# API MPMS CHAPTER 5 SECTION 6 FOR PROVING CORIOLIS METERS –

## AN OVERVIEW

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**Abstract**   Coriolis flow meters have been used for last ten years for Custody Transfer of Liquid Hydrocarbons in the Upstream, Midstream and Downstream oil and gas segments for single-phase flow measurement for White Oils, Black Oils and NGL Liquids. These applications in past were done with variety of methods adopted for verification of these meters performance in the field or laboratory.

In Oct 2002 API published the first edition of the Standard that provides significant recommendations for the usage of this technology for Custody Transfer of Crude Oil and finished liquid hydrocarbon. This document has been added and listed as Chapter 5 Section 6 of the API MPMS document.

This paper will present an overview of the recommendations from this chapter for the application of Coriolis flow meters for Custody Transfer with interpretation of the In-situ Proving Requirements.

## INTRODUCTION

Coriolis flow meters have been used for Custody Transfer of Liquid Hydrocarbons in the Upstream, Downstream and Pipeline segments for single-phase flow measurement of petroleum products such as Crude Oil, White Oil, Black Oil, NGL Liquids etc. Historically these applications were done with variety of methods adopted for verification of these meters performance in the field or laboratory for custody transfer applications.

In Oct 2002, Committee on Petroleum Measurement (COPM) of the API published the first edition of the measurement standard that provides significant recommendations for the usage of this technology for custody transfer of Crude Oil and finished hydrocarbon. This document was added and listed as Chapter 5 Section 6 to the API MPMS document.

The intent of this paper is to give an overview of the recommendations from this standard for the application of Coriolis flow meters for custody transfer with interpretation of the In-situ proving requirements. But first, we will have a quick overview of some operational issues that are unique to these devices.

## BACKGROUND: FACTORS AFFECTING CORIOLIS METER OUTPUTS

Coriolis meter is unique as it measures both mass and density of the fluid. It is necessary to evaluate both the accuracy of the mass measurement and density measurement, when considering the accuracy of the volume output. Coriolis meters can differ dramatically in their specification of density accuracy and therefore, would differ dramatically in their volume accuracy.

The Coriolis meter has two main parts - a sensor and a transmitter. The sensor is made up of single or dual tube configuration through which the fluid passes. The transmitter for each sensor is typically programmed with two unique numeric values: The *manufacturer flow calibration factor* and *density calibration factor*. The factors are a result of the sensor calibration that is normally performed in the laboratory during the manufacturing process. These calibration factors interpret the sensor signals into measurement data and helps ensure that the meter performs to its stated specification. These factors should not be confused with K-Factor or Meter factor (or Density Meter factor). After programming the transmitter with the flow calibration factors, the transmitters output signals are configured.

PSF (*Pulse Scaling Factor*) pulses per unit mass or volume; a coefficient(s) is then entered in the Coriolis meter transmitter that defines this relation

between pulse output of the transmitter and quantity. This is usually expressed in Hz (pulses per second) for a given flow rate. For example, 10000 Hz = 1000 meter cube per hour. A similar *K-factor* is entered into the accessory equipment (such as a flow computer) and is used to translate the pulses back to a quantity (flow rate). The K-factor for the above example can be determined from the PSF by converting the flow rate into units per second. The Hertz value for that flow rate is then divided by the flow rate in units per second which, for this example is: 10000 Hz/(10/36$^{th}$ of meter cube per sec) = 36000 pulses per meter cube.

Figure 1, shows the correction and calibration factors that may affect the mass, volume, density or flow rate determined by the Coriolis meter. The PSF may be entered directly or derived from operator entries such as flow rate and frequency. The *meter factor* for a Coriolis meter could be either a Mass meter factor ($MF_m$) or a Volume Meter factor ($MF_V$), based on the measurement configuration selected. In either case, it is obtained by dividing the actual quantity of fluid passed through the sensor (as determined by proving), by the quantity registered by the transmitter. For subsequent metering operations, the actual quantity is determined by multiplying the indicated quantity by the meter factor. Though most of the Coriolis meter are capable of measuring density well, and can be used as a stand-alone densitometer - this standard does not address its use in this manner, instead recommends applying procedure in the API MPMS Chapter 14 Section 6, Continuous Density Measurement. API MPMS 5.6 only discusses the application of the measured density from the Coriolis meter to convert mass to volume, dynamically.

