

Manual of Petroleum Measurement Standards Chapter 23.2

Reconciliation of Liquid Tank Car(s) Quantities

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Introduction

This standard provides guidance regarding various tank car movement reconciliation methods that will aid in measurement processes and inventory control programs for petroleum and petroleum products. It will be up to the user(s) of this standard to decide and determine the most appropriate methodology that will allow the most accurate volume reconciliation for its system.

Reconciliation of Liquid Tank Car(s) Quantities

1 Scope

1.1 General

Provide methodologies and processes to monitor liquid tank car movements' quantity loss/gain (L/G) ratios, level, and/or quality differences for tank car measurement systems. This document does not establish an industry standard for L/G ratios or level, but under normal operating conditions the standard will assist the user to identify L/G of any tank car system. It will assist to determine:

- ratio or level deviations,
- patterns or trends,
- liquid quality.

This document will also make available operational and statistically based tools to:

- identify when a system exhibits a deviation from its normal operating conditions,
- guidelines for identifying the causes of the deviation from its normal operating perimeters.

1.2 Field of Application

The primary application of this publication is in custody transfer measurement 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.

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 (all relevant chapters)

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

API Manual of Petroleum Measurement Standards (MPMS) Chapter 3.1B, Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging

API Manual of Petroleum Measurement Standards (MPMS) Chapter 3.2, Standard Practice for Gauging Petroleum and Petroleum Products in Tank Cars

API Manual of Petroleum Measurement Standards (MPMS) Chapter 4.5, Master Meter Provers

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

API Manual of Petroleum Measurement Standards (MPMS) Chapter 4.9.2, Methods of Calibration for Displacement and Volumetric Tank Provers—Part 2—Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration

API Manual of Petroleum Measurement Standards (MPMS) Chapter 5, Metering (all relevant chapters)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 6.2A, Truck and Rail Loading and Unloading Measurement Systems

API Manual of Petroleum Measurement Standards (MPMS) Chapter 7, Temperature Determination (all relevant chapters)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 8, Sampling (all relevant chapters)

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 11.3.4, Miscellaneous Hydrocarbon Product Properties—Denatured Ethanol and Gasoline Component Blend Densities and Volume Correction Factors

API Manual of Petroleum Measurement Standards (MPMS) Chapter 12, Calculation of Petroleum Quantities (all relevant chapters)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 12.1.2, Calculation of Static Petroleum Quantities, Part 2—Calculation Procedures for Tank Cars

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

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

API Manual of Petroleum Measurement Standards (MPMS) Chapter 13.3, Measurement Uncertainty

API Manual of Petroleum Measurement Standards (MPMS) Chapter 14.4, Converting Mass of Natural Gas Liquids and Vapors to Equivalent Liquid Volumes (GPA 8173)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.1, Guidelines for Marine Inspection

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.2, Measurement of Cargoes on Board Tank Vessels

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.4, Method for Quantification of Small Volumes on Marine Vessels (OBQ/ROB)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.5, Guidelines for Voyage Analysis and Reconciliation of Cargo Quantities

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.6, Guidelines for Determining Fullness of Pipelines Between Vessels and Shore Tanks

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.10, Measurement of Cargoes on Board Marine Gas Carriers (all relevant chapters)

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17.12, Procedure for Bulk Liquid Chemical Cargo Inspections

API Manual of Petroleum Measurement Standards (MPMS) Chapter 18.2, Custody Transfer of Crude Oil from Lease Tanks Using Alternative Measurement Methods

API *Manual of Petroleum Measurement Standards (MPMS) Chapter 19, Evaporation Loss Measurement* (all relevant chapters)

API *Manual of Petroleum Measurement Standards (MPMS) Standard 2555, Method for Liquid Calibration of Tanks*

AAR¹ *Scale Handbook*

NIST² *Handbook 44*

3 Terms and Definitions

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

3.1

action limits

Lines on a control chart that represent a boundary between taking or not taking action to modify a process.

3.2

central mean 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.

3.3

control chart

A graphical method for evaluating whether a process is in or out of a state of statistical control by using warning and action limits determined by statistical analysis of the process data.

3.4

control chart loss/gain (L/G)

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

3.5

control chart or log of fixed limit

A control chart or log whose control limits are based on adopted fixed values applicable to the statistical measurements displayed on the log or chart. Historically, fixed limits have been used to control the limits on meter factor changes.

3.6

control limits

Lines on a control chart used to evaluate whether or not a process is in statistical control.

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.

¹ Association of American Railroads, 425 3rd Street, SW, Washington, DC 20024, www.aar.org.

² National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD, www.nist.gov.

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

systems 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 (UCLs and LCLs, respectively).

3.11

three standard deviation limit

A control limit equal to three standard deviations from the arithmetic mean of the set.

3.12

transloading

The transfer of a liquid hydrocarbon commodity from one bulk carrier to another bulk carrier where the quantity and quality transferred is measured via a measurement system.

3.13

warning limits

Lines on a control chart that represent a boundary between a predictable and unpredictable process.

4 Measurement Data Analysis

4.1 General

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. Charts used for monitoring measurement 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.

4.2 Loss/Gain (L/G) Analysis

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) or over a single (or multiple) product movements. Losses may be physical (e.g. leaks, evaporation, theft, etc.) or apparent (e.g. errors in measurement, tickets, procedures, etc.). Gains may occur if unmeasured liquid is added to the system—higher than actual receipts. 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.”

The two basic L/G equations (not all inclusive) are shown below. One expresses a loss as a negative value and the other expresses the loss as a positive value.

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:

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

Loss expressed as a positive number:

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

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:

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

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

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

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;

OI is the opening 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 kiloliters) 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 Ch. 12.)

