Unidirectional Captive Displacement Prover for Verification of all Metering Technologies

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1. Introduction: This paper will verify the history, requirements, and operation of all Provers accepted for liquid pipeline meter uncertainty verification in the Liquid Oil/Gas Industry. It will continue with an explanation and the industries wide acceptance of the Uni-directional Captive Displacement Prover (UDCDP). This document will supply the reader with information regarding meter types and the flow volumes that can be used with the UDCDP and will look at the opportunities for the use of a UDCDP as a mass prover. It will also provide the information for field verification of provers known as a water draw.

2. UDCDP History: According to API, Flow Provers must have an uncertainty of less than +/-0.01% for all measurements relating to meter proving including water draw uncertainty, temperature measurement uncertainty on flow proving, pressure measurement uncertainty, etc.

Prior to the late 1970s to achieve the uncertainty of 1 part out of 10,000 using the old Prover counters with an uncertainty of +/- 1 pulse, Provers needed a sufficient volume to gather at least 10,000-meter pulses between detectors. The double chronometry technique pulse interpolation technique developed and patented by Ed Francisco and precision optical switches and modern electronics and high-speed timers eliminated the need for the extremely large volumes to attain the desired uncertainty. This led to the development of the modern Small Volume Prover (SVP) now known as the UDCDP.

Mr. Ed Francisco, the owner of Flow Technology Inc., in the 1960s was contacted by NASA to help with proving meters loading rocket fuel in a very short amount of time. Ed devised the double chronometry pulse interpolation technique to achieve the high accuracy meter proving's in a very short time. Double chronometry for API meter proving as described in API MPMS Chapter 4.6 is simply a method of resolving meter pulses to a resolution of +/-1 part out of 10,000 without the need for counting 10,000-meter pulses during a meter proving.

3. Developments Allowing Acceptance in the Industry: Over the years, technological advancements and improvements were made in the design of the operating system for large bore Positive Displacement (PD) Meters and Turbine Meters. As well as a greater understanding of the specifications of the manufactured pulse output signal for the Coriolis Mass Flow Meters (CMFM's) and Liquid Ultrasonic Flow Meters (LUFM's) meters. The advent of these changes led to improvements to the ease and the ability to verify large bore meters with a UDCDP.

Advancements in meter technology along with the development of larger UDCDP, with larger displacement volumes, allow the industry the opportunity for higher levels of repeatability and uncertainty validation significantly lower than the industry accepted error limits. The pulse interpolation processing solution for capturing less than ten thousand (10,000) total measured pulses originated in the early 1980s. This standardized use of Double Chronometry Pulse Interpolation (Verified in API Chapter 4 Section 6) inside the flow computer allowed acceptance of UDCDP for the Liquid Oil/Gas Industry.

The double chronometry technique is a simple process. The time for the volume displaced and the time for the whole meter pulses collected during that period is timed separately with high-frequency time bases.

The whole meter pulses collected during that time are multiplied by the ratio of the times to correct for differences in the time periods by the formula: (Meter pulse time/Prover volume time) X a number of whole meter pulses. Modern computer time bases currently utilized in flow computers and other double chronometry devices utilized for flow proving time base of at least 1-5 MHz frequency providing an uncertainty of far better than the 1 part out of 10,000 as required.

3.1 Pulse Interpolation Process: The first action begins with a signal from the upstream detector switch, starting clock one (ET1, displacer elapsed travel time), next clock two starts with the detection of the first complete pulse (ET2 for the elapsed time to measure whole pulses). At the same time, the accumulation of pulses (WP, whole meter pulses) from the meter being tested is also started.

Clock one stops accumulating based on a signal from the downstream detector switch. Clock two stops accumulation based on the detection of the first whole pulse signal from the downstream detector switch which also stops the whole pulse accumulation. This method allows for the collection of (E_{T1}) elapsed travel time of displacer, (E_{T2}) elapsed time of whole pulse accumulation, (WP) whole pulse accumulation from the meter and (D_V) which is the already known displaced or calibrated volume for the prover. Taking these measurements multiple times within required repeatability values allows for the calculation of the new K-Factor.

