TROUBLESHOOTING LIQUID PIPELINE LOSSES AND GAIN
Class # 2380.1

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INTRODUCTION

Today's pipelines are multi-dimensional systems providing multiple services for many shippers and customers. Pipeline systems may connect multiple origins and destinations, and carry various products across long distances with changing profiles, pipe dimensions and directions. Monitoring pipeline losses and gains employs tools and analysis methods developed specifically to troubleshoot pipeline variances. Examination of pipeline losses and gains uses basic statistical tools as well as intuitive and creative insight into what controls losses and gains.

The basic tool for evaluating system performance is "Loss/Gain", a measure of how well receipts, deliveries and inventory match up over a period of time. The concept is similar to that used for leak detection, but usually covers a longer time period. Loss/gain is a measure of the quality of the overall measurement in a system, and excessive loss/gain can signal the need for an investigation to identify causes and develop corrective actions.

Good measurement can be enhanced by continuously monitoring the system, equipment and procedures to insure they are operating within acceptable limits. This monitoring may be accomplished by the use of Control Charts.

This paper will review control charts and procedures, which may be used to monitor systems, and offers troubleshooting guides to use when a pipeline system's loss/gain is out of tolerance.

LOSS/GAIN DEFINITION

Loss/Gain (L/G) is basically 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 (leaks, evaporation, theft, admixture shrinkage, etc.), and gains could be real if unmeasured liquid enters a system. More often, there is no actual physical loss or gain, and L/G is simply the result of small inaccuracies in measurement or ticketing/accounting procedures.

Mathematically,

$$L/G = CI + D - BI - R$$

in which CI is closing inventory in the system at the end of the time period (also called ending inventory, EI), D is deliveries out of the system during the time period, BI is beginning inventory at the start of the time period, and R is receipts into the system during the time period. When written in this form, a positive value of L/G represents a gain and a negative value represents a loss. Some oil accounting systems use a positive value as a loss and a negative value as a gain, therefore the equation becomes:

$$L/G = BI + R - CI - D$$

This doesn't change the way the equation is used. Just remember the significance of positive and negative numbers. Some operators prefer the term Over/Short (O/S) or Gain/Loss (G/L) to the term Loss/Gain (L/G).

If inline inventory is assumed constant, as in some crude oil gathering systems, only input and output volumes impact L/G of a pipeline. A line imbalance would not consider line inventory and would be easily corrected by review of the measurement systems only. The analysis becomes more complex if inline inventory is not constant, and is further complicated if the system includes breakout tankage.

Pipeline losses and gains result from inaccuracies in inventory measurement as well as variances at input or output facilities. Recognizing and understanding changes in L/G requires developing a L/G baseline based on “normal” operation.

BASELINE FOR GAINS AND LOSSES

Establishing a L/G baseline takes into account expected swings in pipeline loss/gain that occur as a result of operational or seasonal changes. A periodic time frame is selected to monitor losses and gains and is typically based on a regular time, calendar or operating interval. A monitoring frequency occurring too often does not allow for seasonal or operational loss/gain trends to play out. A period too wide may average problems into operating trends and go undetected.

Pipeline losses and gains are best described in terms of percentages based on a given reference. The reference used is a benchmark to compare loss/gain volumes. Typically, performance percentages are based on L/G barrels as a percentage of barrels received or delivered during a performance period.

PIPELINE INVENTORY

The inventory volume within the pipeline is the most difficult component of the loss/gain equation to capture at any given time. The volume of liquid occupying space in the pipeline constantly changes due to environmental effects on the liquid and the pipe. Physical parameters such as temperature, pressure or density influence the liquid displacement or the amount of space the liquid occupies. With continuously expanding and contracting liquids in the pipe, input and output measurements may be mistaken as inaccuracies if the changing in-line inventory is not accounted for.

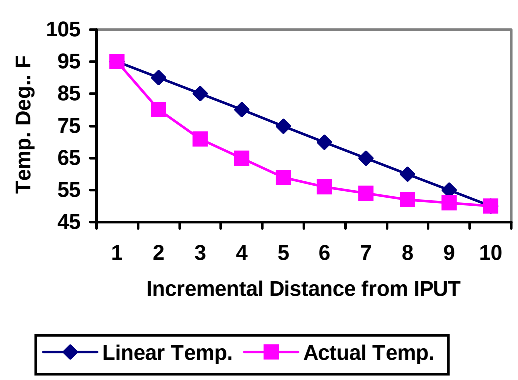
Effects of Temperature:

The effect of temperature alone can be seen when liquids of different temperatures are displaced. A pipeline filled with 95°F liquid, shutdown and cooled to 50°F, would show an initial line imbalance following startup. The liquid in a pipeline at low temperatures occupies less space than the same liquid at a higher temperature. As a result, when the line is restarted, the volume entering the line would not equal the volume leaving the line until the unfilled line space caused by the thermal shrinkage of the liquid is filled.

Changes in liquid temperature between points along pipelines are often assumed linear when, in fact, the temperature change along the length is non-linear. A warm liquid entering a pipeline where pipe and ground temperatures are cooler than the liquid will dissipate liquid heat proportionally based on the temperature differences between the ground and the liquid. The greater the temperature difference, the faster temperature falls off. When liquid first enters the pipeline, temperature dissipation is greatest. As the liquid moves down the line and cools, heat content falls off in a decaying exponential form rather than in a linear form. This example is shown graphically on Figure 1.

A similar, nonlinear, but opposite effect is seen when cooler liquids enter a warmer environment pipeline.