## FIGURE 1: FACTORS AFFECTING CORIOLIS METER OUTPUTS
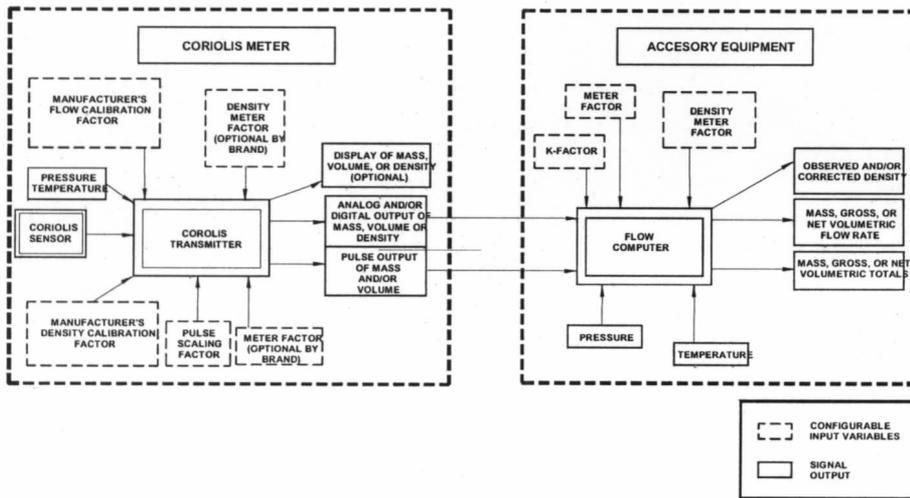


## CORIOLIS METER INSTALLATION AND SYSTEM DESIGN

In general, the Coriolis meters should be oriented such that the meter is completely filled with single phase fluid at all times and in a manner that air cannot be trapped inside the fluid. This is the basic requirement to work in any application.

In custody transfer application, more specific installation guidelines and system design practices are required to be followed:

1.     Due consideration should be given for the supports requirement of the sensor, the alignment of the inlet and outlet flanges of the sensor is critical to avoid piping stresses that may affect the resonance of the tubes(s) inside the meter or orientation of the sensor for the given application. The sensor and the mating pipeline flange contact surfaces should be aligned perfectly parallel to each other. Attempting to correct any angular deviation perpendicular to the flange faces while making up the joint may result in overstressing a portion of the bolts and the connection as shown in figure 2.
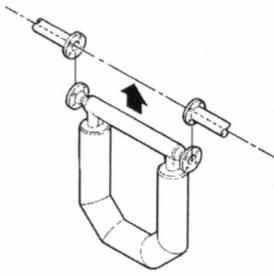
**Figure 2a: Typical sensor installation**



**Figure 2b: Shows sensor mating flange mproper alignment.**
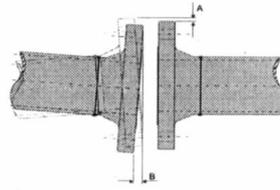


**Figure 2c: No cantilever action due to external load**
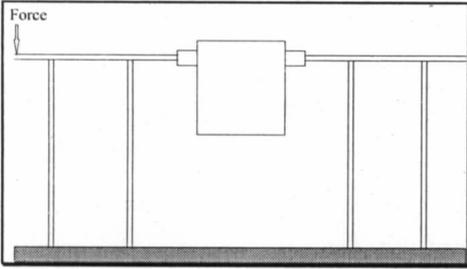


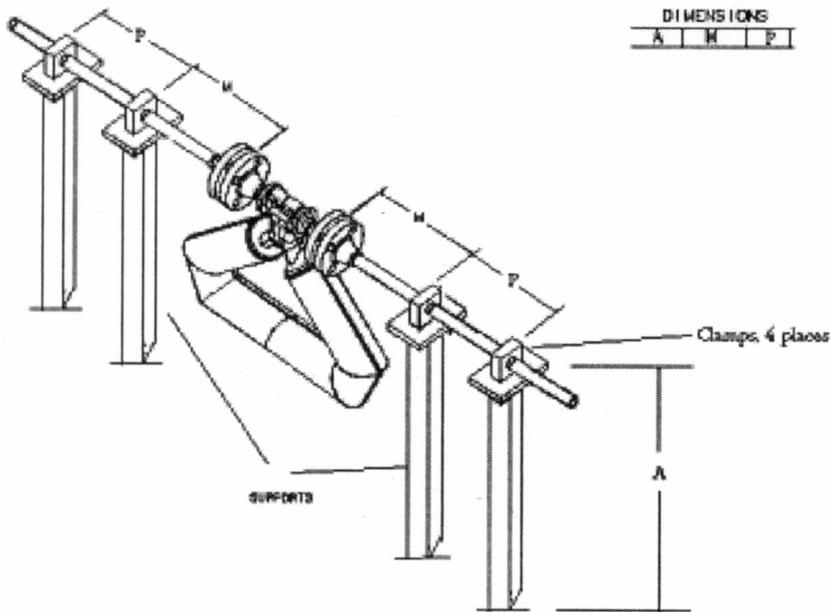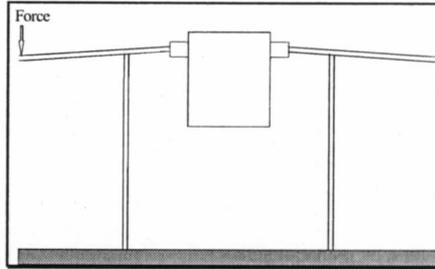**Figure 2d: Cantilever action due to external oad**





**Figure 2e: Typical rigid installation with pipe supports**

2.    Piping vibration and fluid pulsation may affect the ability of the flow sensor to accurately measure stream parameters as the external vibrations or pulsations approaches the resonant frequency of the sensor. Though, possibly dependent on the construction and design

of the meter, external piping vibration should be arrested to not allow any affect on the meter performance at operating frequency or one of its resonant frequency. Pulsation dampeners could be required in some situations.

