CHARACTERISTICS OF ROTARY METER PERFORMANCE

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This paper highlights several rotary meter performance characteristics. These characteristics profile a rotary meter's capabilities in a wide array of applications from production to transmission, and distribution. Most of the characteristics have minimum standards adopted by agencies like AGA or ASTM. I'll identify these standards, and incorporate them where applicable into my paper. In discussing these characteristics, I hope to give the reader a better understanding of the capabilities of rotary meters, and how the gas industry assesses these characteristics. Here's the performance characteristics I'll discuss:

- Rangeability
- Start Rate
- Stop Rate
- Stating & Running Differential
- Accuracy

RANGEABILITY

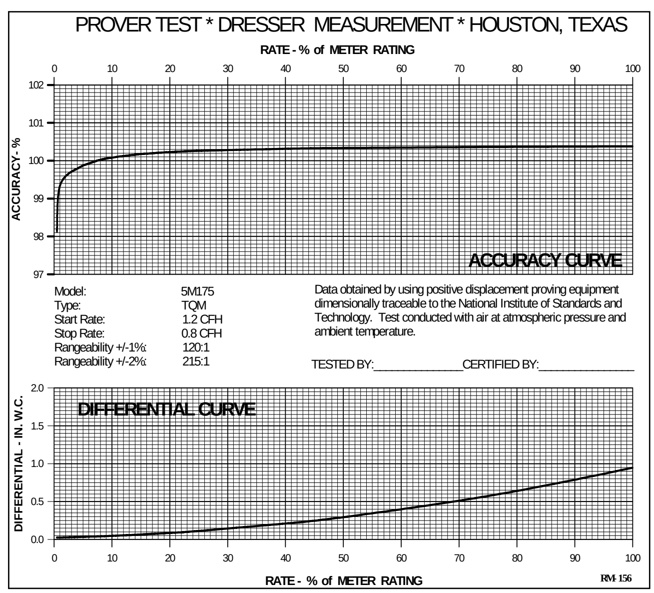
The most frequently used performance standard for a rotary meter is rangeability. Rangeability is a meter's maximum rated capacity in CFH divided by its minimum capacity. Minimum capacity is usually the flow where the meter's accuracy drops below a ± one-percent accuracy band. For example, you'd calculate the rangeability of a 5M175 as follows:

Maximum rated capacity of a 5M:	5,000 CFH
Capacity of 5M at minus 1% accuracy:	41.66
5M175 Rangeability:	120:1

Your rotary meter vendor can supply rangeability information for all the rotaries that you purchase. Typically gas distribution companies focus on rangeability at a ± one-percent accuracy band. You'll see published data for ± two-percent, and the meter's operational range. You calculate operational rangeability by dividing the meter's maximum flow rate by its start rate. I'll discuss start rates in the next section of this paper. Here's a table summarizing rangeability values from a large rotary meter vendor:

Meter Size	Rangeability: ± One Percent	Rangeability: ± Two Percent	Operational Rangeability
8C	26:1	46:1	286:1
11C	31:1	58:1	478:1
15C	40:1	78:1	789:1
2M	68:1	126:1	1053:1
3M	76:1	139:1	1429:1
5M	120:1	215:1	4167:1
7M	67:1	115:1	1321:1
11M	124:1	227:1	2821:1
16M	116:1	223:1	5000:1

If you have the characteristic accuracy curve for a rotary meter you can plot the point on the curve where accuracy reaches a ± 1% or ± 2% point. Since most manufacturers publish curves you have another method of calculating rangeability. Take a look at the following 5M175 accuracy curve:



If you plot the point where the accuracy curve crosses the 99% threshold, you'll see that the corresponding flow is a little less than one percent. This method won't enable you to derive the exact rangeability value. However it will enable you to estimate rangeability if you don't have the suppliers exact values.

