Best Practices for Proving Proline Promass Coriolis Flowmeters

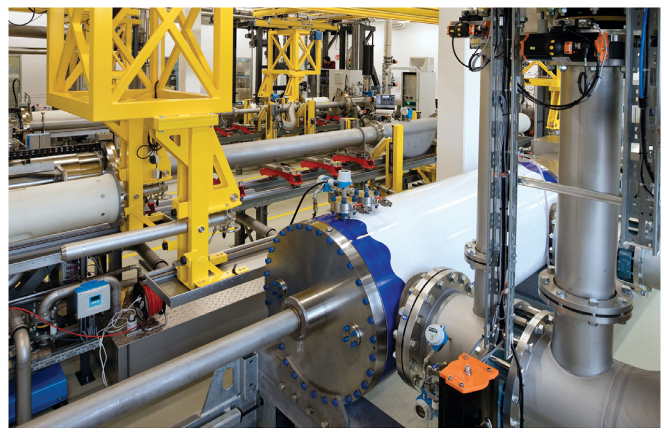
A quick reference guide with recommendations for proving Proline Promass Coriolis flowmeters using a ball prover or small volume prover (SVP).

By Endress+Hauser

Promass flowmeters are extremely accurate and can achieve consistent proving results with ball provers and small volume provers. Attention to detail is required to obtain the optimal repeatability and accuracy of which the meter is capable. The guidelines in this report help users achieve the best proving results possible when proving a Promass Coriolis flowmeter.

Flowmeter operating conditions and sizing

- Ensure the meter is properly sized for process conditions. This will provide optimal proving results.
- Use the Applicator tool to size the Promass flowmeter at https://www.endress.com/en/product-tools.
- Under sizing the flowmeter will result in excessive pressure loss and creates the risks of cavitation and poor repeatability. Insufficient process back pressure results in flashing or cavitation (see details in "site considerations," page 3). This is especially important to consider for applications that load a product to low pressure storage.
- The optimal flow range in which to operate for custody transfer is typically found between the minimum flow rate and maximum pressure drop (e.g. 2 bar [29 psi]). The typical maximum flow velocity is 18 m/s or 60 fps through the measuring tubes. In this range, the meter operates with maximum accuracy and without excessive pressure loss. Performance may be improved by reducing the maximum flow velocity through the meter for applications on lighter fluids with low viscosities (e.g. NGL, Ethane). Use Applicator sizing tool to avoid cavitation and to determine the flow velocity through the measuring tubes.
- A Coriolis flowmeter will measure down to a flow rate of zero. However, accuracy is reduced at very low rates due to zero-point uncertainty. To ensure optimal performance the pipeline flow velocity should be 0.5 m/s (1.6 fps) upstream or greater of the Coriolis flowmeter.



Prover sizing and considerations

- A pass is defined as a single movement of the displacer in a prover that activates the start-stop detectors.
- A meter proving run is defined as one or more consecutive passes (API MPMS 12.2).
- Methods for combining run sets, either by summing or averaging, are defined in API MPMS Chapter 4.8.
- It is not recommended to size the SVP (small volume prover) based solely on its maximum rated flow rate. To ensure the SVP is appropriately sized it is necessary to check piston transit times (pass time). It may be necessary to operate the SVP below its maximum rated flow to extend piston pass times to meet proving performance expectations.
- It might be acceptable to use multiple passes per run, depending on your company's internal measurement standards. However, this solution may not achieve the desired repeatability if the prover is undersized.
- The preferred minimum prover run time should be on the order of 2 seconds in duration and never below 1 second.

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The pre-run time should never be below 0.25 seconds. The minimum pass time is defined by the prover model. Typically, the minimum pass time is 0.5 seconds. Precautions and proper care should be taken to ensure that these run time guidelines can be followed at the maximum flow rate.

Please see the table below for example calculations for prover run times at maximum flow rates for common size provers:

Prover size (gal)	Maximum flow (l/hr)	Maximum flow (barrel/hr)	Run duration (s)
15	111,300	700	1.8
20	143,100	900	1.9
25	190,800	1,200	1.8
40	302,100	1,900	1.8
75	508,800	3,200	2.0
100	667,700	4,200	2.0
170	1,144,700	7,200	2.0

- Increasing the prover pre-run time allows process fluctuations from the re-direction of flow to stabilize before collecting prove data. Process trend data and diagnostics are very useful in evaluating if fluctuations are affecting proving performance. Common practice is to begin proving with pre-run time set to the minimum. Before adjusting pre-run time confirm if all valves and controls in the system are maintaining stable process conditions. If not, it may then be beneficial to increase pre-run time to improve run stability.
- Proving sizing is based on a proper installation per API guidelines with stable process conditions and homogeneous flow. If these conditions are not met it may not be possible to meet the random uncertainty of a meter factor even with an extended number of passes per run.
- Ball provers are designed with much larger volumes than a SVP of similar capacity and may result in improved repeatability.

