STATISTICAL CONTROL OF METER FACTORS – A SIMPLIFIED APPROACH
Class # 2360

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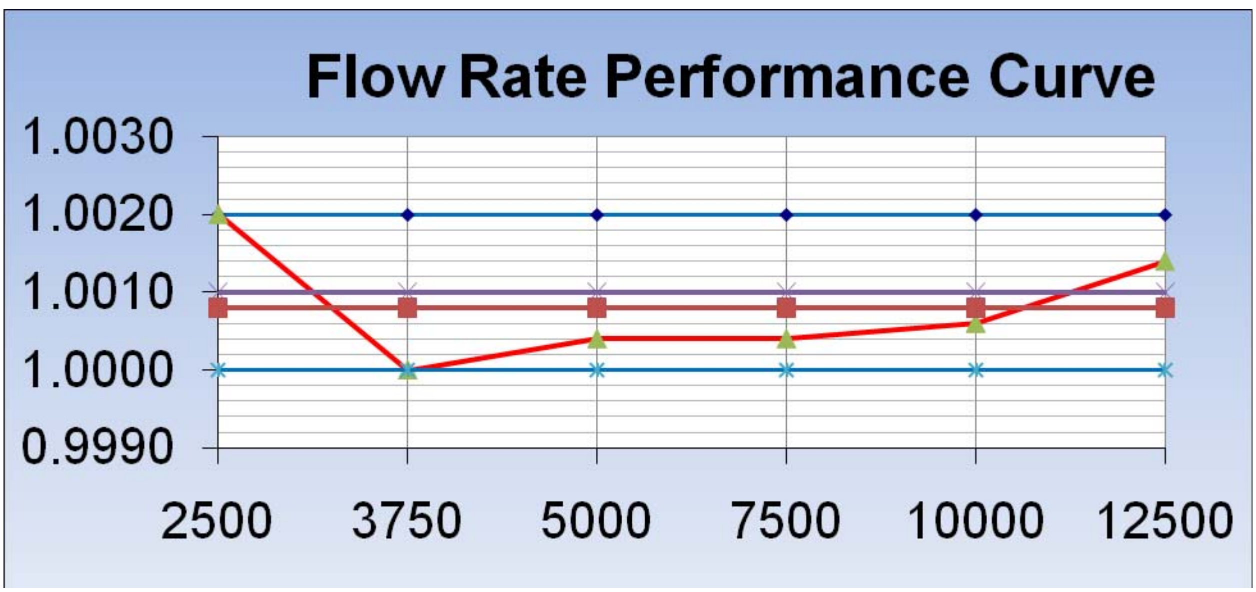
Introduction

This paper will give a brief overview description of a simplified method for monitoring the performance of a flow meter and performing the same exercise on each meter in the system. The idea is to provide graphical assistance, through the use of meter factor control charts in: (a) developing preventive maintenance programs; (b) heightening awareness of "alarm" situations, and; (c) reducing risk to the financial bottom line. Meter factor control charts and logs make it easier to prepare reports to maintenance, operations, financial and executive managers from time to time; and furthermore, they make it easier for the target audience to digest the points being made.

Basic Meter Performance Charts

There are many ways that meter performance can be charted for system loss control and trouble shooting purposes. This paper will concentrate on two types of charts used to simply monitor the performance of the meter itself for a single meter installation:

- Flow Rate Performance Curve
- Meter Factor Control Chart



Flow Rates 20% 30% 40% 60% 80% 100%

Meter Factor at each Point: Curve
Upper Linearity Point LIne: 1.0020
Median Meter Factor Line: 1.0010
Average Meter Factor Line: 1.0008
Lower Linearity Point Line: 1.0000

Flow Rate Performance Curve

On a given day, the meter may be proved at a number of points relating to the maximum design or maximum operating flow rates (e.g., 30%, 40%, 50%, 60%, 80% and 100%). This meter factor information can be used to calculate the linearity of the meter: [± ½] x [(MAX – MIN) / (AVG)] x [100] and can be used to characterize the meter for multiple flow rates on short batch operations (e.g., loading racks). This chart can be used as a tool to judge the condition of the flow meter from time to time. The following will illustrate a somewhat ideal case:

Meter Factor Control Chart

The Meter Factor Control Chart is used to monitor the performance of a flow meter on a batch and/or time basis. The period charted begins with an overhaul or replacement of the flow meter, and any cleaning/inspection of the meter which substantially alters the meter factor. Along with the basic chart of meter factors vs. batches and/or time, a detailed Control Log should be kept to monitor associated data as described below.