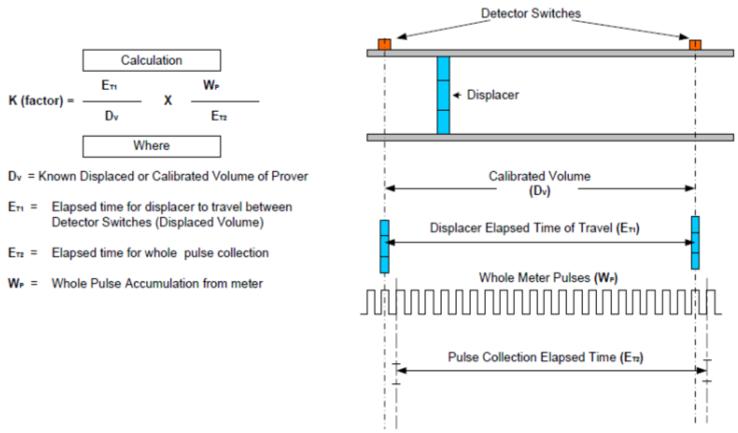

Figure 1: Double Chronometry Pulse Interpolation Formula and Diagrams

3.2 Multi-Pass Proving: Industry acceptance of multi-pass runs for proving allows for adjustment in repeatability limits while still meeting ± 0.0027% uncertainty helped tremendously in allowing for use of the UDCDP in large bore meters. Especially when using newer technologies like Coriolis and Ultrasonic and their manufactured pulse signals. (API Chapter 4, Section 8, Appendix A and Chapter 12, Section 2, Part 3 address the issue of multi-pass uncertainty limits.)

The large bore meter can now be easily verified to an acceptable repeatability value more efficiently and faster than using a bidirectional pipe/ball prover. Allowing pipeline operators, the opportunity to make multiple proving passes while increasing the limits of repeatability while still maintaining the ± 0.0027% uncertainty level required in the industry.

From API MPMS Chapter 4.8 Runs at proving repeatability to meet ± 0.00027 uncertainty of Meter Factor		
Proving Runs	Repeatability Limit	**Meter Factor Uncertainty**
3	0.02	0.00027
4	0.03	0.00027
5	0.05	0.00027
6	0.06	0.00027
7	0.08	0.00027
8	0.09	0.00027
9	0.10	0.00027
10	0.12	0.00027
11	0.13	0.00027
12	0.14	0.00027
13	0.15	0.00027
14	0.16	0.00027
15	0.17	0.00027

Table 1: Pulse Average Table from API MPMS Chapter 4.8

4. What is a meter prover?

A meter prover is a device used to verify flowmeter uncertainty to establish;

- the K-Factor (Pulses per unit volume) of a meter.
- the Meter Factor of a meter (factor used with a meter to correct accuracy for ambient conditions).
- the Linearity over the calibrated flow range for the meter.
- the Repeatability for the meter system.

The meter factor is obtained by dividing the prover test volume by the indicated volume of the meter. Once the meter factor is determined it is used as a volume correction in the calculation for the net standard volume of a receipt or delivery of liquids.

$$\text{(Mfg. or Last) Meter Factor X } \frac{\text{Actual Volume Passed thru Meter}}{\text{Volume Measured by Prover Test}} = \text{New Meter Factor}$$

Figure 2: Meter Factor Formula

4.1 Why companies prove flow meters? The purpose of meter verification or meter proving is to provide accurate measurement which then will minimize losses and maximize profits. The flow metering systems are the “cash registers” for all petroleum operations and this means errors in meter factors can and will generate enormous financial errors in a company’s invoicing in a short period of time.

Example:

If we look at the following example is becoming clear how much money is involved.

