

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 1.0 second 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:

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

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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:

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

Example: CMFHC4 meter at 6500 BPH

- From Table 1: Velocity \approx 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) \div (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) \div (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:

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

Example: CMF400 meter at 2300 BPH

- From Table 1: Velocity \approx 40 fps. TPT \approx 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 \div 170 gallons = 5 total passes (5 total passes \div 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 \div 65 gallons = 12 total passes (12 total passes \div 5 runs = 3 passes per run for 5 runs).

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

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CMFS050	CMFS075	CMFS100	CMFS150					
Above 60 fps	Above 60 fps	Above 60 fps	Above 60 fps					
			40-60 fps 30-75 sec TPT	250 BPH				
		40-60 fps 30-75 sec TPT	30-40 fps 20-30 sec TPT	30-40 fps 20-30 sec TPT	30-40 fps 20-30 sec TPT	170 BPH		
					30-40 fps 20-30 sec TPT	160 BPH		
				15-30 fps 20 sec TPT	15-30 fps 20 sec TPT	120 BPH		
					15-30 fps 20 sec TPT	110 BPH		
				15-30 fps 20 sec TPT	15-30 fps 20 sec TPT	15-30 fps 20 sec TPT	80 BPH	
						15-30 fps 20 sec TPT	60 BPH	
				30-40 fps 20-30 sec TPT	30-40 fps 20-30 sec TPT	7.5-15 fps 10 sec TPT	7.5-15 fps 10 sec TPT	55 BPH
							7.5-15 fps 10 sec TPT	48 BPH
40-60 fps 30-75 sec TPT	15-30 fps 20 sec TPT	7.5-15 fps 10 sec TPT	7.5-15 fps 10 sec TPT	40 BPH				
30-40 fps 20-30 sec TPT	15-30 fps 20 sec TPT	7.5-15 fps 10 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.
 - Minimize piping between the meter and prover.
 - 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).

$$\text{Equation 4: } \rho_b \geq 2 \Delta\rho + 1.25 \rho_e$$

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).
 - Max. temperature difference = 0.2 °F
 - Max. pressure difference = 1 psi
 - 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.

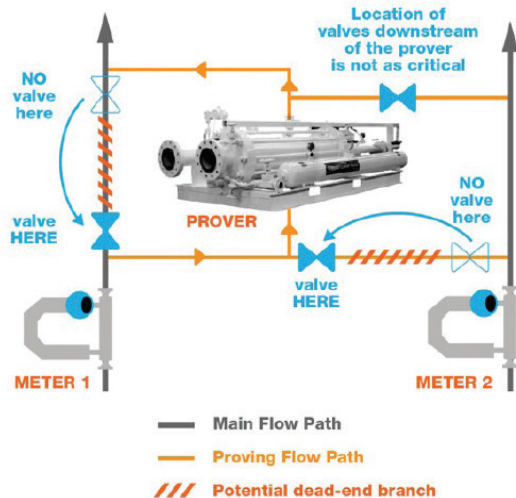
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Proving loops with a shared prover

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



Meter Operation

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

- Select the fastest speed of response available:
 - 5700 transmitter: select “Low Filtering” response mode
 - 2700 transmitter: select “Special” for Update Rate and either “Special” or “Low Filtering” for Calculation Speed
 - Set flow damping to a value between 0.0 and 0.08 seconds.
 - 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:

$$\text{Max. PSF} = (10,000 \times 3600) / \text{Max. Rate}$$

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.

$$\text{Freq} = (\text{Max. Rate} / 3600) \times \text{PSF}$$

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.

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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

Emerson Automation Solutions

7070 Winchester Circle
Boulder, CO USA 80301
T +1 303 527 6277
F +1 303 530 8459
www.Emerson.com