Meter Factor Control Log

The meter factor control is a log for each meter documenting the basic conditions at proving and the meter factor changes as they occur. Data from the Meter Factor Control Log is used to create the Meter Factor Control Charts. A typical Meter Factor Control Log sheet might have the following components:

- Location of meter skid (e.g., pipeline station)
- Meter identification (e.g., tag number, meter number etc.)
- Nominal KF
- Date of proving
- Proving report or sequence number
- Current Meter Factor (MF) or K Factor (KF)
- Lower Control Limit (LCL)
- Higher Control Limit (HCL)
- Mean of the last provings (e.g., the last 5 or some other number)
- Percentage change (delta %) in MF from previous proving to current proving
- Flow rate (BPH) at the time of proving
- API base gravity at the time of proving
- Viscosity at operating temperature
- Temperature (T) at the time of proving
- Pressure (P) at the time of proving
- Non-resettable accumulated total in barrels or other units at the time of proving
- Remarks: Noting initial proving, proving at end of trend and other events

Nominal K Factor (NKF)

The Nominal K Factor is in pulses per unit indicated volume (e.g., pulses per indicated barrel) as configured into the flow computer. A PD meter with a large numeral counter local readout that has an input drive of 8.4 revolutions per indicated barrel and a right angle drive of 1000 pulses per revolution could be said to have an NKF of 8,400 pulses per barrel for purposes of proving the meter.

Initial Proving

The initial proving is the first proving at the time of commissioning or after a meter repair as noted in the remarks section. In the case of Meter Factors it means that the Nominal K Factor configured into the flow computer is not changed for the duration of the control chart (from initial proving to next repair event). In the case of K Factors the new K Factor might be configured into the flow computer each time to effectively make all the Meter Factors equal to 1.0000. In that case the K Factors take the place of the Meter Factors on the control chart.

Lower Control Limit (LCL)

This is the lower limit to which the meter is never expected to exceed for its working life before it is repaired or it experiences some unusual changes in flow conditions (i.e., flow rates, temperatures, pressures). When the limit is exceeded, the Meter Factor Control Log should be consulted to see if there is a rational cause other than meter performance failure.

Upper Control Limit

This is the upper limit to which the meter is never expected to exceed for its working life before it is repaired or it experiences some unusual changes in flow conditions (i.e., flow rates, temperatures, pressures). When the limit is exceeded, the Meter Factor Control Log should be consulted to see if there is a rational cause other than meter performance failure.

Fixing the Upper and Lower Control Limits

When plotting meter factors it is the custom to simply subtract a fixed amount (e.g., 0.0025) from the initial meter factor for the Lower Control Limit and add that same fixed amount (e.g., 0.0025) to the initial meter factor for the Upper Control Limit.

When plotting K factors and setting the Lower and Upper Control Limits, multiply the initial K Factor by a fixed amount subtracted from 1.0000 (e.g., 1.0000 – 0.0025 = 0.9975) to obtain the Lower Control Limit, and multiply the initial K Factor by the same fixed amount added to 1.0000 (e.g., 1.0000 + 0.0025 = 1.0025) to obtain the Upper Control Limit.

Mean of the Last Provings

It is very useful to plot a running mean value. In the examples below, the running mean is plotted by calculating the mean of the last five Meter Factors and plotting that running mean value. This can also be done by taking the mean of all the meter factors since the initial proving for the updated mean. The second approach becomes less useful when the amount of data becomes very large. In other words, if things went very well for two years and then started changing, the running mean would not be as sensitive as it would be if the updated mean used a limited number of past provings. Situations vary but keep these thoughts in mind as you perform these exercises. It is likely that you would reach back further than the five proving shown in the example in many circumstances