Figure 1 - Temperature Profiles



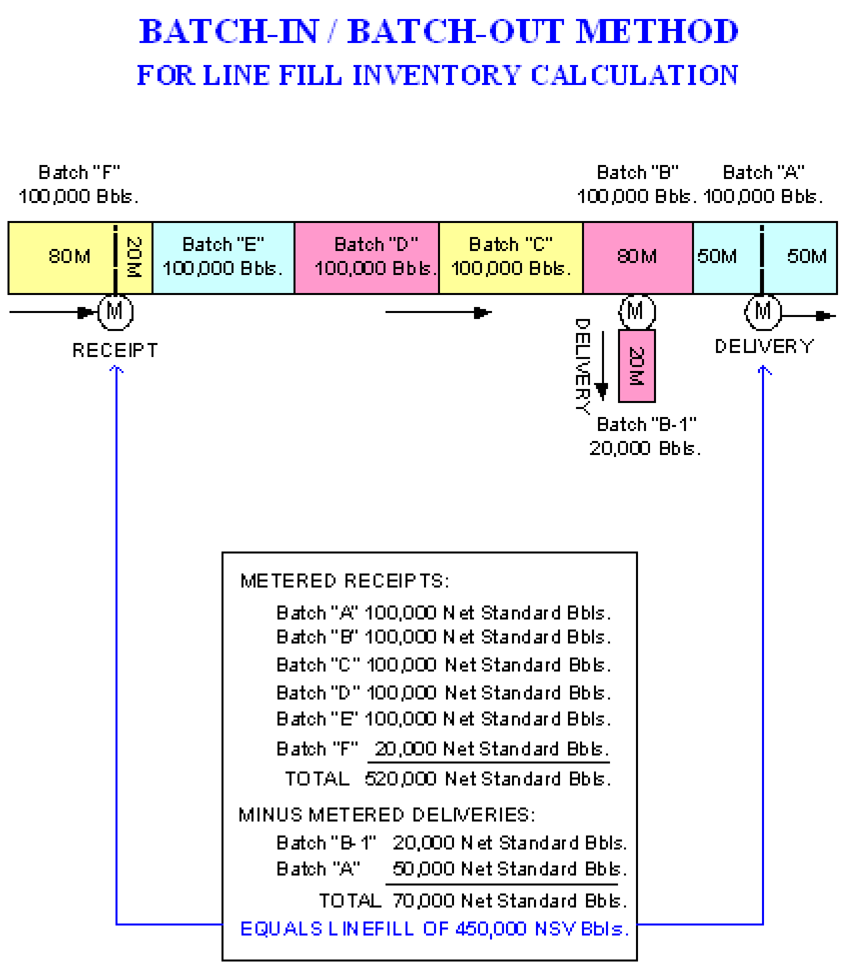
Effects of Line Pack:

Line Pack (pressure) is a component of pipeline inventory that also must be considered when correcting for gains and losses. Liquid entering a static pipeline initially requires the liquid to “pack” the line before the liquid in the pipeline begins to move. In addition to packing, the inertia to move the static liquid mass in the pipeline must be overcome before the liquid can move. A line imbalance will result until the line is packed and liquid momentum is overcome. Consider a large pipeline running at the beginning of the loss/gain period and shut down at the end of the loss/gain period. Unless that line is shut down under the same pressure that it was while running, the calculation of it’s inventory is questionable at best. The converse situation presents the same problem.

Establishing Line Inventory:

Temperature and line pack effects contribute to loss/gain during transient periods. Once steady state is achieved, these effects become part of the base line.

An effective method for determining line inventory that reduces the effect of temperature and line pack has been to use net standard volumes measured into and out of the system over the given time period. This is accomplished by using a batch numbering sequence, which allows volumes to be tracked from receipt through intermediate delivery to final delivery from the system. An example of this type calculation follows:

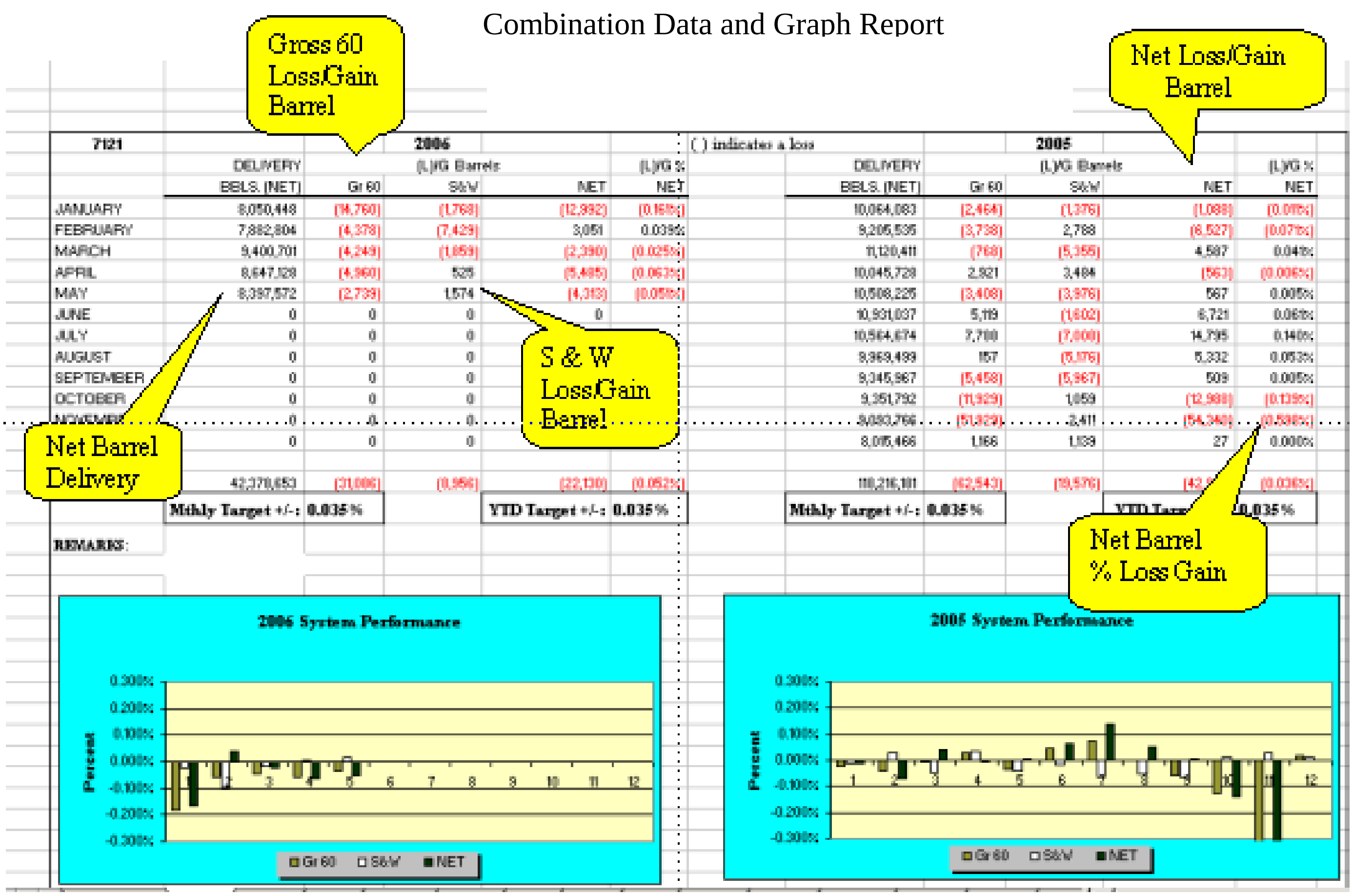


DESIGN AND USE OF CHARTS

Combination Charts/Graphs:

A good starting point in system analysis is a high altitude (helicopter) view, which can give early indications of problems, seasonal trends, etc.

The following report to management is a tool that can be used by Field Operations, Business Representatives and Upper Management to understand a systems performance for a month, cumulative year-to-date and comparison to the prior year. An example of a combination chart/graph follows:



7121	2006					2005				
	DELIVERY	(L)/G Barrels			(L)/G %	DELIVERY	(L)/G Barrels			(L)/G %
	BBLS. (NET)	Gr 60	S&W	NET	NET	BBLS. (NET)	Gr 60	S&W	NET	NET
JANUARY	8,050,448	(14,760)	(1,768)	(12,992)	(0.161%)	10,064,083	(2,464)	(1,376)	(1,088)	(0.011%)
FEBRUARY	7,882,804	(4,378)	(7,429)	3,051	0.039%	9,205,535	(3,738)	2,788	(6,527)	(0.071%)
MARCH	9,400,701	(4,249)	(1,859)	(2,390)	(0.025%)	11,120,411	(768)	(5,355)	4,587	0.041%
APRIL	8,647,128	(4,960)	525	(5,485)	(0.063%)	10,045,728	2,921	3,484	(563)	(0.006%)
MAY	8,397,572	(2,739)	1,574	(4,313)	(0.051%)	10,508,225	(3,408)	(3,976)	567	0.005%
JUNE	0	0	0	0		10,931,037	5,119	(1,602)	6,721	0.061%
JULY	0	0	0			10,564,674	7,700	(7,000)	14,795	0.140%
AUGUST	0	0	0			9,969,499	157	(5,176)	5,332	0.053%
SEPTEMBER	0	0	0			9,345,967	(5,458)	(5,967)	509	0.005%
OCTOBER	0	0	0			9,351,792	(11,929)	1,059	(12,988)	(0.139%)
NOVEMBER	0	0	0			9,093,766	(51,929)	2,411	(54,340)	(0.598%)
	0	0	0			8,015,466	1,166	1,139	27	0.000%
	42,378,653	(31,086)	(8,956)	(22,130)	(0.052%)	118,216,181	(62,543)	(19,576)	(42,[illegible]	(0.036%)
	Mthly Target +/-:	0.035%		YTD Target +/-:	0.035%	Mthly Target +/-:	0.035%		YTD Target +/-:	0.035%

Control Charts

Control charts display a collection of data over some period of time with control limits that are statistically determined values 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 is required.

The data on control charts tend to hover around a central (mean) value that is the arithmetic average of the data represented by a horizontal line on the chart. Upper and lower control limits (UCL and LCL) are set at three standard deviations above and below the mean. A sample control chart is shown on Figure 2.