- An 8-inch crude line delivering the product to a Refinery, at a flow rate of 2150 Barrels/Hour (BPH).
- The flow meter used in the line, which was proved using a Master Meter, is found to be inaccurate by 0.25% and the crude wholesales for $ 35 per Barrel.
- In 1 month, the product was incorrectly invoiced to the amount of:
  2150 X 24 hours X 30 days X .0025 error factor X $35/barrel = $ 135,450.00, miss invoiced – per month, every month the meters are left uncorrected.

It should now be clear how important meter proving is to the petroleum business.

4.2 Classification of Volumetric Proving:

To differentiate between the classifications of volumetric meter proving the terms **static** and **dynamic** will be defined. The difference applies to the way the standard is compared with the reading of the flow meter under test.

In the **static** scenario, the fluid is collected in a test vessel and compared to the gross delivered amount of the meter under test. This is normally an open system (will be a closed system when testing with a volatile product) and will require interruption of the flow process to perform the meter factor verification.

In the **dynamic** scenario, the fluid remains in a closed system whereby the pulse registration of the meter under test and the pulse registration of the standard prover used are compared directly. There is no interruption of the normal flow process during this verification of the meter factor.

4.3 Equipment used for Proving:

There are three types of measurement equipment used for verification in the petroleum industry today, test measure **tank provers, volume displacement provers**, and **master meters**. Decisions for which type of equipment should be used are based on accuracy requirements, testing flow rates, measurement turndown requirements, environment, cost to install, cost to maintain, and in some cases local agency approvals.

Prior to the development of the volume displacement prover, the volumetric **test measure tank prover** was the best product available for volume measurement verification and has been around since the turn of the 20th century. The volume tank prover may be used for the calibration of liquid flow meters but is also approved for performing volumetric water draw calibration of displacement provers per API MPMS Chapter 4.9. The accuracy uncertainty is specified per tank volumes size. (Note: Tanks over 100 gallons have an uncertainty of +/- 0.01% or less per NIST uncertainty analysis; tanks 100 gallons or less range from +/- 0.015% for 100-gallon cans to 0.3% for 1-gallon cans.)

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The **master meter prover** solution having many possible applications for proving is noted in API MPMS Chapter 4.5. Although used in the industry for some time, it does not have total acceptance for custody transfer approval or for use in weights and measures type applications from all local or regional agencies. The required verification of the master meter's accuracy must be established by using a displacement type or a volumetric tank prover. This should be completed prior to the start of any meter verification when product characteristics (products, temperature, pressure, density, viscosity) have changed since the last master meter proving.

The petroleum industry and American Petroleum Institute (API) have accepted the use of **volume displacement provers** in two categories, the **conventional pipe provers** (displacement prover with sufficient reference volume to accumulate 10,000 whole pulses in a single pass) and the **UDCDP** (displacement prover with insufficient reference volume to accumulate 10,000 pulses in a single pass and uses pulse interpolation software). In both cases, it will require multiple passes for proving and establish a test meter's new meter factor. The conventional provers have been utilized for meter proving since the early 1950s and the captive displacement prover entered the market in the mid-1970s after the acceptance of the double chronometry pulse interpolation as identified in API MPMS Chapter 4.6.

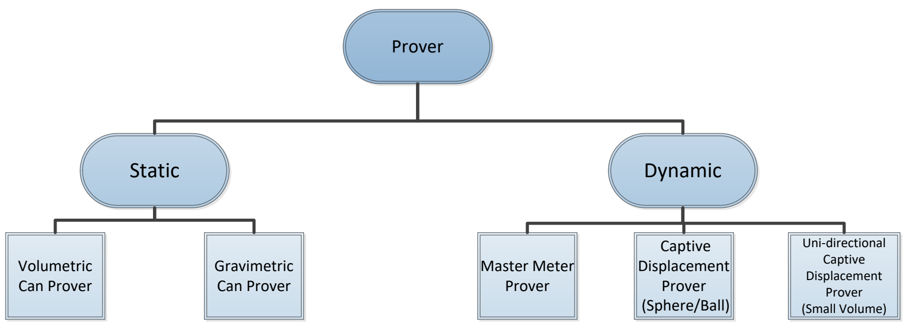

Figure 3: The chart above depicts the classification of each equipment type.

