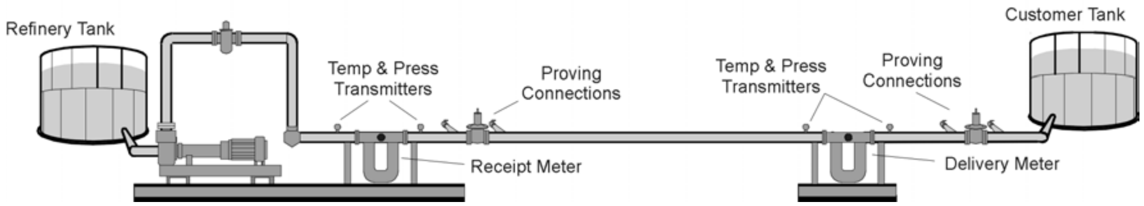
Statement of Problem:

It is the understanding of this author that Company X will attempt to control the loss or gain in a pipeline to within +/- 0.1%. The pipeline is between a Company X refinery and customers of the refinery. Fluids being transported by the pipeline are refined products that include gasoline, diesel, and LPG. The loss or gain in this pipeline, referred to in this paper as L/G, is the difference between the delivery meter measurement and the receipt meter measurement (see figure 1 below).

Actual L/G can be the result of theft, leaks, evaporation, or an error in the interface detection between two different grades of fluids transported in the pipeline. Any loss due to an error in interface detection should result in an offsetting gain of the other product involved in the interface detection.

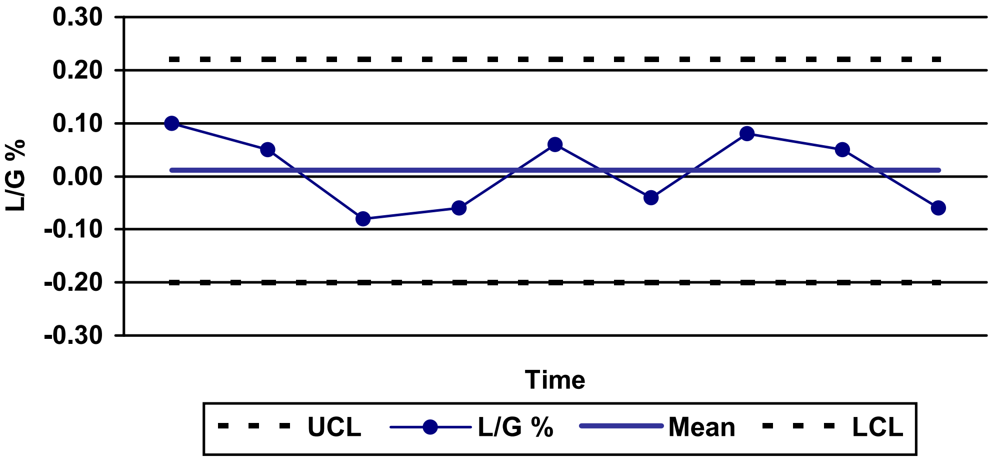
Figure 1 - Pipeline



Apparent L/G is normally the result of measurement inaccuracy. Measurement inaccuracy can be the result of equipment performance or human error.

Accurate fluid measurement requires continuous monitoring to determine if systems, equipment, and procedures are operating within acceptable limits. Continuous monitoring can be done by the use of Control Charts.

Figure 2 - Control Chart



An L/G control chart consists of a plot of % LG over time, the average (mean) LG, and control limits. The control limits define normal and abnormal system performance, and may indicate the occurrence of a system change or the need for corrective action.

The control chart in figure 2 shows a pipeline system with a statistical average (mean) L/G of 0.01%. The upper and lower control limits (UCL and LCL) are 3 standard deviations from the mean. Control limits can be fixed or calculated.

Measurement Accuracy:

There is no such thing as the perfect meter. Because of manufacturing limitations, all meters have a margin of error. This margin of error can be numerically or mechanically corrected in the field by meter proving. The numerical correction for a meter's margin of error is referred to as a Meter Factor and is determined by comparing a prover's known volume with the meter's indicated volume.

Meter Factor (MF) = Prover's Known Volume ÷ Meter Volume

A meter's margin of error (referred to a meter factor or MF from here forward) can be influenced by installation and fluid conditions. The effects of installation and fluid conditions on a meter's MF are dependent upon the meter's design. Table 1 illustrates the effects of fluid conditions on Positive Displacement and Coriolis technology.