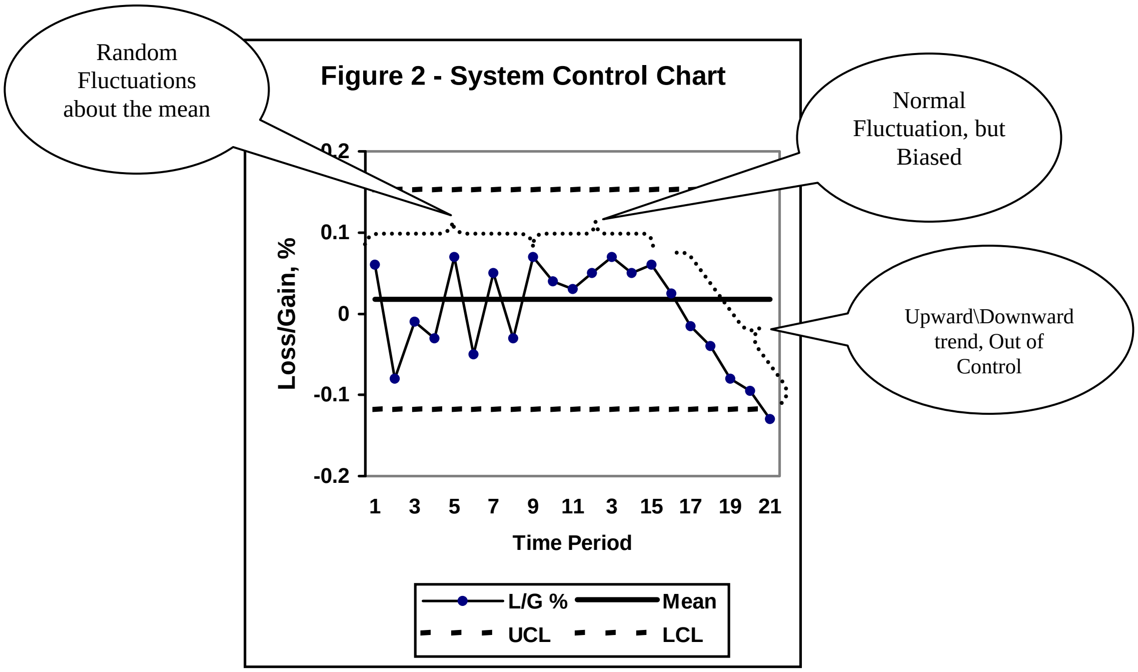
A system is considered to be stable and in control if the data exhibit random variations around the mean and are within the control limits. Outlier data points, i.e., points outside the control limits, usually signal a need for immediate investigation.

The most common control chart for monitoring pipeline systems is one which shows loss/gain as percent of throughput over time.

As stated earlier Loss/Gain (L/G) is the difference between deliveries and receipts, adjusted for changes in inventory, experienced by a system over a given time frame (e.g., day, week, month). More often, there is no actual physical loss or gain and L/G is simply the result of measurement inaccuracies and is considered to be *a* ***"Measure of Our Ability to Measure."***

The first thing to determine is 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 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.

Figure 2 shows three distinct patterns. The first eight points exhibit random fluctuations around the mean and are well within the control limits. This portion of the data is stable and in control. The next seven points are within the control limits and appear to fluctuate randomly, but are all above the mean (a bias). This is a state of stability but not in control because the data do not hover around the mean. The last six points are neither stable nor in control because they are in a definite downward trend.



If the data regularly swing back and forth, 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 more narrow control limits.

A system may be stable and in control, but not acceptable if the mean differs significantly from zero. For example, a pipeline with a mean of -0.25 consistently runs 0.25% short. This may be excessive if shippers are compensated for losses or if it exceeds tariff/contract allowables.

Similarly, a wide span between UCL and LCL may indicate instability in the system and may not be acceptable performance.

The performance of a system may change due to deliberate process changes, such as equipment additions/changes or procedural changes. Sometimes, though, a system will change without any apparent reason. Any process change, be it deliberate or unplanned, will usually show up as a change in the pattern on the control chart.

Any data point that falls outside the control limits is the result of a special cause (e.g., equipment failure, procedural error, etc.) and should be investigated immediately to determine the cause. Special causes often lead to correction or adjustment tickets, and should be investigated as soon as possible before the data become stale and the trail gets cold.

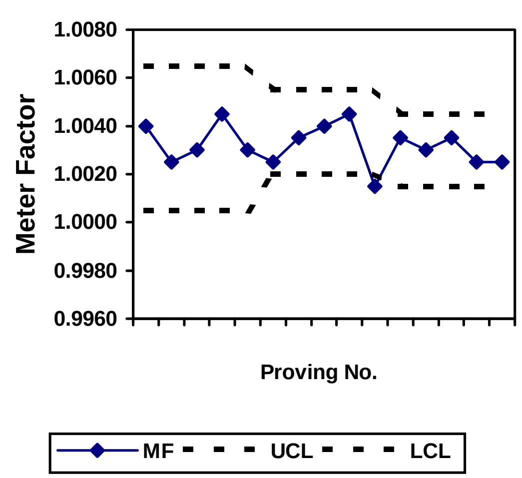
Meter Factor Control Charts:

Control charts may be used to monitor meter performance. The meter factor is plotted as a function of either time or volume of throughput. On meter factor control charts it may be useful to add (1) Warning Limits set at one standard deviation above and below the mean, and (2) Action Limits set at two standard deviations above and below the mean for early detection of potential problems.

According to API MPMS Chapter 13.2, if **Warning Limits** are exceeded, check meter proving equipment and/or operating conditions. If **Action Limits** are exceeded, recalibrate instrumentation and/or inspect, adjust, repair mechanical equipment. If **Control Limits**, UCL or LCL, (a.k.a. Tolerance Limits) are exceeded, check all equipment and procedures, including ticket calculations. Check for equipment failure, and/or check for leaks.

Meter factors often change with time. Therefore it may be preferable to plot meter factors on a "moving range" chart in which control limits are reset more often, such as after every five or ten provings. Figure 3 is a moving range chart with control limits reset after every five meter provings.

