

Manual of Petroleum Measurement Standards Chapter 23.1

Reconciliation of Liquid Pipeline Quantities

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Foreword

This Standard, API *MPMS* Chapter 23.1, supersedes API *MPMS* Standard 2560, *Reconciliation of Liquid Pipeline Quantities*, 1st Edition, and API *MPMS* Standard 2560 has therefore been withdrawn.

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Introduction

In the ideal world, every drop of liquid received into a pipeline system and every drop delivered out of the system, as well as all liquid inventory within the system, would be measured and accounted for precisely, and a comparison of all receipts and all deliveries—adjusted for inventory changes—would be exactly the same. The system would never experience a loss or a gain. Unfortunately, this ideal pipeline balance seldom exists in the real world.

Most pipeline systems typically experience some degree of loss or gain over time. This represents the normal loss/gain performance for a system. From time to time, losses or gains greater than normal may occur for a variety of reasons. Excessive or unexplained loss/gain often leads to contention between participating parties, sometimes requiring monetary settlements to adjust for abnormal loss/gain. In such cases, it is necessary to be able to (1) identify abnormal loss/gain as quickly as possible, (2) determine the magnitude of abnormal loss/gain, and (3) institute corrective actions.

Sometimes losses or gains are real, and adjustments shall be made to correct shipper batches and/or inventories. Most of the time, though, there are no real physical losses or gains. The loss/gain that occurs in day-to-day operation is usually small (a fraction of a percent) and is caused by small imperfections in a number of measurements in a system.

In a sense, loss/gain is a measure of the ability to measure within a system. Loss/gain should be monitored for any given system at regular intervals to establish what is normal for that system and to identify any abnormal loss/gain so that corrective action can be taken.

Reconciliation of Liquid Pipeline Quantities

1 Scope

1.1 General

1.1.1 This publication provides methodologies for monitoring liquid pipeline loss/gain and for determining the normal loss/gain level for any given pipeline system. Troubleshooting suggestions are also presented.

1.1.2 This document does not establish industry standards for loss/gain level because each system is individual and exhibits its own loss/gain level and/or patterns under normal operating conditions.

1.1.3 The document provides operational and statistically based tools for identifying when a system has deviated from normal, the magnitude of the deviation, and guidelines for identifying the causes of deviation from normal.

1.2 Field of Application

1.2.1 The primary application of this publication is in custody transfer liquid pipeline systems in which there is provision for measuring all liquids that enter the system and exit the system, as well as liquid inventory within the system. The application is not intended for nonliquid or mixed-phase systems.

1.2.2 The applications and examples in this document are intended primarily for custody transfer pipeline systems, but the principles may be applied to any system that involves the measurement of liquids into and out of the system and possibly, inventory of liquids within the system. Such systems may include pipelines, marine terminals, marine voyages, bulk loading or storage terminals, tank farms, and rail and trucking systems.

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 (including any amendments) applies.

API Manual of Petroleum Measurement Standards (MPMS) Chapter 2, Tank Calibration

API Manual of Petroleum Measurement Standards (MPMS) Chapter 3.1A, Manual Gauging of Petroleum and Petroleum Products

API Manual of Petroleum Measurement Standards (MPMS) Chapter 4.8, Operation of Proving Systems

API Manual of Petroleum Measurement Standards (MPMS) Chapter 11.1, Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils

API Manual of Petroleum Measurement Standards (MPMS) Chapter 12.3, Volumetric Shrinkage Resulting from Blending Light Hydrocarbons with Crude Oil

API Manual of Petroleum Measurement Standards (MPMS) Chapter 13.1, Statistical Concepts and Procedures in Measurement Methods of Evaluating Meter Proving Data

API Manual of Petroleum Measurement Standards (MPMS) Chapter 13.2, Statistical Methods of Evaluating Meter Proving Data

3 Terms and Definitions

For the purposes of this document, these specific definitions apply.