3. Meter performance, specifically observed zero offset will be adversely affected by axial bending and torsional stresses from pressure, weight, and thermal effects; these stresses and associated loads can be minimized by utilizing properly aligned pipe work and well-designed supports. Refer to figure 2c and 2d.

4. The use of a rigid member or super structure (concrete slab) connecting the four in-line supports (Figure 2e) is imperative to the quad in-line support structure design. A common flaw made by the designer is to design the four supports anchored by individual concrete pedestals in the earth. The concrete will sink into the earth over time and shift due to seasonal changes acting as individual weights on the metering module piping causing bending stress on the Coriolis meter. When the metering module piping construction is performed in the field, a dimensionally square fabrication spool piece should be used to align the upstream and downstream Coriolis mating flanges during the field welding of these flanges to their associated piping.

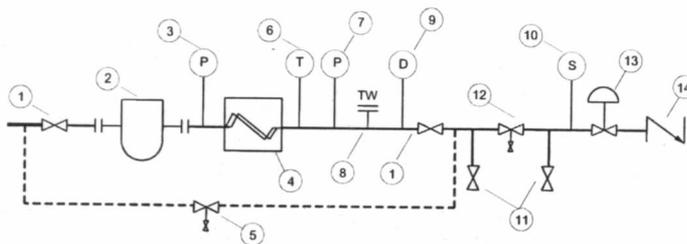5. In case, if multiple flow sensors are installed in close proximity, either in parallel or series. Then vibration isolation or dampening can be achieved by altering piping, isolation valves, and/or supports to the minimize the interference of the vibration generated by each sensor called 'Cross talk'. In some meter design, it may be possible to alter the drive frequency of the sensors, thereby reducing the possibility of mechanical cross talk between adjacent meters.

6. Each sensor has potentially different accuracy specifications. Each individual tube geometry design will have a different sensitivity to flow rate changes, vibration, external piping loads, pulsation, operating pressure and ambient temperature etc. Accuracy and performance for a given installation will vary and be based on these influencing factors. For Example: Variations in line pressure may affect sensor accuracy, as sensitivity to pressure effects typically increases with meter size. Meter performance may tend to deteriorate as sensor tube wall thickness and diameter increases. Hence, a method for real-time pressure compensation may be implemented to compensate for pressure effects on meter performance.

7. A backpressure valve should be located downstream of the meter to avoid cavitation.

8. Proving facilities should be provided downstream of the meter under conditions as close to the normal operating conditions, as practical. Consideration should be given to the location of the meter electronics that generates the pulse output for the prover, so that the proving connections and the transmitter are located in close proximity.

**Figure 3: Describes a typical schematic for Coriolis meter installation for Custody Transfer**

**Notation**

1. Block Valve
2. Strainer/Air Eliminator
3. Pressure Indicating device
4. Coriolis Meter
5. Meter bypass (Optional) with block and bleed valve or blind
6. Temperature indicating device
7. Pressure indicating device
8. Test thermowell (TW)
9. Density Measurement
10. Manual sample point or auto sampler with probe
11. Proving connection, block valves
12. Block and Bleed isolation valves for proving/zeroing
13. Control Valve
14. Check Valve

## OPERATIONAL PERFORMANCE AND METER ZERO

Even when there is no flow in the sensor, the transmitter may indicate some false flow rate caused due to the phase shift between the sensor pick-offs. As mentioned earlier, the source of this phase shift could be due to mechanical noise, pipe stress, process rate changes, electronics drift or a combination that can cause an offset or zero error. Thus, zeroing is required as a part of the normal start up procedure (and later during operation) to eliminate any observed zero offset and hence establish the sensor output at zero flow. This procedure is relatively simple and requires only a few minutes. However, if not properly done, an incorrect or bad zero could result in an erroneous measurement. In the Figure 3 installation configuration, the item 1 represents the valves to stop the flow through the Coriolis meter to allow zeroing. It is preferable to have shut-off valves located both upstream and downstream of the meter to block it in during zeroing. As a minimum, block-and-bleed valve located downstream of the meter is required. Nevertheless, every time the meter is re-zeroed it is essential to generate a meter factor by proving the meter. Thus, needless re-zeroing should be avoided and a stored zero value verification should be done as a part of the normal operating procedure for the meter. With changes in process conditions beyond user defined limits, a change out of the system components or changes in the piping stresses would be the typical reasons for needing to repeat the zeroing procedure. Again, any zeroing procedure should be done prior to proving the meter.