Figure 3 - Moving Range Chart



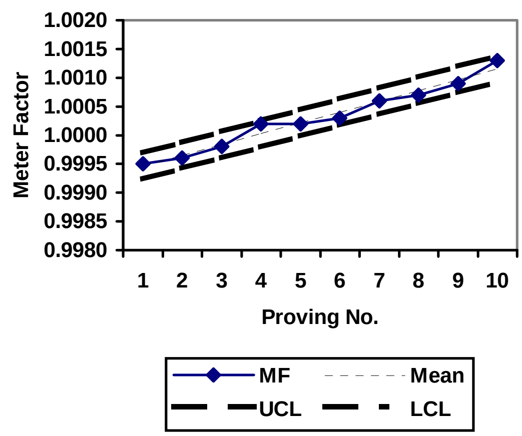
Meter factors usually behave in a predictable way. If operating conditions are essentially constant and wear is not excessive, meter factors may be plotted on conventional control charts with warning, action and control limits. However, if meters are subject to variable operating conditions and/or liquids with different physical properties, their control charts will exhibit enough natural variation to dilute the value of warning and action limits.

For multi-product meters, interpretation of control charts is not straight forward, as the patterns on the charts are composites of several sub-patterns that are dictated by flow rate, temperature, pressure and liquid properties. The data for such meters should be broken into separate plots of meter factor segregated by one variable, such as crude/product type, with other conditions being as nearly constant as possible.

Trending charts:

Trending charts may be used when data exhibit a definite upward or downward trend and do not hover around a simple horizontal mean value. Such charts may resemble a control chart with lines representing average performance (similar to "mean") and control limits that follow the upward or downward trend of the data. A trending control chart is shown on Figure 4.

Figure 4 - Example of Trending Control Chart



Mean and control limit values cannot be represented by fixed-value horizontal lines on a trending control chart. Hence, mean and control limits must be calculated with a mathematical procedure called "linear regression". Many flow computers, computer programs and some types of hand-held calculators have linear regression programs.

Linear regression yields an equation of the form;

> $Y = a + bX$, in which Y is the dependent variable (e.g., meter factor), “a” is a constant (called the zero intercept), “b” is a constant (called the X coefficient), and X is the independent variable (e.g., month, proving sequence, etc.). The values of “a” and “b” are derived from the data and are unique to the particular data set.

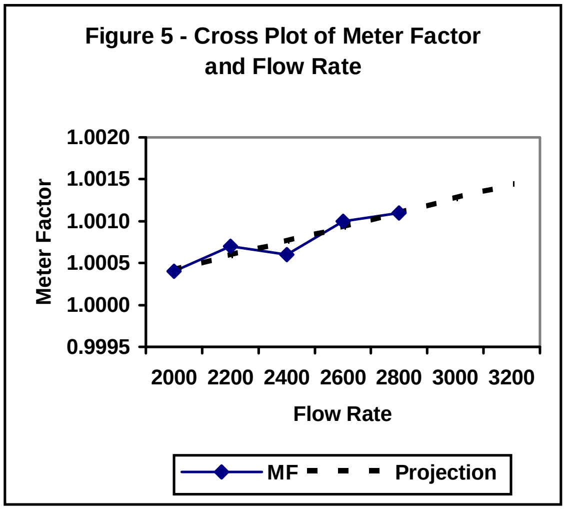
The mean and control limits of trending data are represented by equations rather than fixed values.

A line representing the trending mean can be constructed on a control chart by calculating the end points of the line from the regression equation, plotting those points on the chart and connecting them with a straight line. Lines representing control limits may be constructed at three standard deviations above and below and parallel to the trending mean line.

Cross Plots:

A cross plot is a way of illustrating how one variable changes with respect to another variable change. Cross plots between meter factor and each operating variable can lead to a better understanding of how a meter reacts to changes in each independent variable.

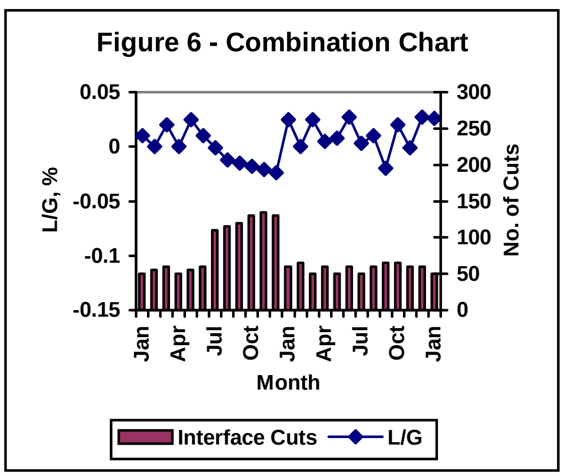
A cross plot of meter factor vs. flow rate on Figure 5, (sometimes known as a meter linearity curve), shows that meter factor increases as flow rate increases. This chart may be inspected to determine if meter factor appears to be reasonable based on flow rate.



Event and Combination Graphs:

Event Graphs may also be useful in analysis of pipeline loss/gain. The graphs indicate the frequency of specific events occurring during an analysis period. Events, such as the number of pipeline shutdowns, number of interface cuts or number of meter provings or ticket switches, are totaled and graphically represented for an inventory period. By themselves, the event graphs provide little insight into causes of gains and losses. However, when used in combination with L/G and other graphs they can assist in troubleshooting loss/gain problems.

A combination graph (see Figure 6) may be used for troubleshooting a L/G trending problem.