3.1

action limits

Control limits applied to a control chart or log to indicate when action is necessary to inspect or calibrate equipment and possibly, issue a correction ticket. Action limits are normally based on 95 % to 99 % confidence levels for statistical uncertainty analyses of the group of measurements.

3.2

control chart

A graphical method for evaluating whether meter proving operations are in or out of a state of statistical control.

3.3

control chart—fixed limit

A control chart in which control limits are based on adopted fixed values. Historically, fixed limits have been used to control the limits on meter factor changes.

3.4

control chart—loss/gain

A graphical method for evaluating whether loss/gain and/or meter proving operations are in or out of a “state of statistical control.”

3.5

control limits

Limits applied to a control chart or log to indicate the need for action and/or whether or not data are in a state of statistical control. Several control limits can be applied to a single control chart or log to determine when various levels of action are warranted. Terms used to describe various control limits are “warning,” “action,” and “tolerance” limits.

3.6

mean or central value

The average or standard value of the data being plotted on a control chart and is the reference value from which control limits are determined.

3.7

repeatability

A measure of the agreement between the results of successive measurements of the same variable carried out by the same method, with the same instrument, at the same location, and within a short period of time.

3.8

standard deviation

The root mean square deviation of the observed value from the average. It is a measure of how much the data differ from the mean value of all the data. Standard deviation can also be a measure of confidence level.

NOTE For further information concerning the application of Standard Deviation, reference [API MPMS Chapter 13.1](#) and [Chapter 13.2](#).

3.9

statistical control

The data on a control chart are in a state of statistical control if the data hover in a random fashion around a central mean value, and at least 99 % of the data are within the three standard deviation control limits, and the data do not exhibit any trends with time.

3.10

tolerance limits

Control limits that define the extremes or conformance boundaries for variations to indicate when an audit or technical review of the facility design, operating variables, and/or computations may need to be conducted to determine sources of errors and changes that may be required to reduce variations. Tolerance limits are normally based on 99 % or greater confidence levels and are used interchangeably with upper and lower control limits.

3.11

upper and lower control limits

Synonymous with tolerance limits.

3.12

warning limits

Control limits applied to a control chart to indicate when equipment, operating conditions, or computations should be checked because one or more data points were outside pre-established limits. Warning limits are normally based on 90 % to 95 % confidence levels.

4 Loss/Gain Analysis

4.1 General

Loss/gain (L/G) is the difference between deliveries and receipts, adjusted for changes in inventory, experienced by a system over a given time period (e.g. day, week, month). Losses may be real (e.g. leaks, evaporation, theft, etc.). Gains may occur if unmeasured liquid is added to the system—higher than actual receipts or lower than actual deliveries. More often, there is no actual physical loss or gain, just simply small measurement inaccuracies or accounting discrepancies. The combination of these small measurement inaccuracies may result in a system being outside of normal or acceptable limits.

L/G analysis typically involves collecting data, calculating L/G, and plotting L/G on any of several different types of charts. These charts may include control limits or other analytical guides that are derived from some simple statistical tools. The tools described in this document may be used by anyone and do not require an understanding of statistics.

The terms “over/short” and “imbalance” are sometimes used interchangeably with “loss/gain.”

4.2 Loss/Gain Equations

4.2.1 The two basic L/G equations are shown below. One expresses a loss as a negative value and the other expresses the loss as a positive value.

4.2.2 It is important to keep in mind which convention is being used in order to correctly decide whether the L/G values represent losses or gains.

Loss expressed as a negative number:

$$L/G = (CI + D) - (BI + R) \quad (1)$$

Loss expressed as a positive number:

$$L/G = (BI + R) - (CI + D) \quad (2)$$

Loss or gain of the system to be reconciled may also be provided as an absolute value to express relative distance of the variance from zero:

$$L/G = |(CI + D) - (BI + R)|$$

System Gain: If $(CI + D) > (BI + R)$

System Loss: If $(BI + R) > (CI + D)$

In such case, gain or loss is always an absolute value,

where

CI is the closing inventory in the system at the end of the time period;

D is deliveries out of the system during the time period;

BI is the beginning inventory in the system at the start of the period;

R is receipts into the system during the time period.