START RATES

A rotary meter's start rate is simply the flow rate at which the impellers start and continue rotating. The start flow rate does not approximate a specific accuracy value. However, most rotary meters register 70 to 90 percent accuracy at the start rate. The specific accuracy value at starting flow will vary by manufacturer and meter size. The American Gas Association adopted a minimum-starting rate for rotary meters. You can find this standard in ANSI report number B109.3. This report details rotary meter construction standards, and acceptable performance levels. Regarding start rates, ANSI B109.3 specifies that each size starts and continues to run at less than or equal to 0.5 percent of rated capacity. Here's a table that highlights typical start rates and the minimum acceptable ANSI B109.3 standard:

METER SIZE	START RATE IN CFH	MINIMUM ANSI STND. IN CFH
8C	2.8	4
11C	2.3	5.5
15C	1.9	7.5
2M	1.9	10
3M	2.1	15
5M	1.2	25
7M	5.3	35
11M	3.9	55
16M	3.2	80

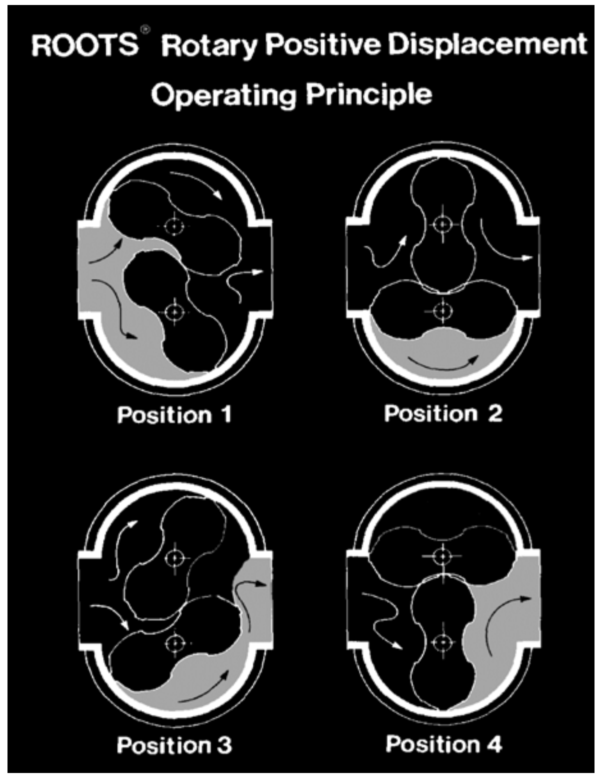
Calculating start rates requires some precision measurement equipment. Typically you'll need a test set-up that includes the following equipment:

- Laminar Flow Element: for measurement of the flow rate
- Liquid Manometer: for readout of the flow rate
- Rheostat: for flow rate adjustment
- Cadillac Blower: for air flow
- Barometer & thermometer: for pressure & temperature readings
- Stopwatch: for assessment of test duration
- Couplings & Flanges: for meter connections

In a typical start flow rate test set-up you pull air through the meter and laminar flow element with a blower. You then set the flow rate with the rheostat to the point where the meter impellers begin rotating. Next you continue adjusting the rheostat until you reach the minimum flow in which the impellers turn for *two minutes.* To assure test accuracy you should run the start test procedure 6 to 10 times. Then average these results for your final start flow. To derive the actual start flow rate you note the differential pressure at each start flow. Calculate the average differential. Plot this average on the calibration curve supplied with your flow element. From this plot you can derive the corresponding flow rate. Finally, you'll integrate pressure and temperature factors into your final calculation. Your flow element includes a chart for pressure and temperature correction factors. This procedure is the framework for an accurate assessment of starting flow rate. It's also the framework for an assessment of the stop rate I'll discuss in the next section.