In general, Coriolis meter accuracy is affected by conditions that change the flexibility of the oscillating sensor tube and/or changes from the stored zero value. Fluid properties (ex: density), operating conditions (ex: flow rate variations, fluid temperature, fluid pressure, cavitation, coating, erosion, corrosion) and installation conditions (ex: Vibration, Mechanical Stress, Pulsation Flow) can all affect Coriolis meter accuracy. To achieve the level of accuracy required for custody transfer measurement, a Coriolis meter should be proved on a similar fluid and under operating and installation conditions as encountered in normal operations. If there are changes in the fluid properties, operating conditions or if there is any alteration to the flow sensor installation then in either case, a change in meter factor may result. Therefore, the Coriolis meter should be proved under the new conditions as soon as practical.

*Consideration for changing the stored zero value in the flow meter (Re-zeroing):* Periodic verification of the stored zero is necessary to ensure that it is within limits defined by one or more of the factors such as manufacturer's recommendation, performance testing/monitoring and custody transfer agreements.

Re-zeroing is necessary when the observed zero value is outside the specified zero offset limits. Since the meter should be proved after re-zeroing, needless re-zeroing should be avoided in order to minimize potential errors associated with meter factor reproducibility.

The observed zero offset is affected by:

1. Flow sensor installation conditions
2. Pipeline stress
3. Fluid temperature
4. Fluid density
5. Ambient temperature at the Coriolis transmitter
6. Change of Coriolis transmitter or the sensor.

The need for re-zeroing the Coriolis transmitter will depend upon the operating flow rate of the system. If the zero value is small, it will have

minimal effect on the meter's accuracy at a normal operating rate. The lower the flow rate, the more significant the zero offset becomes. During zeroing the spot or single readings of the zero value cannot be used for this evaluation. The zero value should be an average of at least 60 seconds. This average value more accurately reflects the variability of the zero. The error associated with the zero offset can be determined from the following equation 1:

$$Err_0 \quad = \quad (Q_0/Q_f) \times 100$$

...1

## PROVING FOR CUSTODY TRANSFER

Proving of Coriolis meters has been an area of major concern and confusion among the users. Different users have applied different methods amidst this confusion.

Field (in-situ) meter proving provides a means of establishing the meter factor for the Coriolis meter under actual operating conditions. There are various methods for applying the meter factor to indicate the actual quantity measured through the meter. The adjustment from indicated to actual quantity can be made by varying the meter factor or K-Factor. Though, generally the preferred method is to apply a meter factor because of its audit trail capability. It is important that the method selected be used consistently. If the meter is used to measure bi-directional flow, a meter factor should be developed for each direction.

In addition to the initial proving a Coriolis meter upon installation, periodic proving is necessary to confirm/re-establish the performance accuracy of the Coriolis meter. Meter proving should be performed if any of the following events occur:

1.      Anytime the meter is zeroed
2.      When the flow sensor installation or mounting conditions are modified.
3.      When the Coriolis meter density measurement is calibrated, if the Coriolis meter is configured to indicate volume.
4.      When any of the assembly components have been replaced.
5.      If a change in the fluid temperature, pressure or density occurs beyond user-

defined limits as determined from field experience.
6.      When a flow rate change occurs that will cause a shift in the meter factor in excess of pre determined tolerance limits. The meter factor shift due to flow rate shall be determined from field proving experience.
7.      At the request of the parties involved in custody transfer
8.      On a schedule based on throughput, elapsed time, or contract
9.      Any time the accuracy of a meter is in question.
10.      When a change in the direction of flow through the meter occurs, if a meter factor has not been determined for the new direction.

Below mentioned are the details of proving methods and proving considerations. For the meter factor calculation, application of the proving results and frequency of proving have been well described in the Appendix E of the API MPMS 5.6 Standard.

Among other considerations, proving conditions should be as close to the actual metering conditions as practical. Occasionally, there may be exceptions to this requirement; however, the essential purpose of proving is to confirm the meter assembly performance at normal operating conditions.

The conditions under which a meter is proven are:

1.      Stable product composition
2.      Stable product temperature and pressure
3.      Stable flow rate
4.      System valves and seals have been checked to ensure there is no leakage
5.      Trial runs have been conducted to evacuate any air/gas from the system.

Table 1a and 1b below provides a summary of the various proving application and methodologies. The other critical areas to note are:

1.      Requirements for stability of temperature, pressure and product composition will vary, depending on the proving method being employed and the properties of the fluid being measured.

2.      If the Coriolis meter is configured to indicate mass and is being proved against a gravimetric tank prover, then the stability of the

fluid properties is less critical because there is no need for a density determination. However, this method of using gravimetric tank prover has serious limitations for field application; in addition this method is not covered in any API MPMS.

3.    If the Coriolis meter is configured to indicate mass and is being proved against a volumetric standard (Volumetric tank prover, conventional pipe prover, small volume prover or volumetric master meter), it is essential that the density remain stable. Stabilizing the density minimizes variations in density between the prover, meter and the density determination used in the calculation. Since the measured flowing density will be used to convert the prover volume to a mass or the Coriolis meter mass to a volume, any difference in the density and the true flowing density during the proving will result in errors in the meter factor. Therefore, to minimize errors, it is extremely important that the density remains stable during the proving. As

an alternate the proving system may incorporate an on-line densitometer, calibrated at regular intervals. This density reference is particularly useful in eliminating errors, if the density varies during a proving.