Percentage Change from Proving to Proving

In addition to control limits it is helpful to take note of any large changes from one proving to the next. It is not necessary to plot this but the Meter Factor Control Log should be consulted after every proving. Company or regulating agency guidelines can also make this mandatory. The accepted value might or might not be the same as that used for the control limits (e.g., 0.0025 up or down). For example, suppose that the initial Meter Factor happened to be 1.0000 and 0.0025 is the chosen value for both control limits and the allowable percentage change. As time progresses the Meter Factors have been well with the upper and lower control limits and the previous MF happened to be 0.9985 while today's MF is equal to 1.0020. Today's MF would still lie well within the upper and lower limits of 0.9975 and 1.0025 but the percentage change from the previous MF to the current MF is 0.0035. In this case the allowable point to point change would be exceeded.

Flow Rate at the Time of Proving

These can be plotted as well but often just keeping a record of the flow rates in the Meter Factor Control Log will give a measurement person the tools he needs to see if changing flow rates are a problem in keeping the metering measurement under control. To get a really good sense of this, a separate plot should be made of Meter Factors vs. Flow Rates on a given day on the same product. A minimum of five or six flow rates should be tested in order to detect any "break points" in the meter factor curve. This is essentially how the meter manufacturer determines the linearity of a meter in water service. Systems that have excessive changes in flow rates might require more sophisticated graphing, archiving and linearization techniques.

API Base Gravity at the Time of Proving

The API base gravity is entered into the Meter Factor Control Log so that changing gravities can be monitored and compared to changing Meter Factors. In a multi-grade system this becomes more complex and some creative graphing, archiving and linearization techniques might have to be employed. In single grade systems the Meter Factor Control Log should be sufficient for analysis purposes.

Viscosity at the Time of Proving at Operating Temperature

Viscosity can often be a key element in analyzing cause of meter factor changes and so it is essential that, if known, it be entered onto a Meter Factor Control Log. For it to have maximum value in an analysis the other parameters must be reasonably stable. Viscosity itself is sensitive to temperature changes but does not follow a straight curve. Rather it might change in so called "steps" or plateaus. That is why it is so important to know the viscosity at the actual operating temperature. Empirically derived viscosity indexes on given liquids can be very useful in estimating the viscosity change from some reference temperature (e.g., 100 degrees F) to the operating temperature.

Temperature at the Time of Proving

Temperature is an essential entry to the Meter Factor Control Log. It is often used to make indirect estimates of viscosity changes when the viscosity value itself is unavailable. It is also useful in determining the likelihood of the building up or purging of in certain crude oil applications.

Pressure at the Time of Proving

Pressure is a useful entry to the Meter Factor Control Log but not as essential as some of the others. Mainly it is used to make indirect evaluations and reality checks on the other parameters (e.g., reasonable expectation of having enough back pressure etc).

Non-resettable Accumulated Totalizer Reading

The non re-settable totalizer reading in volume units (e.g., barrels, gallons, cubic meters, etc.) is a useful record for keeping track of the total throughput between meter repairs. It is also an indispensable tool when adjustments have to be made if the meter proving occurred between ticket periods. The reading taken should always be the non re-settable reading for audit trail purposes even though another column might show the throughput volumes between provings.

Remarks

Making suitable entries in the "remarks" section is a vital tool for being able to make sense of the data at a later date, and to facilitate any adjustments that might have to be made. As a minimum, it should note the initial proving of a Meter Factor Control Log cycle and when that cycle ends (e.g., due to a meter repair). The "remarks" sections is also the place to note any unusual events or flow conditions outside pre-determined parameters (e.g., flow rate changes, temperature changes, pressure changes, viscosity changes and/or API gravity changes).

Meter Factor Control Chart Review

The Meter Factor Control Chart is prepared from the data in the Meter Factor Control Log. Looking at a plot of meter factors is quite intuitive because the meter factors essentially hover around an axis of 1.0000. Even so it is very helpful to enter a lower control limit (LCL) and an upper control limit (UCL) so that visually one can easily digest the meaning of the graph. Looking at a plot of K Factors is not so intuitive because K factors vary considerably in their magnitude. Therefore, the Lower and Upper Control Limits are even more necessary with K factors because they provide needed help to the viewer to get a better sense of the chart.