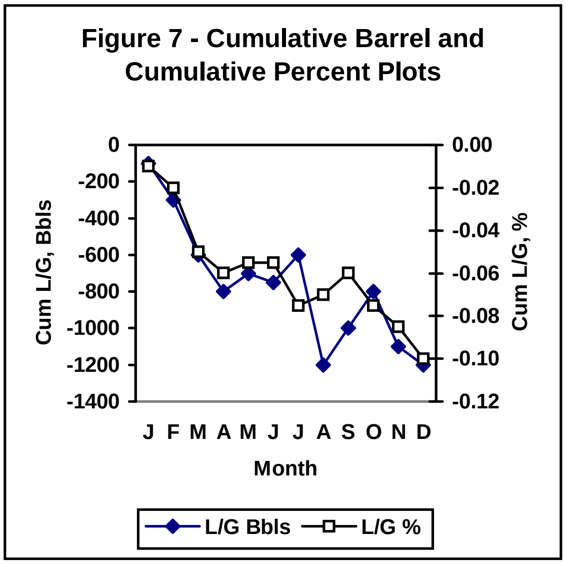


The L/G portion of the combination graph represents the L/G performance for each month. The L/G graph displays a small, but definite, trend beginning in the 7th month. When an event bar graph representing total interface cuts occurring each month is superimposed onto the L/G graph, a definite relationship between the downward L/G trend and the number of cuts (events) can be seen.

Other combination graphs may include, for example, number of meter provings, number of ticket switches, number of daylight deliveries, etc. If the events cause abnormal L/G, a relationship should be evident between the number of events and the L/G percent.

Cumulative charts:

Cumulative charts plot cumulative values of some variable (e.g., L/G) vs. time. The cumulative value is obtained by arithmetically adding the value of each data point to the sum of all the data points preceding it. Cumulative L/G data may be plotted as cumulative barrels or cumulative percent. See Figure 7.



The data in cumulative charts do not hover around a central mean value. They exhibit an upward or downward trend. The shape of the curve is the main characteristic of cumulative charts, and changes in shape or general trend are important.

Cumulative L/G charts often indicate the onset of a change before it is evident on a conventional control chart. A system that is performing normally will generally exhibit a steady trend. A sudden shift in the pattern or a change in the general slope of the data usually indicates that something happened.

Note that the “cumulative sum” data used for these charts is not the same as “Year to Date” which is a form of a “moving sum”.

In the cumulative sum method (Table 1), L/G percent is calculated for each time period, and each value of L/G percent is added to the sum of all the preceding values of L/G percent.

Table 1 – Cumulative Sum Method

Month	Thruput Bbls	L/G Bbls	L/G %	L/G Cum %
1	100,000	100	0.100	0.100
2	120,000	150	0.125	0.225
3	110,000	120	0.109	0.334
4	100,000	110	0.110	0.444

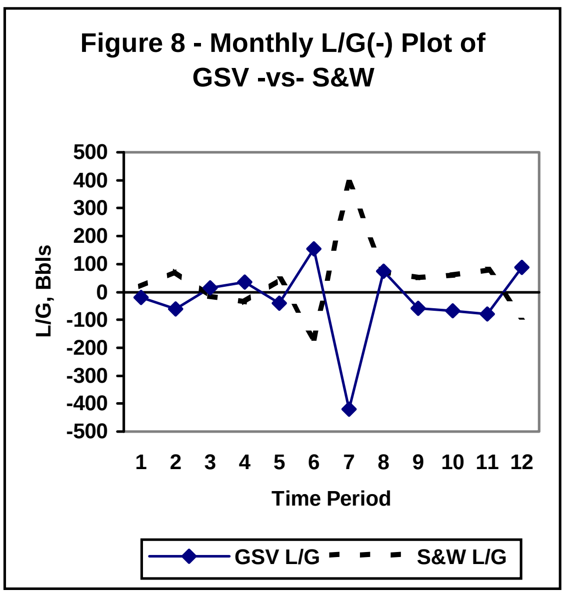
In the moving sum (YTD) method (Table 2), for each time period (1) the value of throughput bbls is added to the sum of all the preceding values of throughput bbls, (2) each value of L/G bbls is added to the sum of all the preceding values of L/G bbls, and then (3) each L/G bbl sum is divided by the corresponding throughput bbl sum and converted to percent. Using the same throughput (T/P) and L/G numbers as in the previous example:

Table 2 – Moving Sum Method

Month	T/P Bbls	L/G Bbls	Cum T/P Bbls	Cum L/G Bbls	L/G %
1	100,000	100	100,000	100	0.100
2	120,000	150	220,000	250	0.114
3	110,000	120	330,000	370	0.112
4	100,000	110	430,000	480	0.112

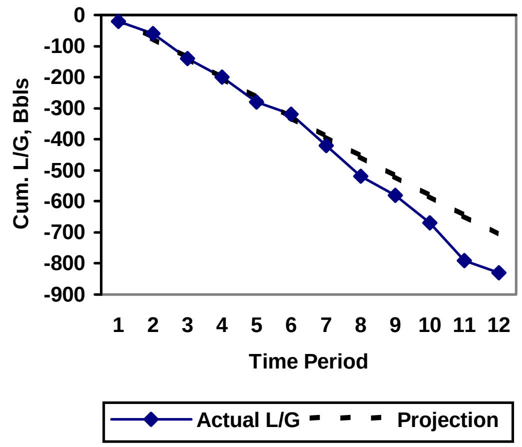
It should be apparent that a plot of the percent values from this moving sum would be a nearly horizontal line, which is not useful for our purposes.

As a rule, L/G is calculated using Net Standard Volume (NSV) that is volume at 60°F, “0” psig and no impurities, because this is custody transfer quantity. For crude oils, it can be enlightening to also plot one of the following (1) Gross Standard Volume (GSV) against NSV on the same chart. Generally, the two lines will be essentially parallel, separated by a small amount (equivalent S&W quantity). If one line suddenly trends away from the other, something changed in S&W measurement or sampling procedures. (2) Plotting GSV L/G against S&W L/G, Figure 8, will assist in determining if you have a quantity (GSV) or quality (S&W) determination problem, **or both**.



