical Uncertainty	72
17	Nonlinearity of Instrumentation	87
18	Example Meter Proving Run Data	88
19	Example Problem Elevation Profile	93
20	Example Problem Viscosity vs Temperature	93
21	Example Problem Transient Scenario	94
22	Example Problem Instantaneous Imbalance	95
23	Example Problem 10-s Percent Imbalance	95
24	Example Problem Steady State Tornado Diagram	101
25	Example Problem Maximum Transient Imbalances	103
26	Example Problem Transient Contributions to Uncertainty	103
27	Example Problem Transient Tornado Diagram	104
28	Example Problem Transient Alarm Analysis	105
29	Example Problem, Original 1993 API 1149 Estimates	107
A.1	Process Summary	110
B.1	Robustness/Availability	114
B.2	SCADA Uncertainties	115
B.3	General Flowchart	116
B.4	Reference Model	117
B.5	Other Uncertainties	118
B.6	Summary of Steady State Runs	119
B.7	Tornado Diagram, Steady State	119
B.9	RM Ideal (Reference) State Results	120
B.8	Steady State, Impact of Balancing Period	120
B.10	Summary of Transient Runs	121
B.11	Tornado Diagram, Transient	121
B.13	Overall Relative Uncertainties	122
B.12	Transient, Impact of Balancing Period	122
B.14	RM Ideal (Reference) State Results	123

Contents

	Page
B.15 Summary of Transient Runs	124
B.16 Tornado Diagram, Transient.	124
B.18 Overall Relative Uncertainties	125
B.17 Transient, Impact of Balancing Period	125
B.19 Reference Model	126
B.20 Other Uncertainties	127
B.21 RM Ideal (Reference) State Results	128
B.22 Summary of Transient Runs	128
B.23 Tornado Diagram, Transient.	129
B.24 Transient, Impact of Balancing Period	129
B.25 Overall Relative Uncertainties	130
B.26 Reference Model	131
B.27 Other Uncertainties	132
B.28 RM Ideal (Reference) State Results	133
B.29 Summary of Transient Runs	133
B.30 Tornado Diagram, Transient.	134
B.31 Transient, Impact of Balancing Period	134
B.32 Overall Relative Uncertainties	135
B.33a Reference Model	136
B.33b Reference Model	137
B.34 Other Uncertainties	138
B.35 RM Ideal (Reference) State Results	139
B.36 Summary of Transient Runs	139
B.37 Tornado Diagram, Transient.	140
B.38 Transient, Impact of Balancing Period	140
B.39 Overall Relative Uncertainties	141
B.40 Reference Model	141
B.41 Reference Model (continued).	142
B.42 Reference Model (continued).	143
B.43 Other Uncertainties	144
B.44 RM Ideal (Reference) State Results	145
B.45 Summary of Transient Runs	145
B.46 Tornado Diagram, Transient.	146
B.47 Transient, Impact of Balancing Period	146
B.48 Overall Relative Uncertainties	147
B.49 Reference Model	148
B.50 Other Uncertainties	149
B.51 RM Ideal (Reference) State Results	150
B.52 Summary of Transient Runs	150
B.53 Tornado Diagram, Transient.	151
B.54 Transient, Impact of Balancing Period	151
B.55 Overall Relative Uncertainties	152
B.56 RM Ideal (Reference) State Results	153
B.57 Summary of Transient Runs	154
B.58 Tornado Diagram, Transient.	54

Contents

	Page
B.60 Overall Relative Uncertainties	155
B.59 Transient, Impact of Balancing Period	155

Tables

1 CPM Methods According to API 1130	5
2 Example Summary of Reference Model Runs	10
3 Example Summary of Metric Analysis	10
4 Telecommunications Uncertainties	21
5 Leak Detection Techniques and Their Metrics	27
6 Leak Detection Techniques and Required Data	27
7 Template Uncertainty Table	29
8 Adjustments to the Sample Variance by Desired Confidence	34
9 Confidence Intervals for the Mean, in Multiples of S	35
10 Template Uncertainty Table	42
11 Major Uncertainty Factors	47
12 Data from Multiple Proving Runs	90
13 Example Problem Instrument Bias and Precision	96
14 Example Problem SCADA Uncertainties	96
15 Example Problem Input Subsystem MTBF	97
16 Example Problem Availability Calculation	97
17 Uncertainties	98
18 Pressure Values	99
19 Temperature Values	99
20 Example Problem, Steady State RM Runs for Bias	100
21 Example Problem, Steady State RM Runs for Precision	100
22 Example Problem Steady State Alarm Analysis	101
23 Example Problem Maximum Transient Imbalances	102
24 Example Problem, Transient RM Runs for Bias	104
25 Example Problem Transient Alarm Analysis, with RM Imbalance	105
26 Example Problem Transient Alarm Analysis, Without RM Imbalance	105
27 Example Problem, Original 1993 API 1149 Estimates	107
28 Example Problem, Original 1993 API 1149 Estimates with Transient Correction	108