Table 1 – Factors Affecting Meter Performance

	Positive Displacement	**Coriolis**
Flow rate	MF shift in the same direction as the change	Less affect
Density Change	MF shift in the same direction as the change	Less affect
Viscosity	MF shift in the opposite direction of the change	Less affect
Temperature	MF shift in the same direction as the change	Less affect
Pressure	MF shift in the same direction as the change	Less affect
Low lubricity	Increased wear results in an upward shift of MF	No affect
Entrained solids	Increased wear results in an upward shift of MF	No affect
Air slugs	Damage and replacement	No affect
Meter wear	Increased slippage results in an upward shift of MF	No affect

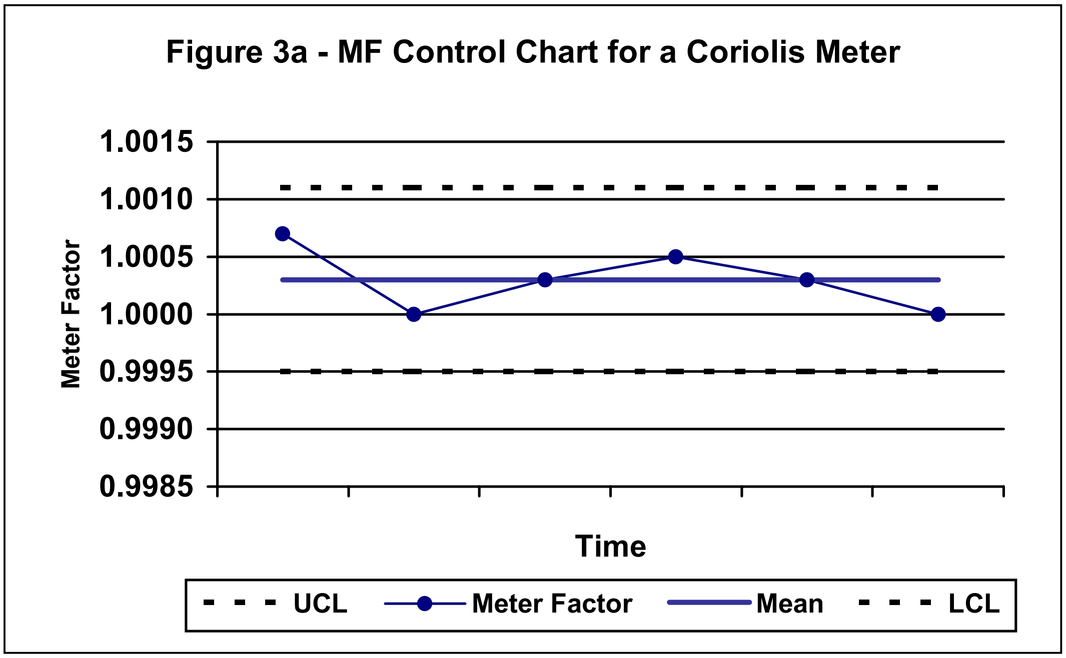
Because a meter's installation as well as fluid conditions can influence the meter' MF, accurate determination of the meter's MF requires that the meter be calibrated in line under normal operating conditions. The term “proving” refers to the act of calibrating a meter in its installation under normal operating conditions.

MF Control Charts

It is obvious that accurate measurement of product is critical to improving the measurement of actual L/G in a pipeline. Essentials of accurate measurement are: (1) A properly functioning meter and (2) An accurate Meter Factor (MF).

Control charts can be used in the case of MFs to evaluate a meter’s performance and to assess the validity of meter factors. An MF control chart contains a plot of meter factors, “control limits”, and a “mean”. Meter factors can be tested by comparing them for consistency with historical data.

Figure 3a is a control chart of MFs for a Coriolis meter. The mean MF is 1.0003, while the UCL and LCL are 3 standard deviations (+/- 0.0008) from the mean.



This chart shows little fluctuation in the MF of a Coriolis meter over time. This is due to the fact that Coriolis meters have no moving parts to wear. However, Figure 3b shows a significant shift in the MF of a positive displacement meter installed in the same pipeline in series with the above Coriolis meter.