L/G may be reported in units of volume (e.g. gallons or bbl) or mass (e.g. lb or metric tons).

When expressed in percent, the actual L/G quantity is divided by the quantity of total receipts for a receipt-based system or by the quantity of total deliveries for a delivery-based system and multiplied by 100.

NOTE In the equations above, variables shall be expressed in like units of measure. Variables calculated under the same conditions (e.g. gross standard volume [GSV]/net standard volume [NSV], standard temperature and pressure) will yield the most meaningful information. (Reference API MPMS Chapter 12.)

4.3 Presentation of Data

4.3.1 Data may be presented in the form of control charts, trending charts, or cumulative charts. Guidelines on such charts may include control limits and trending lines.

4.3.2 Charts used for monitoring pipeline systems should be living documents and should be updated whenever new data are available. Accumulating data for some period of time and periodically updating charts (e.g. semiannually) serves no useful purpose. Charts and monitoring procedures can be effective only if charts are current and used as constructive tools.

4.4 Control Charts

4.4.1 Good measurement can be ensured by continuously monitoring measurement results to determine if systems, or equipment and procedures, are performing in predictable ways and are operating within acceptable limits. This may be done by the use of control charts.

4.4.2 Control charts display a collection of data over some period of time and include control limits shown as horizontal lines on the charts. Control limits help to define normal and abnormal system performance and may indicate when something in the system has changed and/or corrective action(s) may be required.

4.4.3 Control limits are often determined by historical performance of the system. In other cases, the control limits are set on an established arbitrary value, e.g. contractual limits. Control charts are the most common method of ascertaining system L/G performance. Control charts display a collection of data over some period of time and include the control limits. Control charts help to define normal trends of a system and may indicate when something has changed. Typical L/G charts, as shown in Figure 1, indicate a system's performance based on a percentage of throughputs over time. Typically, because accounting systems encompass a 30-day period, monthly evaluations of a system are commonly used to evaluate performance. Control charts may be prepared for any time span (e.g. weekly or daily) if adequate data are available.

4.4.4 Control charts may be maintained for entire systems or for individual segments of a system if adequate measurement and records are available at the junctures of segments.

4.4.5 The data on control charts tend to hover around a central (mean) value, which is the arithmetic average of the data and can be represented by a horizontal line on the chart. The control chart also includes upper and lower control limits (UCL and LCL, respectively) that may be (1) defined as engineering limits, which are values based on experience or performance objectives, or (2) defined statistically as three standard deviations above and below the mean. Standard deviation is a statistical measure of the spread of a data set with respect to the mean value of the set. Procedures for calculating statistical quantities are shown in Annex A.

Figure 1 shows a typical control chart.