A cumulative chart, Figure 9, can be used to estimate the volume lost if there is actually a leak or spill. For this purpose, the cumulative barrel plot is most convenient, assuming no other measurement problems. The data before the leak, which in this example occurred about the seventh month, are used to develop a regression line that represents the typical behavior of the curve before the leak. The regression line is used to project what the system L/G would have been if the leak had not happened. In this example the leak was found and repaired in the eleventh month, and the accumulated loss by that time is 790 barrels. If no oil had been physically lost, the projected cumulative L/G would have been 640 barrels as estimated from the projected regression line. The difference of 150 barrels is the estimated loss due to the leak.

Figure 9 - Cumulative Barrel Plot Used to Estimate Quantity of Leak



Other Charts:

Multiple meter charts are discussed in the Chapter 13.2 of the API Manual of Petroleum Measurement Standards (MPMS). These charts may be useful from time to time for comparing the relative performances of a group of meters. The MPMS chapter should be referenced for more information on these types of charts.

The meter factors of a group of meters in a metering bank may be compared with each other to indicate a failing meter or measurable changes in the meter prover. If the meter factors for one meter start to show a pattern or trend which is different from the patterns of the other meters in the bank, that meter may be experiencing problems. On the other hand, if all meters in a bank start to show an unusual trend, the prover, which is common to all meters, may be in question (e.g. have leaking valves, defective switches, or may need to be recalibrated. Another avenue to pursue would be changes in chemical additives along the pipeline (e.g. corrosion inhibitor changes, antistatic additives, drag reducing agents, etc.).

INACCURACIES AND UNCERTAINTIES

Many everyday occurrences can cause inaccuracy or uncertainty in measurement and, thereby, contribute to losses and gains in a system.

Meters:

Meter factor is sensitive to almost every operating condition. Changes in flow rate, temperature, pressure and API gravity can cause measurable changes in meter factor. Expect a measurable change in meter factor with the following changes in operating conditions:

	Crude Oil	Products
Flow Rate (PD meter)	± 20 %	± 20 %
Flow Rate (Turbine)	± 10 %	± 20 %
Temperature	± 10 °F	± 30 °F
Pressure	± 50 psi	± 50 psi
Gravity	± 5 °API	± 10 °API

Meter factor may be very sensitive to changes in flow rate if the meter is operating outside the linear range.

Operating conditions - flow rate, temperature, pressure, etc. - must be stable before meter proving is started. It is possible to have five consecutive proving runs within 0.05% while the system is still stabilizing, and the average of those five runs would not be the true meter factor. Inspection of the data can determine when the system is stable.

Changes in fluid viscosity without a corresponding change in API gravity will cause a major shift in turbine meter factor. This is the effect of a DRA (Drag Reducing Agent) being used upstream of the meter.

Leaking valves in manifolds can permit liquid to bypass a meter, or permit liquid to enter or exit a system without being accounted for. Leaking block valves can cause errors in meter proving.

Dirty or dented field measures (water draw cans) will cause errors in prover calibration.

Using wrong meter factors on run tickets is a common source of error.

Tanks:

Tank tables may be slightly in error if tanks were strapped with incorrect strapping-tape tension, or if strappings were not corrected for temperature of the tape and/or the tank shell, or if liquid in the tank at the time of strapping were ignored.

Tank gauging may be inaccurate if tanks are tilted, have flexing bottoms, or the insides of the walls are coated with sludge and encrustation.

Tank tables that are not corrected for bulge due to hydrostatic head will be in error.

Temperature measurements in tanks may be wrong if thermometers are not suspended in the liquid long enough to reach thermal equilibrium.

An innage gauge may be in error if a free water layer in the bottom of a tank is frozen, thereby stopping the gauge-tape bob above the true bottom.

Measurements made in tanks with floating roofs in the critical zone are uncertain and may be subject to significant error.

Snow, water, ice or other debris on a floating roof will change the buoyant weight of the roof and result in a gauging error.

An unslotted gauge-well can result in erroneous liquid depth measurement in the gauge-well because the depth of the hydrostatic column in the gauge-well may be different from the depth of the hydrostatic column in the tank due to differences in liquid densities in the gauge well and in the bulk of the tank.
Outage gauge errors may be caused by r[illegible]n are loose or have moved. Reference

height markers on gauge-hatches affixed to the top of cone-roof tanks without gauging wells may be subject to vertical movement as a tank fills or empties due to flexing of the tank wall.

System and General:

Uncalibrated or non-NIST traceable equipment - such as thermometers, hydrometers, temperature gauges, gauge tapes and centrifuge tubes - may be inaccurate. If so, this will add a bias to the system L/G.

Perhaps the most common errors occurring on manually calculated run tickets are arithmetic errors and wrong correction factors pulled from tables.

Tickets, which don't get into the accounting process on time will cause an apparent loss or gain in one month and an offsetting gain or loss the next month.

Tanks which are gauged for inventory and which are moving at the time of gauging must be gauged at the same time of the same day, or stilled long enough to be gauged without liquid moving in or out.

Marine loading and unloading lines should always be either completely full or completely empty at the beginning and end of the loading or unloading operation. Marine lines often are very large diameter and/or long. As a result, the amount of liquid remaining in partially filled marine lines may be significant and cannot be measured.

Sampling in lines and tanks requires good mixing to assure that a representative sample is obtained.

Sumps collect drips and drain from a number of sources, and may add a bias to a system L/G if the sumps are emptied by pumping into a pipeline system without being measured. Usually, sump volumes are small enough to be insignificant. However, the volumes may be significant if sumps accumulate large volumes such as frequent drain downs from provers or scraper traps.