STOP RATE

A rotary meter's stop rate is the flow rate where the impellers do not rotate. An examination of the following diagram illustrates this performance characteristic:



This diagram depicts the pockets of gas trapped between the meter impeller and cylinder. During each impeller rotation, the rotary meter traps four pockets of gas. There's a small gap between the impeller edge and cylinder. This gap, typically in thousands of an inch, varies by meter size. At the rotary meter's stop rate, gas flows through this gap unmeasured. You assess the stop flow rate in a similar manner in which you assessed the start flow rate. One step in the start rate test procedure, not mentioned in the previous section, requires a determination of the flow where impellers do not rotate. Most rotary meter vendors publish this data. It's very useful in judging the rotary's overall performance capabilities. Here's the stop rate data published by one major rotary meter vendor:

METER SIZE	STOP RATE IN CFH
8C	2.0
11C	1.7
15C	1.6
2M	1.1
3M	1.8
5M	0.8
7M	3.4
11M	3.2
16M	1.9

The difference between the start and stop rate for a specific size is due to test parameters. Remember the start rate flow is sustained for two minutes. Flows between the published start and stop rates due not meet the two minute duration criteria. The next performance criteria I'll discuss concerns pressure drop across the meter.

STARTING & RUNNING DIFFERENTIAL

Differential pressure measurements are an important component of rotary meter performance assessment. A rotary meter's differential characteristics reflect an array of performance capabilities. I'll group these capabilities as minimum standards, and as an indication of changes in meter accuracy. First let's examine the ANSI differential standards. The ANSI B109.3 standard requires a *minimum* starting differential, and the publication of running differential values. This standard mandates the documentation of the differential at starting flow. Moreover, the starting differential shall not exceed 0.10-inch water column when tested with air at atmospheric conditions. The following table shows one manufacturer's compliance with this part of the ANSI B109.3 standard:

METER SIZE	AVG START ΔP		AVG RUNNING ΔP*	
	AIR	GAS (0.6 SP)	AIR	GAS (0.6 SP)
8C	.01	.006	.346	.208
11C	.005	.003	.459	.275
15C	.014	.008	.590	.354
2M	.006	.004	.639	.383
3M	.008	.005	.828	.497
5M	.005	.003	.946	.568
7M	.013	.008	1.270	.762
11M	.007	.004	1.387	.832
16M	.009	.005	1.641	.985

* Differential at 100% flow rate

Running differential is important at many different flow rates other than full capacity. Since producers and LDCs use differential testing for maintenance purposes, we need data at all of a meter's operating flows. If you develop a differential curve—at least three flow rates—upon initial installation, you can use differential testing to determine if a meter's accuracy has changed from the last test. Therefore the manufacturers curve, if operating pressure is below 15 PSIG, or your own curve for elevated pressures are important. The curves show that differential pressure changes as flow or pressure increases, and as internal resistance builds due to dirt or foreign materials.

Another important issue concerning rotary meter differentials is their performance in low-pressure systems. The running differential data shown in the previous table is at each meter's maximum flow rate. As the values in the gas column show, each meter size does not have pressure drops high enough to cause problems in the low-pressure systems found in urban areas.

ACCURACY

In the concluding section of this paper I'll discuss rotary meter accuracy from two perspectives. First, I'll profile the B109.3 accuracy standard. Secondly, I'll discuss overall rotary meter accuracy. Overall rotary accuracy incorporates many of the operating characteristics—rangeability, start/stop rates—I've discussed in this paper.

The ANSI B109.3 standard mandates that rotary meters initial accuracy, at 10 to 100 percent of flow, be 100 ± 1 percent. Additionally B109.3 requires manufacturers to perform accelerated life tests on each meter size. The manufacturer must operate the meter at 100 percent of flow for 4,000 hours. After this accelerated life test the sustained accuracy must be with the same tolerance (100 ± 1 percent at 10 to 100 percent of capacity). The following table highlights one vendors initial and sustained accuracy test results:

METER SIZE	INITIAL ACCURACY		SUSTAINED ACCURACY	
	10%	100%	10%	100%
8C	99.33	100.09	99.61	100.25
11C	99.43	100.11	99.65	100.08
15C	99.55	100.13	99.55	100.22
2M	99.60	100.04	99.65	100.20
3M	100.10	100.34	99.97	100.22
5M	100.21	100.54	100.15	100.54
7M	100.30	100.45	100.27	100.59
11M	100.04	100.36	100.00	100.50
16M	100.24	100.60	100.21	100.74

Now I'd like to tie together the characteristics I've discussed in this paper. Real world applications subject rotaries to varying periods of start flows, stop flows, and maximum flow-rates. How do today's meters perform in widely varying flow conditions? By calculating overall accuracy you can answer this question. Since manufacturers publish characteristic accuracy curves you can calculate the hour by hour or day by day accuracy of a rotary meter. The following examples utilize performance characteristics of *new meters*. You can temper the results with in-service performance data if your company tracks as-found accuracy tests. Let's take a look at two examples.

My first theoretical example is a fast food restaurant load with a 15C175 rotary meter and a 10 PSIG delivery pressure. I'll profile the overall rotary meter accuracy for a twenty-four hour period. Since the rotary meter manufacturer publishes start/stop data, and characteristic accuracy data for the meter's full operating range, we can derive the accuracy over this twenty-four hour period. Here's a summary of the flows, time variables, and accuracy's for this example:

24 HOUR OVERALL ACCURACY FOR 15C175 FAST FOOD LOAD

Flow Rate (CFH)	Stnd. Flow Rate (SCFH)	Hours (H)	Act. Volume (SCF)	Accuracy (%)	Measured Vol. (SCF)
800	1,325	4	5,301	100.18	5,310
250	414	4	1,656	99.98	1,656
100	166	3	497	99.55	495
35	58	5	290	98.33	285
1	2	8	13	0.00	0

Total Measured Volume: 7,746 (SCF)
Total Actual Volume: 7,757 (SCF)
OVERALL ACCURACY: 99.8573 %

In determining overall accuracy I used the 15C's published accuracy—from the accuracy curve and B109.3 performance summary—for each of the five flow and duration conditions. With this information I calculated measured volume (column six). Overall accuracy is simply total measured volume divided by total actual volume. This approach can help you determine overall accuracy for many different applications. Let's take a look at a different theoretical load. In this example I'll determine overall accuracy for a one year time period:

365 DAY OVERALL ACCURACY FOR 3M175 OFFICE BUILDING LOAD

Flow Rate (CFH)	Stnd. Flow Rate (SCFH)	Hours (H)	Act. Volume (SCF)	Accuracy (%)	Measured Vol. (SCF)
1	1	115	3,073	0.00	0
2	2	60	3,207	0.00	0
4	4	30	3,207	82.51	2,646
10	11	30	8,016	90.44	7,250
20	22	30	16,033	97.60	15,647
200	223	30	160,326	99.85	160,079
400	445	20	213,768	100.06	213,904
1,500	1,670	15	601,222	100.23	602,629
2,000	2,227	20	1,068,839	100.26	1,071,619
3,000	3,340	15	1,202,444	100.32	1,206,251

Total Measured Volume: 3,280,025 (SCF)
Total Actual Volume: 3,280,134 (SCF)
OVERALL ACCURACY: 99.9966 %

Using new meter accuracy data we can easily calculate overall rotary meter accuracy. Overall accuracy incorporates all the rotaries performance characteristics from start rate flow rates through 100 percent capacity. This approach to accuracy assessment provides a good starting point in determining the viability of a rotary in your measurement applications. Compare overall accuracy with historical performance information, and you'll get a clear picture of what the rotary can do.

During the last thirty years rotary meter manufacturers have made great strides in improving all performance characteristics. New materials (cast iron to aluminum), better machine tools (manually operated to computer controlled), and better business process (quality inspectors to statistical process control) have paved the way to improved rotary meter performance characteristics. The future holds many more improvements as manufacturers continue researching technological changes.