Conclusion

Once Meter Factor Control Charts are being used in a consistent manner, the user will find that there are many other possibilities for graphing data in a meaningful way. This not only gives you effective tools for analysis but also provides you tools for presenting your analysis and conclusions to other interested parties.

See next three (3) pages for examples of:

- Meter Factor Control Log for Meter Factors
- Meter Factor Control Chart
- K-Factor Control Chart
- K Factor Control Log

Table 1 METER FACTOR CONTROL LOG

ISHM	VALLEY	PIPELINE	STATION	Meter ID Number		202	
				Nominal KF		1025	p/bbl
Date	**No.**	**MF**	**LCL**	**UCL**	**Mean (5)**	**delta %**	**BPH**
1/5/09	1	**0.9974**	0.9949	0.9999	0.9974	0.00%	720
1/15/09	2	0.9967	0.9949	0.9999	0.9971	-0.07%	732
1/25/09	3	0.9956	0.9949	0.9999	0.9966	-0.11%	744
2/5/09	4	0.9972	0.9949	0.9999	0.9967	0.16%	723
2/15/09	5	0.9957	0.9949	0.9999	0.9965	-0.15%	742
2/25/09	6	0.9963	0.9949	0.9999	0.9963	0.06%	746
3/5/09	7	0.9982	0.9949	0.9999	0.9966	0.19%	722
3/15/09	8	0.9987	0.9949	0.9999	0.9972	0.05%	742
3/25/09	9	0.9975	0.9949	0.9999	0.9973	-0.12%	735
4/5/09	10	0.9975	0.9949	0.9999	0.9976	0.00%	744
4/15/09	11	0.9990	0.9949	0.9999	0.9982	0.15%	725
4/25/09	12	0.9996	0.9949	0.9999	0.9985	0.06%	765
5/5/09	13	0.9998	0.9949	0.9999	0.9987	0.02%	777
5/15/09	14	0.9995	0.9949	0.9999	0.9991	-0.03%	788
5/25/09	15	0.9998	0.9949	0.9999	0.9995	0.03%	756
6/5/09	16	0.9998	0.9949	0.9999	0.9997	0.00%	765
6/15/09	17	0.9999	0.9949	0.9999	0.9998	0.01%	746
6/25/09	18	1.0060	0.9949	0.9999	1.0010	0.61%	722
No.	**API b**	**T**	**P**	**Barrels**	**Remarks**		
1	40.2	70.4	205	1,000,204	Meter Overhauled		
2	40.0	72.5	210	2,000,421	OK		
3	39.9	80.0	222	3,000,638	OK		
4	38.9	82.0	214	4,000,855	OK		
5	39.5	83.6	316	5,001,072	OK		
6	40.2	81.5	217	6,001,289	OK		
7	40.5	78.0	214	7,001,506	OK		
8	41.2	82.7	225	8,001,723	OK		
9	40.4	84.0	227	9,001,940	OK		
10	40.5	83.5	230	10,002,157	OK		
11	40.6	82.6	226	11,002,374	OK		
12	40.7	81.8	216	12,002,591	OK		
13	40.8	82.6	208	13,002,808	OK		
14	40.9	80.7	200	14,003,025	OK		
15	40.6	81.4	210	15,003,242	OK		
16	40.2	82.3	222	16,003,459	OK		
17	40.0	84.5	225	17,003,676	OK		
18	40.5	86.0	209	18,003,893	Meter needs repair		