Real losses may result from uncontrolled evaporation of stocks or shrinkage due to mixing stocks with significantly different gravities or chemical composition.

Check for changes in measurement personnel (do changes occur when relief people are performing measurement activities?), measurement procedures, equipment and piping, computers and/or calculations, accounting practices, calibration of equipment. Perform a thorough inspection of the facilities and procedures.

Infrequent measurement training of personnel can weaken overall measurement and sometimes set up biases due to slightly different procedures at receipt and delivery points.

TROUBLESHOOTING

It is not uncommon for the problem solving process to take as long to resolve as it did for the problem to appear. With a keen eye for detail some losses can be resolved in minutes, whereas some may take weeks, months, or even longer.

Analyzing Measurement Data:

The first step in identifying losses involves a review of the data. A loss/gain report is usually the measurement personnel's tool to red flag that a system is out of control. So why not start by carefully reviewing the report and insure that input data was accurate and timely? Computer generated reports are only as good as the data entered. It is important to first understand the data entry process and then the integrity of the data used to populate the report.

Looking for the Obvious:

Custody measurement records such as tickets, proving reports, and meter performance logs can be obtained and reviewed from the office environment. Often, human error, equipment failure, or software glitches can quickly be identified. Measurement calculations should be reviewed to check for measurement error.

Reviewing records and historical data is of key importance. Look for patterns, often hidden among the noise caused by large month to month variations. Are step changes linked to operational changes at the facility? There are many possible operational changes that can affect reported losses. Areas of change to investigate are:

- Personnel
- Procedures
- Facilities
- Equipment
- Calibration of equipment
- Piping
- Computers/Calculations
- Security
- Accounting Changes

Interviewing Personnel:

The best method of identifying change is by interviewing the measurement personnel responsible for the system(s). This includes the measurement technician or gauger, as well as the electrical and mechanical technicians performing work at the sites. Supervisors who may have information pertinent to the entire process should also be consulted. The key to obtaining useful information from field measurement personnel is to establish a dialogue, which is non-offensive. Sharing ownership of the problem as well as the credit for the resolution is often the best approach.

Reviewing the Facility:

Another step in the process involves a visit to the measurement facilities to review the measurement system design, equipment and procedures. Then determine if the proper procedures are being followed in accordance with company and industry guidelines. Observe piping details, equipment placement, and visual records that may be indicators to or influence the measurement performance. Also, it is very important to be able to discuss the facility and its operation with the measurement personnel who conduct day-to-day activities. They usually know the facility much better than the investigator and can often provide a detailed history of changes for a facility.

RESOLVING THE LOSS OR GAIN

A loss investigation is successful when the cause has been identified and the appropriate actions are taken to resolve or correct the problem. A key role of the loss investigator is to thoroughly document the findings from background to resolution so there is a clear understanding of the problem, how the problem lead to a loss (or gain), and most importantly what is required to resolve the problem. Investigative reports should provide detailed recommendations and responsibility assignments to insure complete resolution.

IMPROVING THE MEASUREMENT SYSTEM

It is probably true that most measurement systems could be improved in one form or another. Unfortunately, improvements usually have associated costs. Justifications for these costs are usually decided based on some acceptable level of system performance, or in other words, the costs of the losses. It is important to understand the capabilities of a particular system and what uncertainty to expect in the monthly loss numbers. The uncertainty is difficult to assess and usually depends on the equipment and the procedures in-place.

An analysis of the measurement system can be used to define the current capability and the improvement that might be accomplished with upgraded equipment and procedures. Installing more accurate measurement equipment, using improved operational procedures, and instituting an on-going training program for measurement personnel should help pipeline L/G stability.

Monitoring losses and gains on pipeline systems is an essential part of the measurement process. Understanding the overall measurement process and utilizing a stepped approach to loss investigations can be valuable in launching improvement initiatives.

Step changes in losses or gains are usually the result of change in personnel, equipment, or procedures in the measurement process.

Establishing training programs, tightly controlled policies, and periodic assessment of measurement facilities are effective prevention measures which can eliminate the need to respond to audit or management concerns arising from pipeline losses.

There is a tendency in the industry today to "benchmark", i.e., compare the performance of one company against that of other companies. Benchmarking is a useful tool for some business aspects but not for others, such as "What is an acceptable normal loss/gain percentage?" It is important to understand that each pipeline, terminal, etc. is an individual with its own characteristics, and each system will establish a loss/gain pattern that is controlled largely by the measurement design, equipment and procedures of the system and, therefore, is unique to that system.

CONCLUSION

Troubleshooting pipeline losses involves an understanding of the loss/gain process, and requires collecting and analyzing data, interviewing measurement personnel, and visiting measurement facilities to assess equipment performance and witness measurement activities. Ultimately, loss investigations should include a conclusion of the findings along with recommendations for correction and improvements.

The examples in this paper are drawn mostly from pipeline operations, but the principles apply to any system, which includes (1) measurement into the system, (2) measurement out of the system, and (3) inventory within the system (including tanks, vessels, reservoirs, system piping, etc.). Such systems include pipelines, marine terminals, marine voyages, bulk loading or storage terminals, tank farms, rail and trucking systems.

Some change in loss/gain performance may be possible through improved procedures and better or more frequent calibration of equipment. But, major changes in "normal loss/gain" may require more or better equipment. Then it is a matter of economic justification. The cost to the system due to its losses may justify better equipment.

In any event, a well-designed, up-to-date monitoring procedure can describe the normal performance of a transportation or storage system, and can identify problems that need attention.

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