4.    The need for a stable fluid density also applies to a Coriolis meter configured to indicate volume being proven against a gravimetric tank prover. Again this method has serious limitations for field application; in addition this method is not covered under in API MPMS.

5.    For inferential mass proving described in the above point, if there are density variations during the proving, it is likely that additional proving runs will be required to obtain an acceptable meter factor. The proving data should be scrutinized for outliners to determine such errors and proving be repeated at lesser density variation times with good proving practices and judgment - when trying to compare mass measurements versus volume measurement.

Table 1a : Application Specific Proving Overview

| Application Overview | | | | | |
| --- | --- | --- | --- | --- | --- |
| Proving Considerations | Tank Prover Volumetric | Conventional Pipe Prover | Small Volume Prover | Master Meter | |
| | | | | Volumetric | Mass |
| Prover Design | MPMS Chapter 4 | MPMS Chapter 2 | MPMS Chapter 4.3 and 4.6 | MPMS Chapter 5 | Not in API MPMS |
| Truck/Wagon Loading | Yes | Yes | Yes | Yes | - |
| Bulk Pipeline transfer | No | Yes | Yes | Yes | - |
| Jetty loading/Unloading | No | Yes | Yes | Yes | - |

# Table 1b : Proving Overview

| Proving Considerations | Tank Prover | | Conventional Pipe Prover | Small Volume Prover | Master Meter | |
|---|---|---|---|---|---|---|
| | Gravimetric | Volumetric | | | Volumetric | Mass |
| Prover Design | Not in API MPMS (Varies) | MPMS Chapter 4 | MPMS Chapter 2 | MPMS Chapter 4.3 and 4.6 | MPMS Chapter 5 (Varies) | Not in API MPMS (Varies) |
| Proving Procedure | Not in API MPMS (Varies) | MPMS Chapter 8 | MPMS Chapter 8 | MPMS Chapter 4.8 | MPMS Chapter 5 and 4.8 | Not in API MPMS (Varies) |
| Process Measurement – Coriolis Meter Mass | A | B - $[D_{fp}, T_p, P_p]$ | B - $[D_{fp}, T_p, P_p]$ | B - $[D_{fp}, T_p, P_p]$ | B - $D_{fp}$ | A |
| Process Measurement – Coriolis Meter Volume | D - $[D_{fp}, T_p, P_{p\,m}, P_m]$ | C - $[D_{fp}, T_p, P_{p\,m}, P_m]$ | C - $[D_{fp}, T_p, P_{p\,m}, P_m]$ | C - $[D_{fp}, T_p, P_p\,T_{m}, m]$ | C - $[D_{fp}, T_p, P_{p\,m}, P_m]$ | C - $[D_{fp}, T_p, P_{p\,m}, P_m]$ |
| Meter Factor Calculations – Coriolis Meter Mass | A | B | B | B | B $CTS_P =1$ $CPS_P = 1$ | A |
| Meter Factor – Coriolis Meter Volume | D | C | C | C | C $CTS_P =1$ $CPS_P =1$ | C |

Where,

$A : MF_m$ = Prover Mass/$IM_m$

$B : MF_m$ = (Prover Volume x $CTS_P$ x $CPS_P$ x $D_{fp}$)/$IM_m$

$C : MF_v$ = (Prover Volume x $CTS_p$ x $CPS_p$)/$IV_m$ x ($CTL_P$ x $CPL_P$)/($CTL_m$ x $CPL_m$)

$D : MFv$ = (Prover Mass)/($IV_m$ x $D_{fp}$) x ($CTL_P$ x $CPL_P$)/($CTL_m$ x $CPL_m$)

## NUMBER OF RUNS FOR PROVING

For successful proving of Coriolis meters, longer prover pre-run are required to accommodate the meter's response time. From measurement standpoint, it is desirable to have, as long a proving run time as practical, to get good repeatability. Also, provisions should be made to allow the flow through the meter to be stopped so the meter can be zeroed. If the meter is configured for volume measurement it can be proved in the same manner as any volumetric flow meter. If the meter is configured for mass measurement, then accurate determination of the process fluid density is required to convert the prover volume to mass. As long as these key points are kept in mind, equipment and procedures can be put in place to achieve reliable proving results.

Further, the required number of test runs for each proving varies, depending up on

1.      Type of proving method being employed
2.      Coriolis meter type and size
3.      Operating flow rate and quantity of fluid accumulated during each proving run

Experience with the meter/proving system will ultimately establish the number of runs required. Typical examples of number of runs performed for each proving method are given in Table 2. Obviously from measurement standpoint, it is desirable to have at least a minimum of three runs during proving for any technique to have a better-defined maximum and minimum for the meter factor calculations.