Meter configuration

- Ensure that output damping, flow damping and density damping are set to zero. From the factory, the default configuration of an Endress+Hauser Promass Coriolis flowmeter is zero for all of these damping values. If these parameters are not set to zero, these factors average out and delay the measurement, which can cause a mismatch between the meter's output and the volume displaced through the prover at any given time. As a result, a change in flow rate during a prover pass may result in an incorrect meter factor and/or poor repeatability.
- If the operating pressure within the flowmeter is expected to be above 5 bar (75 psig) during proving operations, the Promass flowmeter should be programmed to compensate for the pressure effects on the measurement.
- It is recommended to utilize live pressure values from a pressure input (i.e. 4-20 mA, Modbus).
- As an alternative it is possible to program the device with the corresponding static pressure value representative of the pressure during the proving operation. However, a static pressure value might result in reduced repeatability if the pressure is fluctuating during proving.

Recommended pulse/frequency output set-up for proving

- Promass 300/500 transmitters do not have a fixed K-factor as is common for mechanical meters. Due to this, it is important to adjust the output settings to:
  1. The maximum flowrate, which should be proved
  2. The maximum input frequency of your flow computer

- The maximum provided frequency of Endress+Hauser Promass transmitters is typically 10kHz. Frequency is selected by operating mode of the output.
- It is recommended to set the operating mode to frequency to achieve the best repeatability when proving using short pass times.
- As an example, the maximum flowrate to prove is 6,000 bbl/hour.
- The flow computer input can handle 10,000 pulses per second, an input frequency of 10kHz.

Best practice is to calculate the K-factor using 10 to 20% higher maximum flowrates to never exceed the input frequency of the flow computer, this would lead to the following Promass transmitters output setting:

a. Assign frequency to: volume flow
b. Minimum frequency values stays at factory default setting: 0.0 Hz
c. Maximum frequency value is set to match the maximum input frequency of your flow computer: 10,000 Hz
d. Minimum flowrate (value at minimum frequency) is set to: 0 bbl/h
e. Maximum flowrate (value at maximum frequency) is set to: 7,200 bbl/h (= 6,000 bbl/hour x 1.2)

The K-factor for flow computer is calculated as follows:

$$\text{K-Factor} = \frac{\textit{Frequency Max. x 3600}}{\textit{Flowrate Max.}}$$

$$\text{K-Factor} = \frac{10{,}000 \times 3{,}600}{7{,}200} = 5{,}000$$

Where:
K-Factor = characterization factor in pulses / bbl
10,000 = maximum frequency value [Hz]
3,600 = conversion hour to seconds
7,200 = maximum flowrate [bbl/h]

Note: Flowrate value at maximum frequency of the Promass transmitter. On request we can supply an excel based calculation tool to assist.

Diagnostic evaluation

- Utilizing Heartbeat diagnostic capabilities of a Promass Coriolis flowmeter provides users the opportunity to identify the presence of unfavorable process conditions, such as two-phase flow or impairments to the meter itself. Impairments includes buildup or corrosion of the measurement tubes.

- Heartbeat diagnostic messages can be read out directly from the Promass display along with the signal status categorization (per Namur NE 107) and the suggested remedy instruction. Additional information is accessible through an external interface, such as DeviceCare, the web-server interface or integration through the meter's data communication bus (e.g. Modbus).
- If meter repeatability is unstable the exciter current or oscillation damping in conjunction with density can be observed to determine if the process fluid is completely homogeneous. Direct observation of these diagnostics may indicate more subtle effects and their timing relative to other process events.
- While flowing, the excitation current should be stable. Observed excitation current or oscillation damping deviations of greater than +/-5% indicate poor fluid conditions.
- Deviations in excitation current or oscillation damping are likely due to transient events from fluid cavitation, gas carry under or the presence of solids. Process fluid fluctuations will lead to non-repeatable proving results.

Site considerations

- Double block-and-bleed isolation valves are recommended for all bypass and leak paths between the meter and prover.
- The meter must be proved on the process fluid under operating conditions of temperature and pressure.
- The distance between the meter and the prover should be minimized to ensure best possible results. Normally the flow sensor is located upstream of the proving connection and adequate connections be provided to bleed off any trapped air in the piping between the meter and the prover.
- The Coriolis flowmeter must be oriented in a position that ensures the device will be completely filled with fluid under all flow and static conditions.
- In case of volumetric flow measurement, the external temperature sensor should be installed near the flowmeter so that the measurement is representative of the fluid temperature in the meter. As per API 5.6 this is downstream of the meter. In addition, if dynamic pressure compensation is utilized in the application, the pressure sensor should be installed near the flow sensor and is downstream of the meter.
- The exciter current, oscillation damping and density readings will fluctuate if the liquid is outgassing. Proving should not be attempted until the outgassing issue is rectified.
- Ensure that there is adequate back pressure on the meter under test and prover to avoid cavitation or gas breakout. The following equation should be used to determine the minimum back pressure requirements (from API MPMS 5.6):

$$P_b = 2\,\Delta p + 1.25\,P_e$$

Where:
P_b = Minimum back pressure
Δp = Pressure drop (Pressure loss) through the flowmeter at the maximum operating flow rate
P_e = Vapor pressure of the fluid at operating temperature

