Guidelines for the Selection and Operation of Provers with Micro Motion ELITE® Coriolis Flow Meters

Micro Motion® ELITE® flow meters are high-precision Coriolis flow meters that are often used in the oil and gas industry in conjunction with volume provers. These guidelines are designed to aid in the selection of a prover size that will result in consistent proving repeatability, while taking into consideration the balance between:

• **Maximum proving efficiency**

• **Minimum prover size and cost**

• **Minimum prover wear and maintenance**

Substantial experience from laboratory testing and field proving forms the basis of the prover size recommendations and the Total Prove Time (TPT) predictions in these guidelines. However, results may vary if unstable process conditions exist during proving.

It should be noted that these guidelines are based on conservative estimates from the available data. If repeatability requirements are already consistently being met, there is no need to change the process or the prover size.

Proving Methods and Proving Data Evaluation

The *American Petroleum Industry (API) Manual of Petroleum Measurement Standards (MPMS) Chapter 4.8, Second Edition, Operation of Proving Systems, Annex A, Evaluating Meter Proving Data* explains the relationship between the number of proving runs, the observed repeatability, and the random uncertainty of the resulting meter factor. One important principal is that a lower meter factor uncertainty will always result as more runs are collected and averaged.

Prover Sizing and Selection for Fixed-Volume Provers (Does Not Apply to Master Meter Provers)

Important Note: The prover size should never result in a pass time of less than 0.5 seconds or a pre-run time of less than 0.25 seconds.

Total Prove Time (TPT) is defined as the total accumulated amount of time during which the prover displacer was travelling between the detector switches. The minimum TPT that is needed to achieve the target meter factor random uncertainty can be used to size the prover.

Estimated minimum TPT values that may be expected to pass repeatability requirements for different meter sizes and flow rates are shown in Table 1. The velocity of the fluid as it travels through the meter flow tubes is also shown in Table 1 in units of feet per second (fps). Velocities above 60 fps are not recommended when proving with a fixed-volume prover and may result in excessive TPT to pass repeatability. For applications above 60 fps, master meter proving is recommended instead of fixed-volume provers.

Equation 1 describes TPT:

$$TPT = \frac{\text{Base Prover Volume(BPV)}}{\text{Flow rate}} \times (\# \text{ of runs}) \times (\# \text{ of passes per run})$$

To use Table 1 to size a prover, there are two methods to select from:

Method 1 (Determine the BPV): Find the minimum TPT value from Table 1. Multiply the flow rate by 0.0117 to convert from BPH to gallons per second. Then enter the TPT, flow rate, the number of runs, and the passes per run (if averaging multiple passes per run) into Equation 2 to find the minimum BPV needed in gallons.

Equation 2:

$$BPV = \frac{\text{TPT x Flow Rate}}{(\# \, of \, \text{Runs}) \times (\text{Passes per Run})}$$

Example: CMFHC4 meter at 6500 BPH

- **From Table 1: Velocity ≈ 30 fps. TPT = 20 seconds.**

- **Convert: 6500 BPH X 0.0117 = 76 gallons per second**

- **If 5 single-pass runs are required, BPV = (20 seconds X 76 gallons per second) ÷ (5 runs X 1 pass per run) = 304 gallons or 7.2 BBLS.**

- **If 10 runs and 3 passes per run are acceptable, BPV = (20 seconds X 76 gallons per second) ÷ (10 runs X 3 pass per run) = 50 gallons or 1.2 BBLS.**

Method 2 (Determine the Number of Passes Needed): Find the minimum TPT value from Table 1. Multiply the flow rate by 0.0117 to convert from BPH to gallons per second. Then, insert the flow rate and a BPV in gallons into Equation 3 to estimate the total number of passes that will be needed for a prover size with that BPV. If averaging multiple passes per run, divide the total number of passes needed by the number of runs and round up to determine the minimum number of passes per run needed. For single-pass runs, the number of runs needed will equal the total number of passes needed.

Equation 3:

$$Total \; \# \; of \; Passes = TPT \times \frac{\text{Flow rate}}{\text{Base Prover Volume(BPV)}}$$

Example: CMF400 meter at 2300 BPH

- **From Table 1: Velocity ≈ 40 fps. TPT ≈ 30 seconds.**

- **Convert: 2300 BPH X 0.0117 = 27 gallons per second**

- **If the BPV is 170 gallons (4 BBLS), Total # of passes = 30 seconds X 27 gallons per second ÷ 170 gallons = 5 total passes**

  (5 total passes ÷ 5 runs = 1 pass per run for 5 runs).

- **If the BPV is 65 gallons (1.55 BBLS), Total # of passes = 30 seconds X 27 gallons per second ÷ 65 gallons = 12 total passes**

  (12 total passes ÷ 5 runs = 3 passes per run for 5 runs).