Chart 1 METER FACTOR CONTROL CHART

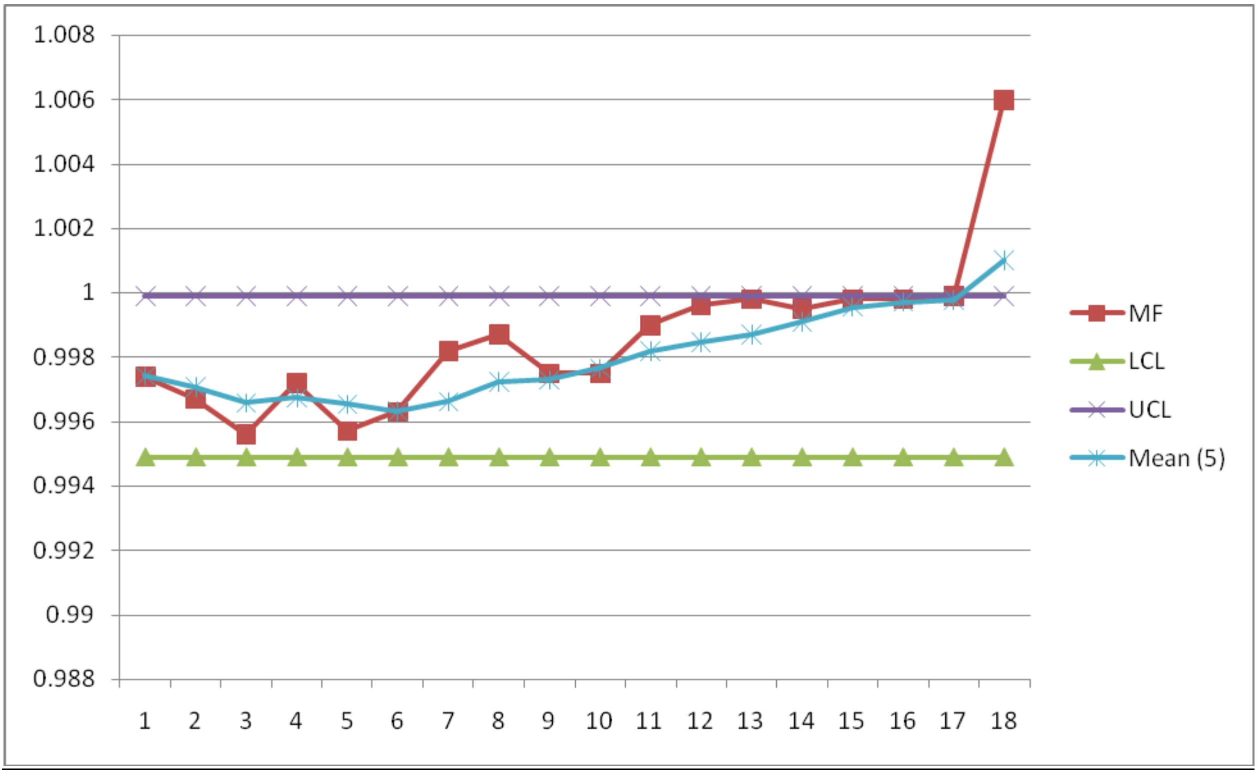


Chart 2 K FACTOR CONTROL CHART

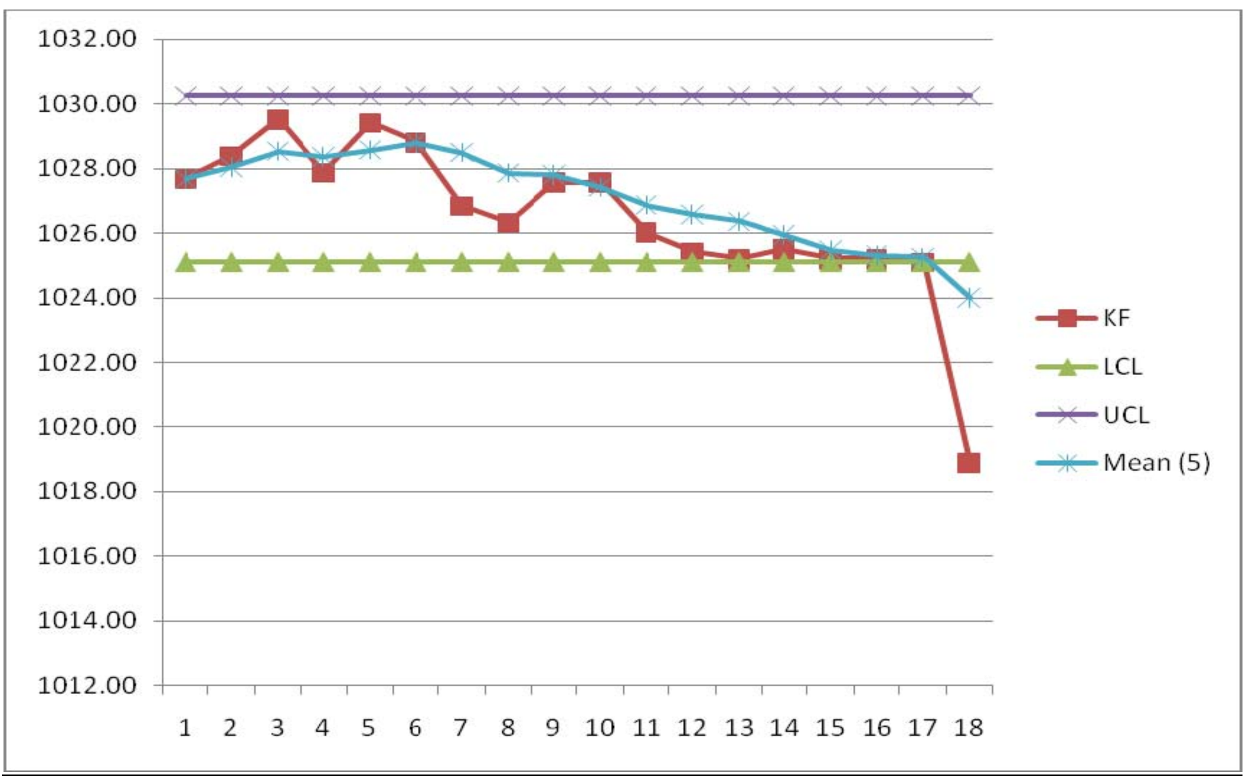


Table 2 K FACTOR CONTROL LOG

ISHM VALLEY PIPELINE STATION Meter ID Number 202

Date	No.	KF	LCL	UCL	Mean (5)	delta %	BPH
1/5/09	1	1027.67	1025.10	1030.24	1027.6719	0.00%	720
1/15/09	2	1028.39	1025.10	1030.24	1028.0328	0.07%	732
1/25/09	3	1029.53	1025.10	1030.24	1028.5319	0.11%	744
2/5/09	4	1027.88	1025.10	1030.24	1028.3684	-0.16%	723
2/15/09	5	1029.43	1025.10	1030.24	1028.5800	0.15%	742
2/25/09	6	1028.81	1025.10	1030.24	1028.8070	-0.06%	746
3/5/09	7	1026.85	1025.10	1030.24	1028.4979	-0.19%	722
3/15/09	8	1026.33	1025.10	1030.24	1027.8587	-0.05%	742
3/25/09	9	1027.57	1025.10	1030.24	1027.7969	0.12%	735
4/5/09	10	1027.57	1025.10	1030.24	1027.4254	0.00%	744
4/15/09	11	1026.03	1025.10	1030.24	1026.8693	-0.15%	725