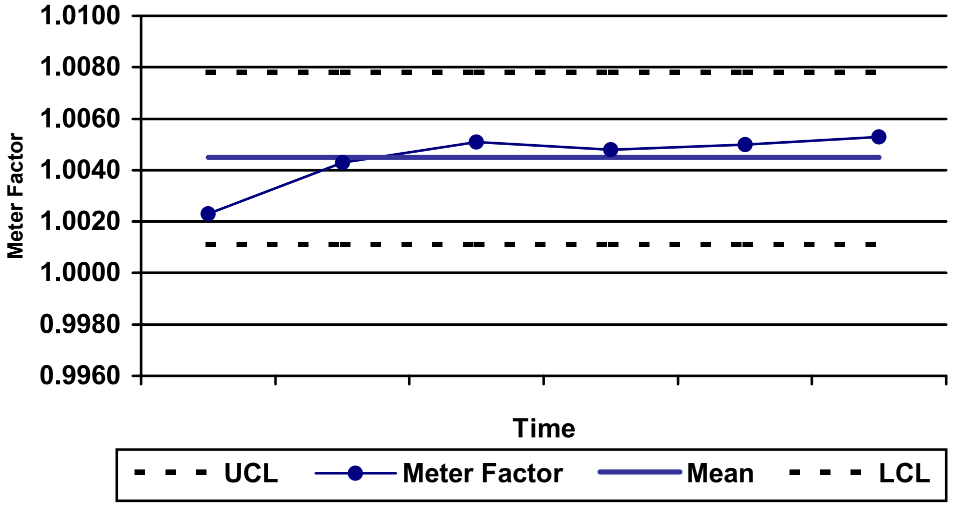


Figure 3b - MF Control Chart for a Positive Displacement Meter

The mean MF of the positive displacement meter in this same application is 1.0045. Based on the periodic proving data, the recommended controls limits of 3 standard deviations on this meter would be +/- 0.003.

The effects of fluid conditions and meter wear on the MF of a meter technology such a positive displacement make it necessary to prove the meter regularly and to tightly monitor its MF. To assess the accuracy of a meter's MF requires a historical record be kept of proving data including fluid conditions. Table 2 is a record of the proving data for the MFs plotted in the above control charts.

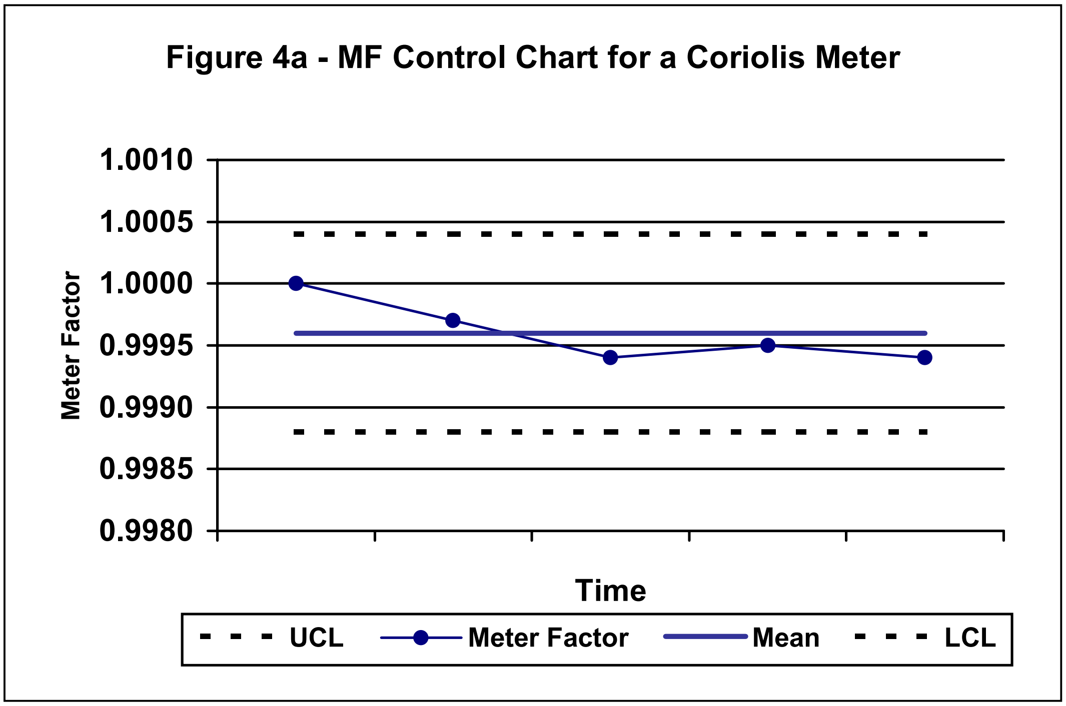
Table 2 - Proving Conditions

Date	Meter Temp.	Ambient Temp.	Pressure	Flow Rate BPH	API	P.D. MF	Coriolis MF
1/20/00	72.2	65	92	98	42.2	1.0023	1.0007
2/18/00	72.4	75	88	95	48.3	1.0043	1.0000
3/17/00	75.3	65	84	96	41.0	1.0051	1.0003
4/21/00	77.2	70	82	96	41.3	1.0048	1.0005
5/18/00	86.1	95	82	95	43.9	1.0050	1.0003
6/16/00	84.9	75	79	102	39.8	1.0053	1.0000