ELITE® Coriolis Flow Meters

CMF200	CMF300	CMF350	CMF400	CMFHC2	CMFHC3	CMFHC4	
						Above 60 fps	
						40-60 fps, 30-75 sec TPT	13,000 BPH
					Above 60 fps	30-40 fps, 20-30 sec TPT	8500 BPH
				Above 60 fps	40-60 fps, 30-75 sec TPT		6500 BPH
			Above 60 fps				5700 BPH
		Above 60 fps			30-40 fps, 20-30 sec TPT	15-30 fps, 20 sec TPT	5200 BPH
				40-60 fps, 30-75 sec TPT			4250 BPH
	Above 60 fps						3500 BPH
			40-60 fps, 30-75 sec TPT	30-40 fps, 20-30 sec TPT			3250 BPH
					15-30 fps, 20 sec TPT		2600 BPH
Above 60 fps						7.5-15 fps, 10 sec TPT	2300 BPH
			30-40 fps, 20-30 sec TPT	15-30 fps, 20 sec TPT			2200 BPH
							2125 BPH
		40-60 fps, 30-75 sec TPT					1740 BPH
						up to 7.5 fps, 5 sec TPT	1625 BPH
							1500 BPH
		30-40 fps, 20-30 sec TPT	15-30 fps, 20 sec TPT				1300 BPH
	40-60 fps, 30-75 sec TPT	15-30 fps, 20 sec TPT		7.5-15 fps, 10 sec TPT			1100 BPH
					7.5-15 fps, 10 sec TPT		1060 BPH
	30-40 fps, 20-30 sec TPT						870 BPH
			7.5-15 fps, 10 sec TPT				750 BPH
	15-30 fps, 20 sec TPT			up to 7.5 fps, 5 sec TPT			640 BPH
		7.5-15 fps, 10 sec TPT					550 BPH
40-60 fps, 30-75 sec TPT			up to 7.5 fps, 5 sec TPT			> ±0.1% accuracy	470 BPH
	7.5-15 fps, 10 sec TPT				up to 7.5 fps, 5 sec TPT		435 BPH
30-40 fps, 20-30 sec TPT							320 BPH
		up to 7.5 fps, 5 sec TPT		> ±0.1% accuracy			275 BPH
15-30 fps, 20 sec TPT			> ±0.1% accuracy		> ±0.1% accuracy		220 BPH
7.5-15 fps, 10 sec TPT	up to 7.5 fps, 5 sec TPT	> ±0.1% accuracy					160 BPH
							110 BPH
up to 7.5 fps, 5 sec TPT							55 BPH

Table 1. Estimated Minimum Total Prove Time (TPT)

Values shown are the velocity inside the meter in feet per second (fps)

followed by the Total Prove Time (TPT) in seconds.

TPT = prover pass time X passes per run X runs per proving*
(*total number of runs required to reach ±0.027% meter factor uncertainty may vary.)

ELITE® Coriolis Flow Meters

CMFS050	CMFS075	CMFS100	CMFS150	
			Above 60 fps	
		Above 60 fps	40-60 fps 30-75 sec TPT	250 BPH
	Above 60 fps		30-40 fps 20-30 sec TPT	170 BPH
Above 60 fps		40-60 fps 30-75 sec TPT		160 BPH
		30-40 fps 20-30 sec TPT	15-30 fps 20 sec TPT	120 BPH
				110 BPH
	40-60 fps 30-75 sec TPT	15-30 fps 20 sec TPT		80 BPH
			7.5-15 fps 10 sec TPT	60 BPH
	30-40 fps 20-30 sec TPT			55 BPH
40-60 fps 30-75 sec TPT				48 BPH
	15-30 fps 20 sec TPT	7.5-15 fps 10 sec TPT		40 BPH
30-40 fps 20-30 sec TPT			up to 7.5 fps 5 sec TPT	30 BPH

Table 1 (cont.) Estimated Minimum Total Prove Time (TPT)

Increasing the BPV will result in meeting the minimum TPT with fewer passes. Increasing the number of passes will allow reaching the minimum TPT with a smaller prover. A decision may be made either to size the prover with a smaller BPV (lower capital investment) with a longer overall proving time, or with a larger BPV with reduced runs (less long-term wear and tear) and shorter overall prove time.

Prover Conditions

It is important to prove at conditions that are as similar as possible to the expected operating conditions. There are many conditions and factors that can influence the success of proving systems.

- Prover equipment and all supporting reference measurement devices must be well-maintained and verified to ensure measurement traceability, reproducibility, and repeatability (API MPMS Ch. 4 and Ch. 21.2, paragraph 2.11).

- Stability of flow rate, density, temperature, and pressure is critical during proving. System design, prover settings, and maintenance can all impact flow rate stability during proving.

- The liquid inside the piping connecting the meter to the prover should remain stable.

  o Minimize piping between the meter and prover.

  o Avoid dead-end branches between meter and prover that may act as a volume "spring" with compressible fluids.