The number of runs required to achieve the desired tolerance of meter factor uncertainty should be defined and agreed by all contractual parties. Once established, the same procedure should be followed consistently in order to better track the performance of the meter.

**Table 2 : Number of Runs**

| Proving Method | Number of Runs |
|---|---|
| Conventional Pipe Prover | 5 Consecutive runs |
| Small Volume Prover | 2-5 runs of multiple passes each |
| Tank Prover | 2 Consecutive runs |
| Master Meter | 2 Consecutive runs |

\* Run defined as round trip for bidirectional prover

## REPEATABILITY

The objective of proving a flow meter is to obtain a meter factor, which provides proper accounting of the inventory being measured. The repeatability is used as an indication of whether the proving results are valid. Too much variability could be an indication that there is something wrong with the meter, the prover, or some other component in the proving system. The general criterion used when proving flow meters is that the repeatability of the proving results be within 0.05%.

### 1. Average Data Method

The API recommended equation for calculating repeatability as shown in below equation

$$\text{Repeatability (\%)} = (\text{Pulse}_{max} - \text{Pulses}_{Min}) / \text{Pulses}_{Min} * 100 \quad \dots 2$$

A series of proving runs are conducted, and the maximum and minimum number of accumulated pulses from all of the proving runs are used in above equation to determine the repeatability.

### 2. Average Meter factor Method

Calculating repeatability using the above Equation is only valid if the prover and meter are both measuring in the same units of measure (for example, both measure volume). If the meter and prover measure in different units (for example, meter measuring mass and prover measuring volume), the repeatability calculation must be based on the calculated meter factor, as Shown in equation below:

$$\text{Repeatability (\%)} = (\text{MF}_{max} - \text{MF}_{min}) / \text{MF}_{min} * 100 \quad \dots 3$$

If the repeatability calculation were based on the accumulated pulses instead of the meter factor, any variations in product density that might occur during proving would not be taken into account. This can lead to calculating a repeatability value greater than could be attributed to the meter.

## REPRODUCIBILITY AND TREND CHARTING

Reproducibility is defined as the ability of a meter and prover system to reproduce results over a long period of time in service where the range of variations of pressure, temperature, flow rate any physical properties of the metered fluid is negligibly small. The expected reproducibility is generally determined from experience with each individual proving system. A change in the meter factor greater than the user defined limits should be considered suspect and every effort should be made to ensure that the Coriolis meter and proving system are functioning properly. Statistical control charting of meter factors will be valuable in analyzing the reproducibility of Coriolis meters and determining the required frequency of proving. It is recommend that techniques listed in the API MPMS Chapter 13 'Statistical Aspects of Measuring and Sampling' be employed. Figure 4 shows one such method.

Figure 4 : Sample meter factor trend chart : Acceptable meter factor range is determined from first meter factor. When a new meter factor falls outside the established meter factor Uncertainity limits, a new meter factor is determined, and new limits are established.
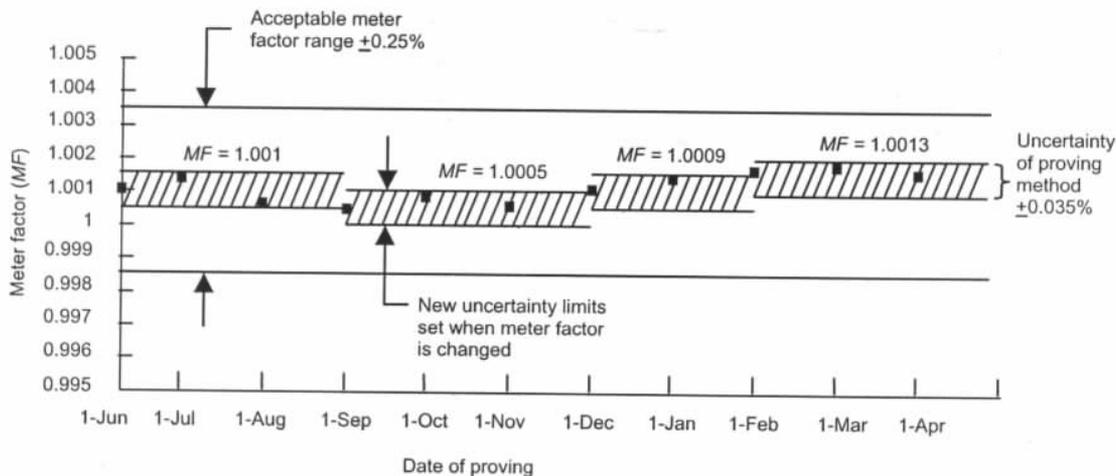


## TRENDING ZERO VARIATION

The trending chart provided in form 2, is for tracking variations in the meter's zero offset, and establishing requirements for re-zeroing the meter. This chart is divided into three sections:

1. The upper graph is used for entering the meter's actual zero reading. It is important that the value entered here is in mass flow units, not volume units. (The units shown on the form are lb/min, but any mass flow rate units can be used.) No x-axis values, except zero, are shown, because the magnitude of the zero offset is dependent on the sensor size and the process conditions.