4/25/09	12	1025.41	1025.10	1030.24	1026.5817	-0.06%	765
5/5/09	13	1025.21	1025.10	1030.24	1026.3558	-0.02%	777
5/15/09	14	1025.51	1025.10	1030.24	1025.9446	0.03%	788
5/25/09	15	1025.21	1025.10	1030.24	1025.4718	-0.03%	756
6/5/09	16	1025.21	1025.10	1030.24	1025.3076	0.00%	765
6/15/09	17	1025.10	1025.10	1030.24	1025.2461	-0.01%	746
6/25/09	18	1018.89	1025.10	1030.24	1023.9824	-0.61%	722

No.	API b	T	P	Barrels	Remarks
1	40.2	70.4	205	1,000,204	Meter Overhauled
2	40.0	72.5	210	2,000,421	OK
3	39.9	80.0	222	3,000,638	OK
4	38.9	82.0	214	4,000,855	OK
5	39.5	83.6	316	5,001,072	OK
6	40.2	81.5	217	6,001,289	OK
7	40.5	78.0	214	7,001,506	OK
8	41.2	82.7	225	8,001,723	OK
9	40.4	84.0	227	9,001,940	OK
10	40.5	83.5	230	10,002,157	OK
11	40.6	82.6	226	11,002,374	OK
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17	40.0	84.5	225	17,003,676	OK
18	40.5	86.0	209	18,003,893	Meter needs repair