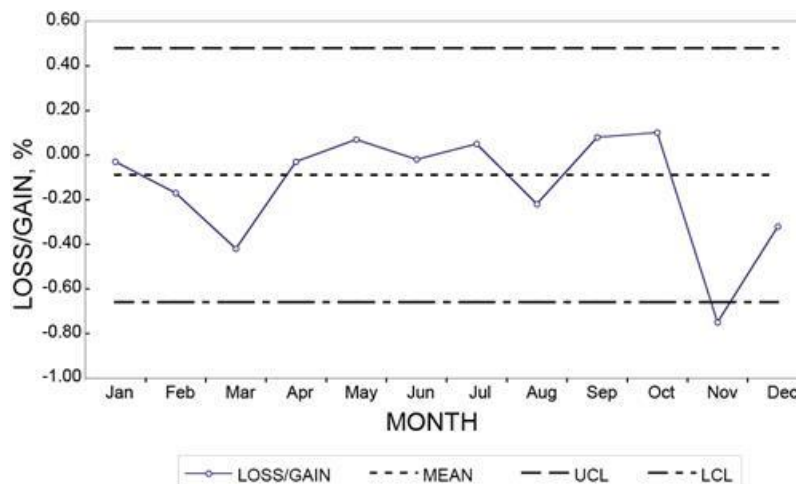


Figure 1—Sample Control Chart

4.4.6 The data shall be representative of the normal performance of the system, as the control limits will be used to predict near-future performance. Any data point that is known to be the result of a special cause should be shown on the control chart but should not be included in the calculation of mean, standard deviation, or control limits, and the number of data points shall be adjusted accordingly. A special cause is an event (e.g. meter failure, late run ticket, line displacement with water for hydrostatic pressure test, etc.) that results in mismeasurement for a given period of time but is not a part of the normal operation of the system.

4.4.7 Charts can be used to determine system stability, cyclical trends, or step changes in performance. One of the most important benefits of using charts to assess performance is the instant visual representation it provides. The adage “a picture paints a thousand words” best summarizes the effectiveness of control charting.

4.5 Pipeline System Control Charts

4.5.1 A useful tool for monitoring pipeline systems is the control chart that shows L/G as percent of throughput over time. Total receipts are used for throughput in receipt-based systems, and total deliveries are used for delivery-based systems.

4.5.2 Strictly speaking, for control limits to be statistically significant, a minimum of 30 data points are required. For practical purposes, control limits for a pipeline system that is monitored monthly will often be based on monthly L/G data. For our purposes, the 24 data points are acceptable. It is common practice to set limits at the beginning of each calendar year based on the prior history. These limits are carried forward for the calendar year unless there is a change in the process that would require new limits.

Figure 2 shows the L/G data for two years. Those data will be used to set control limits for the following year.

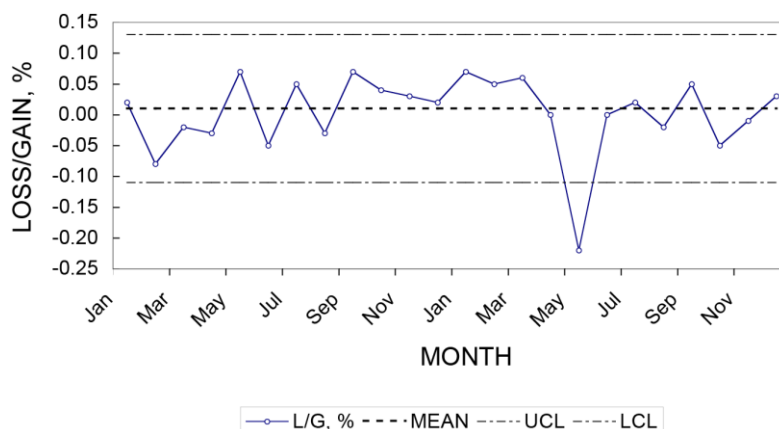


Figure 2—Two Years of Data for Control Limits

Figure 3 shows the first three-month data compared with the two-year historical control limits.

