Reconciliation of Liquid Pipeline Quantities

API STANDARD 2560
FIRST EDITION, DECEMBER 2003

REAFFIRMED, JANUARY 2010

energy API

AMERICAN PETROLEUM INSTITUTE

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Measurement Coordination

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Reconciliation of Liquid Pipeline Quantities

1 Introduction

1.1 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.

1.2 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.

1.3 Sometimes losses or gains are real, and adjustments must 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.

1.4 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.

2 Scope

2.1 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.

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

2.3 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.

3 Field of Application

3.1 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, exit the system and liquid inventory within the system. The application is not intended for non-liquid or mixed phase systems.

3.2 The applications and examples in this document are intended primarily for custody transfer pipeline systems, but the principles may be applied to any system which involves the measurement of liquids into and out of the system and possibly inventory of liquids within the system.

4 Reference Publications

API *Manual of Petroleum Measurement Standards*

Chapter 2	"Tank Calibration"
Chapter 4.8	"Operation of Proving Systems"
Chapter 12.1	"Upright Cylindrical Tanks and Marine Vessels"
Chapter 12.2	"Calculation of Liquid Petroleum Quantities Measured by Turbine or Displacement Meters"
Chapter 12.3	"Calculation of Volumetric Shrinkage From Blending Light Hydrocarbons with Crude Oil"
Chapter 13.1	"Statistical Concepts and Procedures in Measurement"
Chapter 13.2	"Statistical Methods of Evaluating Meter Proving Data"

5 Definitions

For the purposes of this document these specific definitions apply.

5.1 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 percent to 99 percent confidence levels for statistical uncertainty analyses of the group of measurements.

5.2 control chart—fixed limit: A control chart whose control limits are based on adopted fixed values. Historically, fixed limits have been used to control the limits on meter factor changes.

5.3 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."

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

5.5 control limits: Are limits applied to a control chart or log to indicate the need for action and/or whether or not data is 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.

5.6 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.

5.7 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* Chapters 13.1 and 13.2

5.8 statistical control: The data on a control chart are in a state of statistical control if the data hover in a random fashion about 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.

5.9 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 which may be required to reduce variations. Tolerance limits are normally based on 99% or greater confidence levels, and are used interchangeablely with Upper and Lower Control Limits.

5.10 upper and lower control limits: Synonymous with tolerance limits.

5.11 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 percent confidence levels.

6 Loss/Gain Analysis

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.

Loss/gain analysis typically involves collecting data, calculating loss/gain, and plotting loss/gain on any of several different types of charts. These charts may include control limits or other analytical guides which 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.

6.1 LOSS/GAIN EQUATIONS

6.1.1 The two basic Loss/Gain equations are shown below. One expresses a loss as a negative value and the other expresses the loss as a positive value.

6.1.2 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

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

Loss expressed as a Positive Number

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

In which:

CI = Closing inventory in the system at the end of the time period,

D = Deliveries out of the system during the time period,

BI = Beginning inventory in the system at the start of the period,

R = Receipts into the system during the time period,

L/G may be reported in units of volume or mass (e.g., bbls or lbs).

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 must be expressed in like units of measure. Variables calculated under the same conditions (e.g *GSV*/*NSV* volumes, standard temperature and pressure) will yield the most meaningful information. (Reference *MPMS* Chapter 12.)

6.2 PRESENTATION OF DATA

6.2.1 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.

6.2.2 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 (say, semiannually) serves no useful purpose. Charts and monitoring procedures can be effective only if charts are current and used as constructive tools.

6.3 CONTROL CHARTS

6.3.1 Good measurement can be assured 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.

6.3.2 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 define normal and abnormal system performance, and may indicate when something in the system has changed and/or corrective action(s) may be required.

6.3.3 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 loss/gain 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 loss/gain 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.

6.3.4 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.

6.3.5 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*) which may be (1) defined as engineering limits which are values based on experience or performance objectives, or (2) defined statistically as three standard deviations (σ) 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 Appendix A.

Figure 1 shows a typical control chart.

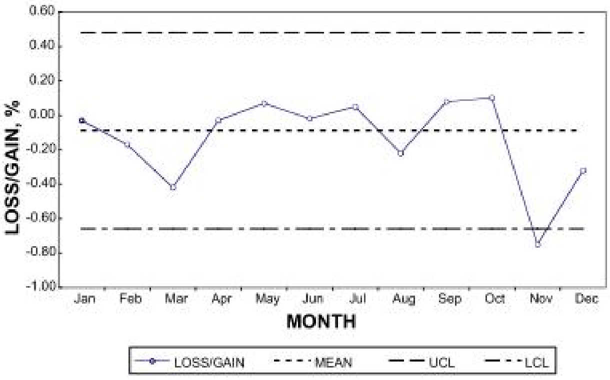

Figure 1—Sample Control Chart

6.3.6 The data must be representative of the normal performance of the system, as the control limits will be used to predict near future performance. Any data point which 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 must 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.) which results in mis-measurement for a given period of time, but is not a part of the normal operation of the system.

6.3.7 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.

6.4 PIPELINE SYSTEM CONTROL CHARTS

6.4.1 A useful tool for monitoring pipeline systems is the control chart which shows loss/gain 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.

6.4.2 Strictly speaking, for control limits to be statistically significant, a minimum of 30 data points is required. For practical purposes, control limits for a pipeline system which 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