4.3 Control Charts

4.3.1 General

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 using control charts.

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.

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.

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. This central value can also represent a “target loss/gain” that has been set contractually based on anticipated or expected L/G of the system. The control chart also includes UCLs and LCLs 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 the specific number of deviations are determined by the user(s). Procedures for calculating statistical quantities are shown in Annex A.

NOTE For further information concerning the application of standard deviation, reference API MPMS Ch. 13.2 and Ch. 13.3.

Figure 1 shows a typical control chart.

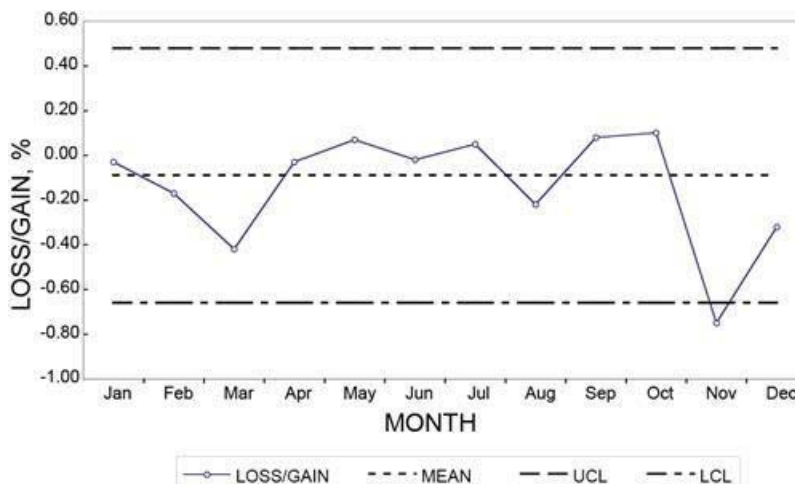


Figure 1—Sample Control Chart

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.

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.

4.3.2 Measurement System Control Charts

A useful tool for monitoring measurement 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.

Strictly speaking, for control limits to be statistically significant, a minimum of 30 data points are required. For practical purposes, control limits for a measurement 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 2 years. Those data points will be used to set control limits for the following year.

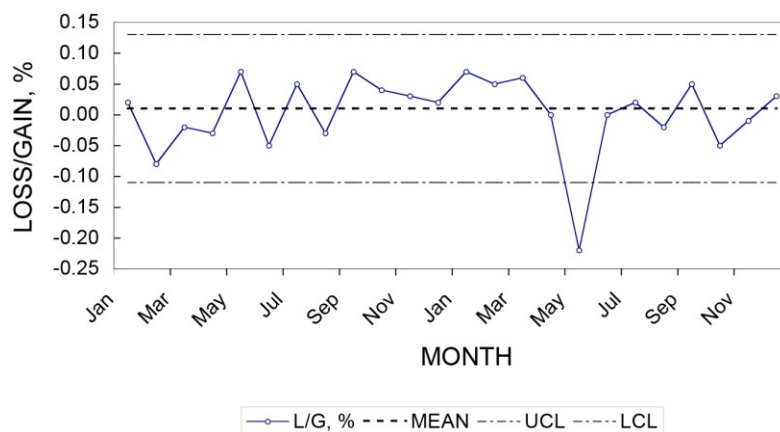


Figure 2—Two Years of Data for Control Limits

Figure 3 shows the first 3-month data compared with the 2-year historical control limits.

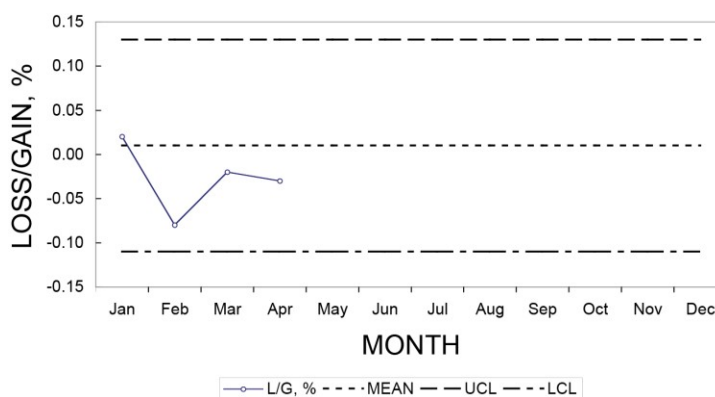


Figure 3—Control Chart for the Following Year

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 measurement 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.

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.

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 2-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.

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.

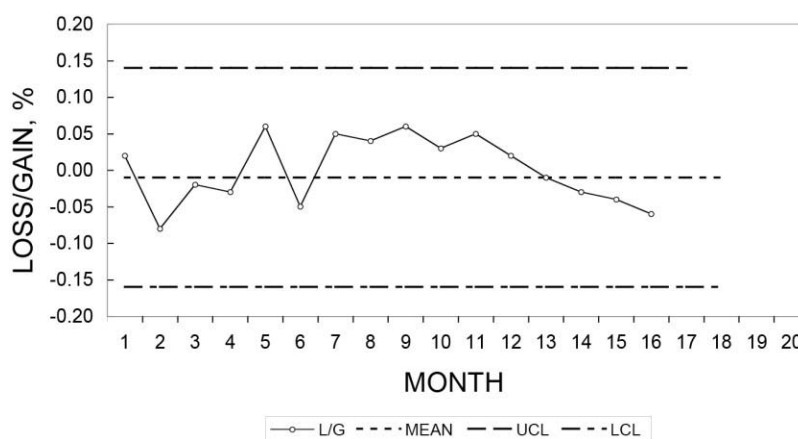


Figure 4—Control Chart with Three Patterns

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 a 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).

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.

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.