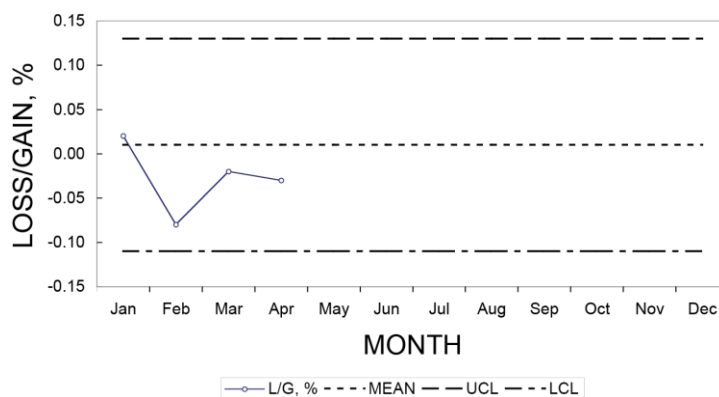


Figure 3—Control Chart for the Following Year

4.5.3 Setting fixed limits for L/G, without regard to actual data, may provide performance guides that may be required for contractual reasons. Whenever possible, it is more practical to set limits based on historical data. A pipeline system tends to operate at a level of performance that is dictated by physical configuration, equipment, procedures, maintenance practices, environmental conditions, and employee training. All of these factors combine to produce a natural randomness and, sometimes, a natural bias in a system. For systems that have other constraints, such as loss allowance, it may be desirable to include a second set of limits set at the value of

the loss allowance. This would indicate how the system is performing with respect to the loss allowance and if the assigned loss allowance is realistic.

4.5.4 It is good practice to determine whether or not a system is stable and in control. A system is generally considered to be in control if the data are all within control limits that have been established from the data. Data points outside the control range indicate poor control. A system is said to be stable if the data exhibit only random fluctuations around the mean without trends.

4.5.5 When physical or operational changes are made to a system, the L/G pattern for the system will often change. When this happens, the prior two-year history may not be suitable for setting the control limits. In such cases, a moving range chart may be used until sufficient history is developed to define the system's new pattern. In a moving range chart, the mean and standard deviation are recalculated each time new data are available using all data since the change. The resulting mean and control limit lines on the control chart may exhibit an immediate step change to a new level of control or may change gradually for some period of time until the system stabilizes at a new level of control.

4.5.6 As an example, Figure 4 shows three distinct patterns that may be found on control charts. The points 1 through 7 exhibit random fluctuations around the mean and are well within the control limits. This portion of the data is stable and in control. The points 7 through 12 are within the control limits and appear to fluctuate randomly, but are all above the mean. This is a state of stability but not in control because the data do not hover around the mean. In fact, it would appear that the system has attained a new state of control that is centered around a higher mean value. The points 11 through 16 are neither stable nor in control because they are in a definite downward trend. The data do not center around a mean and appear to be headed off the chart.

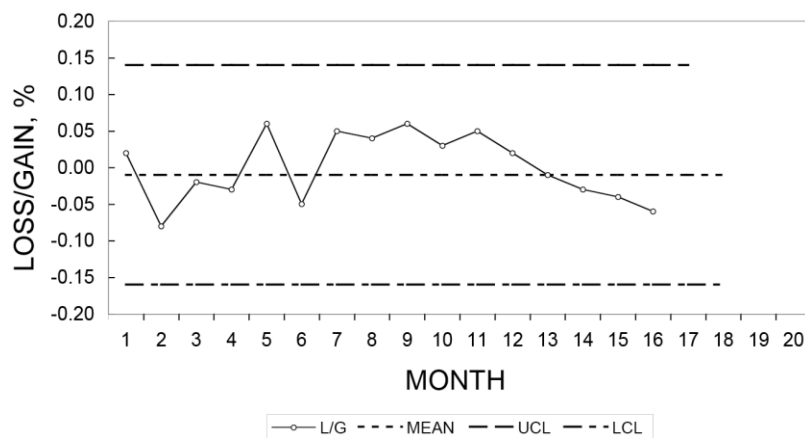


Figure 4—Control Chart with Three Patterns

4.5.7 As a rule, five consecutive points above or below the mean indicate a loss of control or a change to a new level of performance. Five consecutive points trending in one direction (up or down) indicate a loss of control. For some systems, even fewer points in a row may be significant warning. Examples might be leaking tanks (in which case the losses are real) or meters that are wearing badly and are not being proved often enough (which are book losses).

4.5.8 An upward trend is no better than a downward trend. Either condition is out of control. A system gain can be just as bad as a system loss. Losses and gains occur because of some deficiency in measurement.

4.5.9 If the data tend to swing back and forth as shown in Figure 5, the system is cyclic. If the cause of the cycles could be eliminated, the system should be able to achieve a state of better control with narrower control limits.