2. The center of the chart is used for recording process data to determine if there is dependence between the meter zero value and a particular process condition, such as temperature.

3. The lower graph is used for determining the percentage error that the meter zero reading creates, based on the operating flow rate. There are no x-axis values shown, except zero, because the magnitude of the zero offset error depends on the sensor, the process conditions, and the operating flow rate.

## PROVING METHODS

### 1. Direct Mass Proving

In a direct mass proving, the mass of the fluid in the prover is physically measured. The mass measured by the prover is then compared to the mass measured by the meter to compute a meter factor. The common methods are : Gravimetric and Mass Master Meter. Both of these methods have serious limitations for field (in-situ) application and are not covered in any API MPMS Standard.

### 2. Inferred Mass Proving

In an inferred mass proving, the mass of the fluid in the prover (reference quantity) is calculated rather than physically measuring it as in direct mass proving method. The inferred mass is calculated by multiplying the volume and density of the reference fluid together. The inferred mass is then compared to the meter's indicated mass to calculate a meter factor. The accuracy of this method is equally dependent upon the accuracy of both the volume and the density measurements. Hence, the selection of the method to determine a reference density at the prover is critical for a successful prove. To determine the fluid density at the prover, it is preferred to use an on-line density meter. The density meter must be installed, operated, and calibrated per API MPMS Chapter 14.6. The resulting output of this meter should be averaged during each prover run or pass.

### 3. Volumetric Proving

In a volumetric proving, the volume of the fluid in the prover is determined by the methods listed

below. The prover volume is then compared to the meter's indicated volume to generate a meter factor.

a.      Conventional Pipe Prover
b.      Small Volume Prover
c.      Volumetric Master meter
d.      Volumetric Tank Prover

## LABORATORY VERSUS IN-SITU PROVING

Questions often arise concerning the differences between proving or calibrating a meter in the laboratory (bench) versus in-situ (field). These two proving locations can produce different results in a meter and cannot necessarily be interchanged without producing some measurement error. A bench prove is usually ideal conditions and on a stable fluid (water). This minimizes the effects of outside influences on the meters accuracy. An in-situ proving verifies the meters accuracy under operating conditions. Operating conditions can affect a meters accuracy and repeatability. An in-situ proving compensates or corrects for those influences. Conditions that might affect the in-situ meter proving are

1.      Mechanical stress on the meter
2.      Flow Variations
3.      Piping configurations
4.      Fluid pressure and extreme temperature
5.      Ambient temperature changes
6.      Fluid type and composition

## ZEROING METER FOR LABORATORY CALIBRATION

It is impractical to duplicate the mechanical stresses of a field installation in a lab or bench proving. As this changes will affect the meter's zero, it is necessary to minimize the changes in calibrating by zeroing the meter twice: prior to performing the bench prove once it is installed in the proving apparatus and again after the meter is installed back at its field location.

## AUDITING AND REPORTING REQUIREMENTS

An electronic liquid measurement system (ELM) should be capable of establishing an audit trail by compiling and retaining sufficient information for the purpose of verifying custody transfer quantities. Since the accuracy of an ELM is also affected by the calibration provided by a prover, an audit trail is also necessary for the prover. The audit trail should include Quantity transaction records, configuration logs, event logs, alarm logs, corrected quantity transaction records, and field test records. Refer to API MPMS Chapter 21.2, 'Electronic Liquid Measurement' for guidance and definitions.

## NOTATION

$Err_0$      =      Zero Error (%)
$Q_0$      =      Observed Coriolis meter flow rate with no flow (zero values)
$Q_f$      =      Flow rate during operation
$D_{fp}$      =      Fluid density at flowing conditions at the Coriolis meter
$CPL_M$      =      Correction for pressure effect on fluid at the Coriolis meter
$CPL_P$      =      Correction for pressure effect on fluid at the prover
$CTS_P$      =      Correction for pressure effect on steel at the prover
$CTL_M$      =      Correction for thermal expansion of fluid at the Coriolis meter
$CTL_P$      =      Correction for thermal expansion of fluid at the prover
$CTS_P$      =      Correction for thermal expansion of steel at the prover
$IM_m$      =      Indicated Coriolis meter mass
$IV_m$      =      Indicated Coriolis meter volume
$MF_M$      =      Meter factor when the Coriolis meter is configured to indicate mass
$MF_V$      =      Meter factor when the Coriolis meter is configured to indicate volume

## SUMMARY

Coriolis have been and are being used for custody transfer. Based on the application, different methods are required to verify their field performance. Irrespective of the method employed, these meters should to be proved in-situ, in the field. Hence, any verification method (proving) shall be field verifiable and it must provide traceable data. Proper statistical tools help in tracking the meter performance and zero. This results in confidence building of the measuring system performance and better understanding of the transaction. The API 5.6 MPMS could form the basis for the legal metrology for custody transfer of petroleum products.