- Sufficient back pressure must be maintained on both the prover and the meter to avoid vapor breakout and to maintain a stable flow rate during displacer launch and travel. Minimum recommended back pressure is shown by Equation 4 (from API MPMS Ch. 5.6).

Equation 4: $\rho_b \geq 2\,\Delta\rho + 1.25\,\rho_e$
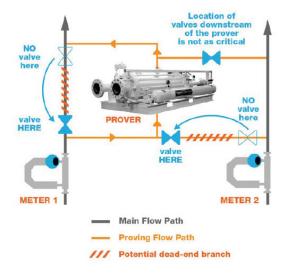
Where: ρ_b = Minimum back pressure (psig)

$\Delta\rho$ = Pressure drop across meter at max. flow rate

ρ_e = Equilibrium vapor pressure at operating temperature (psia)

- Accurate prover density measurement is crucial when mass proving with a volumetric prover. The following tolerances are advised when using a pycnometer (API MPMS Ch. 14.6).

  o Max. temperature difference = 0.2 °F
  o Max. pressure difference = 1 psi
  o Density Meter Factor (DMF) repeatability should be 0.05% or better between consecutive pycnometer tests

- Flow pulsation from PD pumps, including lack of back-pressure regulation, may influence repeatability and additional passes may be needed to meet random uncertainty requirements.

- Enabling compensation for the effect of pressure on the meter (consult the Transmitter Configuration and Use Manual) can improve repeatability in applications where line pressure varies by more than 30 psig during proving runs.

ELITE® Coriolis Flow Meters

Proving loops with a shared prover

To avoid dead-end paths upstream of the prover when proving Meter 1, locate divert valves for Meter 1 proving loop as shown.

- Main Flow Path
- Proving Flow Path
- Potential dead-end branch

Meter Operation

When using smaller provers, it is important to ensure that the meter is configured for optimum filtering and speed of response.

1. Select the fastest speed of response available:

    o 5700 transmitter: select "Low Filtering" response mode

    o 2700 transmitter: select "Special" for Update Rate and either "Special" or "Low Filtering" for Calculation Speed

2. Set flow damping to a value between 0.0 and 0.08 seconds.

3. Set density damping to 0.16 seconds.

• Proving Wizard software is available from Emerson to aid in preparing Micro Motion Coriolis meters for proving

Coriolis flowmeters do not have a fixed K-factor (number of pulses output per unit of flow). The number of pulses output per unit of flow (e.g. pulses per barrel) from a Coriolis meter is an adjustable parameter that can be set to any desired value. However, the frequency of pulses during the highest flow rate must not exceed the pulse input capacity of the prover pulse counting device.

API MPMS Chapter 5.6 Measurement of Liquid Hydrocarbons by Coriolis Meters defines a pulse scaling factor (PSF) as the number of pulses output by a Coriolis meter per unit of flow. In this way, a Coriolis meter PSF is like a mechanical meter's K-factor, but adjustable.

Micro Motion transmitters typically provide a frequency output of up to 10,000 Hz (10,000 pulses per second). Many field device pulse input specifications have a similar maximum pulse input rate of 10,000 Hz. However, some field devices have a maximum pulse input rate that is less than 10,000 Hz. The PSF of the Coriolis flowmeter can be adjusted to stay within the constraints of any field device that is counting the pulses from the meter per the equations shown here:

Max. PSF = (10,000 X 3600) / Max. Rate
Where:
Max. PSF   = maximum PSF in pulses per unit mass or volume to prevent exceeding 10,000 Hz
10,000   = maximum frequency output in Hz
3600   = conversion factor for seconds from hours
Max. Rate   = maximum flow rate in barrels or lbs per hour
The equation above can be rearranged to determine the output frequency at a given flow rate.
Freq = (Max. Rate / 3600) x PSF
Where:
Freq   = frequency output in Hz
Max. Rate   = maximum flow rate in barrels or lbs per hour
3600   = conversion factor for seconds from hours
PSF   = pulse scaling factor in pulses per unit mass or volume

When the meter factor remains stable between proving events, this indicates that the meter zero setting value is good. A change in the meter factor may or may not be related to the meter zero, so it is important to always perform a Zero Verification Test (consult Transmitter Configuration and Use manual) before making any zero adjustments. Only adjust the meter zero if advised to by the Zero Verification Test. If a meter zero is adjusted, reprove the meter.

Master Meter Proving

Micro Motion Coriolis meters can be used as master meters per API MPMS Ch. 4.5 for proving with the following advantages:

- A Coriolis master meter can be used to prove in either volume and/or mass units.

- Pass duration can be lengthened to improve repeatability.

- Maintaining stable process conditions is much easier with no effects due to a displacer launch.

- Low maintenance and high reliability, with no seals or moving parts.

Need More Information?

Emerson has extensive field experience in mass and volume proving of our Micro Motion Coriolis meters. Contact us at 1-800-522-6277 or visit our website at www.MicroMotion.com