Without an accurate determination of MF, the Coriolis meter would under measure by an average of 880 gallons every 30 days. At the same time, the positive displacement meter would under measure by an average of 13,141 gallons.

Figures 4a and 4b are further illustration of the importance of utilizing reliable measurement equipment and establishing an accurate MF. Like the examples above, the Coriolis meter and PD meter are installed in series in the same pipeline. Each of the meters is proved under the same operating conditions using the same proving equipment.

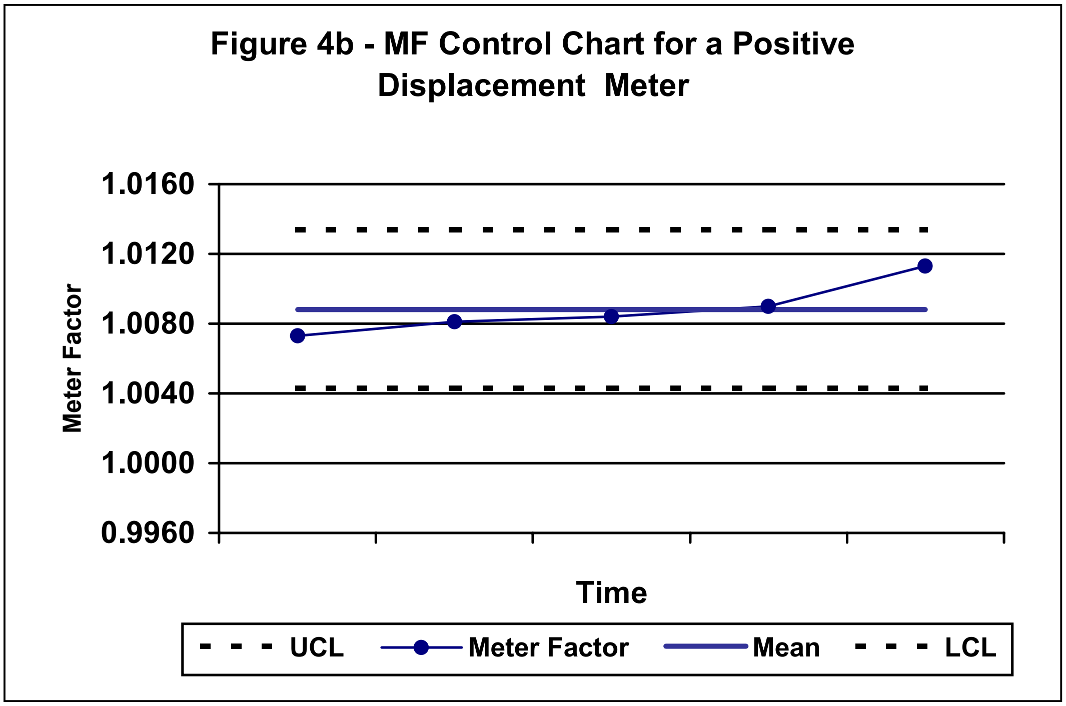
The Coriolis meter in Figure 4a has an average MF of 0.9996. The standard deviation of its MF from the average is 0.00026.



Date	Meter Temp.	Ambient Temp.	Pressure	Flow Rate	API	P.D. MF	Coriolis MF
1/25/00	55.5	50	30	115	46.1	1.0073	1.0000
2/29/00	69.1	65	29	116	42.8	1.0081	0.9997
3/28/00	79.0	65	28	116	41.8	1.0084	0.9994
4/25/00	75.2	65	27	116	41.7	1.0090	0.9995
5/3/00	85.1	80	28	116	41.2	1.0113	0.9994

The PD meter in this same system has an average MF of 1.0088. The standard deviation of its MF from the average is 0.0015.

Without an accurate determination of MF, the Coriolis meter would over measure by an average of 1401 gallons every 30 days. At the same time, the positive displacement meter would under measure by an average of 30,547 gallons.