**REFERENCE**
1.    American Petroleum Institute Manual of Petroleum Measurement Standards, Chapter 5 Section 6 "Measurement of Liquid Hydrocarbons by Coriolis Meters," First Edition, October 2002.
2.    Internal Literature, documents and article of Emerson Process Management.

**Form 1 : Sample Meter factor Chart to trend performance from one proving to next**

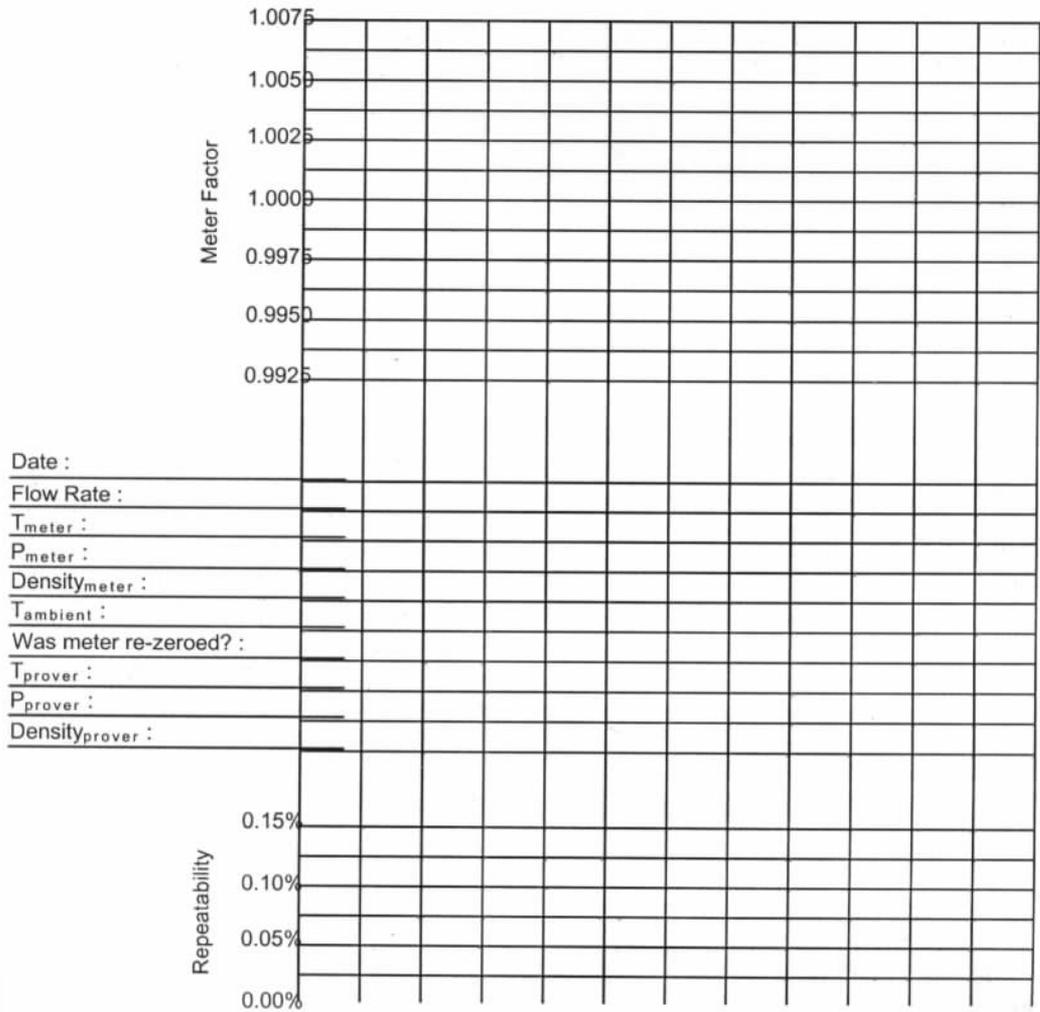Location _____    Sensor Model _____

Fluid _____    Sensor Serial Number _____

Prover Site _____    Transmitter Model _____

Prover Base Volume _____    Transmitter Serial Number _____

Passes Per Run _____    Calibration Factor _____

Meter Measuring Mass or Volume _____    K-Factor _____



Date :
Flow Rate :
$T_{meter}$ :
$P_{meter}$ :
$Density_{meter}$ :
$T_{ambient}$ :
Was meter re-zeroed? :
$T_{prover}$ :
$P_{prover}$ :
$Density_{prover}$ :

## Form 2 : Sample Meter Zero Chart to trend performance

Location _____  Fluid _____

Sensor Model _____  Transmitter Model _____

Sensor Serial Number _____  Transmitter Serial Number _____

Average Zero Reading (lb/min)

0.00

| Date : | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Operating Flow Rate : | | | | | | | | | |
| $T_{meter}$ : | | | | | | | | | |
| $P_{meter}$ : | | | | | | | | | |
| Density$_{meter}$ : | | | | | | | | | |
| $T_{ambient}$ : | | | | | | | | | |
| Was meter rezeroed? : | | | | | | | | | |

Zero Offset Factor (%)

0.00