Be sure to use consistent units for pressure

Meter zero

The zero value of a Promass Coriolis flowmeter is established at the factory during calibration under the tightest tolerances and highest accuracy. Actual installed process conditions, ambient temperature, installation conditions and pipeline stress can cause the meter's zero to deviate from this factory value. For applications that require the highest measurement performance, it is advisable that the Coriolis meter is zeroed during initial start-up procedure.

Acceptable proving results

API MPMS recommendations for the proving of custody transfer flow metering technologies are widely followed in

Promass Zero Point Stability per Model

Nominal Diameter	Promass F 300/500 (lb/min)	Promass F 300/500 (kg/h)	Promass O 300/500 (lb/min)	Promass O 300/500 (kg/h)	Promass X 300/500 (lb/min)	Promass X 300/500 (kg/h)	Promass Q 300/500 (lb/min)	Promass Q 300/500 (kg/h)
½" – DN15	0.007	0.20						
1" –DN25	0.019	0.54					0.013	0.36
1½" – DN40	0.083	2.25						
2" – DN50	0.129	3.5					0.066	1.8
3" – DN80	0.330	9.0	0.330	9			0.20	5.4
4" – DN100	0.514	14	0.514	14			0.42	11.5
6" – DN150	1.17	32	1.17	32				
10" – DN250	3.23	88	3.23	88				
14" – DN350					5.03	137		

the oil & gas industry. MPMS Chapter 4.8 details the requirements for the number of runs required to achieve 0.027% uncertainty at 95% confidence level. Historically operators have used a repeatability limit of five runs at 0.05% to achieve this result. However, with small volume provers it may be necessary to perform additional runs. Examples can can be seen in Table A.1 of MPMS Chapter 4.8.

Master meter proving

Endress+Hauser Coriolis flowmeters can be used as master meters for proving per API MPMS Chapter 4.5 which has the following benefits:

- A Coriolis master meter can be used to prove in volume or mass units
- Run time duration can be increased to improve repeatability
- No mechanical moving parts results in low maintenance and high reliability

Definitions according API Chapter 5.6

Proving: The process of comparing the indicated quantity which passes through a meter under test, at operating conditions, to a reference of known quantity in order to establish a meter factor. This process is normally conducted in the field.

Zero stability: The deviation from a zero indication by the meter over an appreciable time when no physical flow is occurring, and no output inhibiting is applied.

Zeroing: A procedure that eliminates observed zero offset. The stored zero value is used by the Coriolis transmitter to calculate flow rate.

Calibration: The process of utilizing a reference standard to determine a coefficient which adjusts the output of the Coriolis transmitter to bring it to a value which is within the specified accuracy tolerance of the meter over a specified flow range. This process is normally conducted by the manufacturer.

Note: The Manufacturer Flow Calibration Factor should not be confused with K-Factor or Meter Factor (MF).

Manufacturer flow calibration factor: A numerical factor which may or may not be used to address flow sensitivity of each individual Coriolis meter sensor. It is unique to each sensor and derived during sensor calibration. When programmed into the Coriolis transmitter, the flow calibration factor(s) helps ensure that the meter performs to its stated specifications.

K-factor: Pulses per unit quantity (volume or mass); a coefficient, entered in the accessory equipment by a user, which relates a frequency (mass or volume) input from the Coriolis transmitter to a flow rate.

Coriolis meter factor: A dimensionless number obtained by dividing the actual quantity of fluid passed through the meter (as determined by proving), by the quantity registered by the meter. For subsequent metering operations, the actual quantity is determined by multiplying the indicated quantity by the meter factor.

$$\frac{\text{Corrected prover volume}}{\text{Corrected meter volume}} =$$

API MPMS CH. 4.8 Table A.1 Repeatability criteria to meet +/-0.027% uncertainty

Number of Proving Runs	Repeatability Limit for 0.027% Uncertainty
3	0.02%
4	0.03%
5	0.05%
6	0.06%
7	0.08%
8	0.09%
9	0.10%
10	0.12%
11	0.13%
12	0.14%
13	0.15%
14	0.16%
15	0.17%
16	0.18%
17	0.19%
18	0.20%
19	0.21%
20	0.22%