Regular Meter Proving

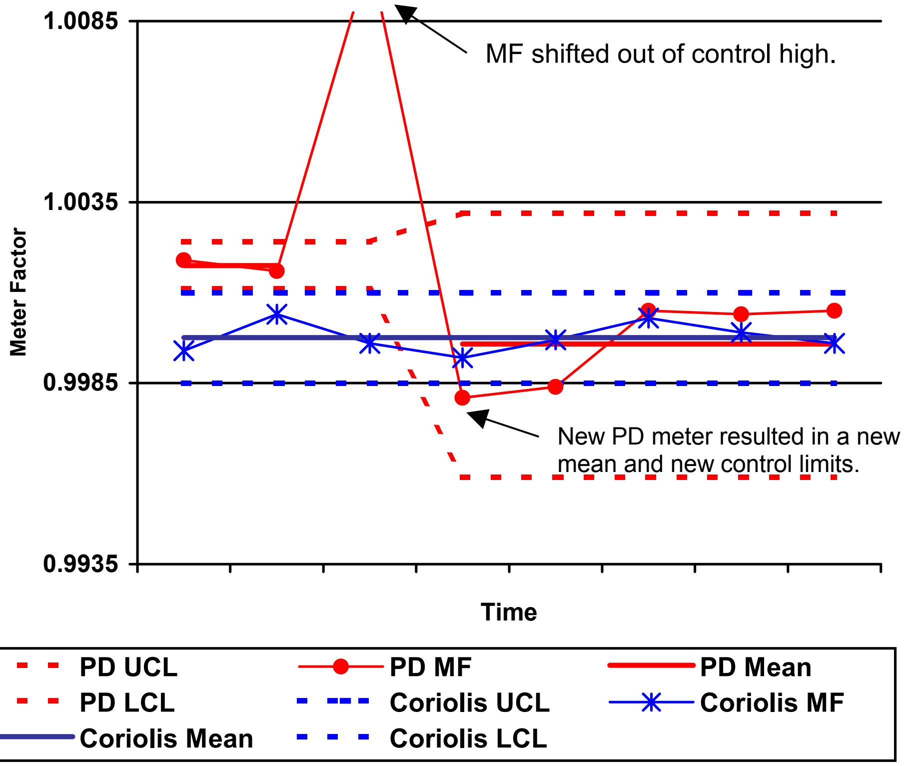
All the MF charts displayed in this paper are produced from actual provings and are typical for these two technologies. To learn more about the use of control charts for monitoring MF, refer to API Chapter 13.2 Methods of Evaluating Meter Proving Data.

Regular meter proving is important for two reasons: (1) Charted proving data provides a diagnostic tool as to the health of the meter and (2) Meter proving at actual operating conditions improves the accuracy of the meter's measurement performance.

The importance of regular meter proving is illustrated in Figure 5. Figure 5 is a plot of MFs from a PD meter and a Coriolis meter installed in series in the same pipeline. Each meter is proved every 30 days under the same conditions using the same proving equipment. There was a shift in the PD meter's performance between the 2nd and 3rd provings. The shift was above the upper control limit therefore prompting corrective action. It was determined that the meter should be replaced. The average MF for the new meter is 1.8% below the average MF for the old meter. The older PD meter had been under measuring due to wear. This change in the performance of the PD meter would have gone unnoticed without regular meter proving.

Using the MF from the 2nd proving would have resulted in the meter under indicating the flow by 0.9%. If unchecked, this shift would result in a loss of 34,667 gallons in a 30-day period.

Figure 5 - MF Control Chart for a Coriolis Meter



<u>Conclusion:</u>

No one can guarantee that two meters located in series will agree within +/- 0.1%. Improving measurement accuracy will reduce the apparent loss of product. The affects of temperature and pressure on the expansion of the product was not discussed in this paper but must be considered in comparing the measurement of one meter to another meter in series.

Meter design plays a significant role in measurement accuracy. A mechanical meter such as a positive displacement meter provides accurate measurement. However, it's accuracy is influenced by changes in fluid conditions and by time in service. The accuracy of an electronic based meter such as Coriolis is less influenced by changes in fluid conditions and time in service.

It is the experience of this author that Coriolis will provide you the best sustained accuracy necessary to achieve your goal of +/- 0.1% LG. It is also imperative that regular meter provings be performed to provide an accurate MF and to detect any changes in the system operation or meter performance.