5. Key Components and General Operation of Product used as Provers:

5.1 The **volumetric test measure tank prover** is covered in the API MPMS Chapter 4.4 and was the first product to gain acceptance in the industry for meter accuracy verification in the field. This device is mechanical in design and is the simplest to use and operate. The primary tank prover consists of a certified volume tank or test measure (sized by the required amount of fluid delivered in 1 minute at the actual maximum flow rate) with graduated neck and a gauge glass and scale (scale is designed for ± 0.5 percent of tank certified volume) on the top and possibly the bottom of the tank to measure the tank zero start and stop volume position respectively. There will be temperature measurement locations on an open or closed type system. On a closed tank system, pressure measurement is added as well as inlet/outlet flow connections and drain valve, vapor recovery or release system, overlapping tank side site glasses, and many other components as illustrated in API MPMS Chapter 4.4. When moving from a stationary tank prover to a portable system the additional components needed are a vehicle or trailer, leveling equipment, hoses and connectors, and possibly a small liquid pump-off system.

The use of a tank prover is simple in operation; the most important part is selecting the correct size tank for the meter flow rate(s) to be calibrated. Once all piping connections are established and the tank is verified as empty the inlet flow to the prover begins and fills the tank to the appropriate level. When the tank volume reaches the upper neck gauge glass and the fill line falls within determined tank volume scales, the flow is stopped. The technician reads the scale for the exact gross volume measurement in the tank and this volume has a direct relationship with the registered volume of the meter under test. These values are then used to calculate the test meters new meter factor. If changes are made, a verification proving is then required to assure that any changes applied had the desired result.

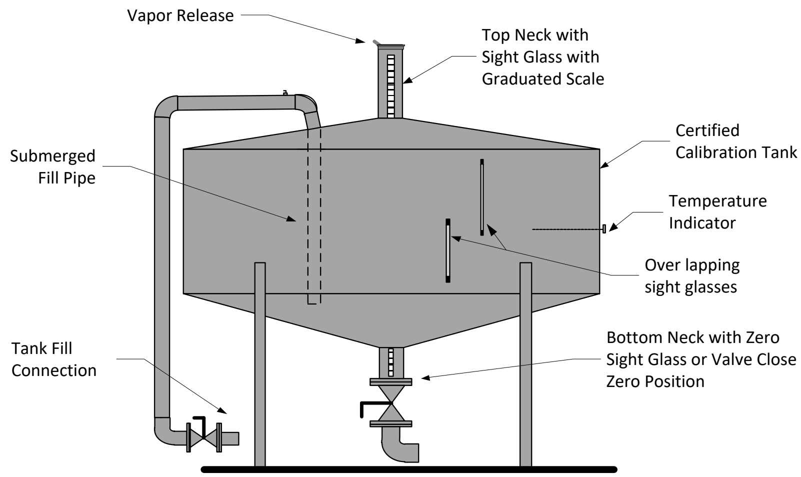

Figure 4: Components in a standard Tank Prover

Critical Characteristics of Tank Type Provers

- Using the one minute of flow rule for tank size, prover tank can become very large and difficult to maneuver and use
- They can need to be drained after each proving – in some cases product will have to be pumped to a slop tank resulting in considerable product loss.
- If used on a loading bay it can stop truck loading for a long period of time.
- Particle or heavy viscous product build-up can cause volume changes
- Well maintained tanks require little maintenance costs.

<u>**5.2**</u> The **gravimetric test measure tank prover** is accepted for use in meter proving. When using a gravimetric tank prover, the most significant component is the certified weights used to calibrate the scale and the scale(s) itself. The scale is used to weigh the tank empty to establish tare weight and verify the weight of the product in the tank once a quantity is measured through the meter and into the scale tank. The volume amount is verified by the equipment mass weight on the scale. Once the weight of the product is determined, the product density must be verified and used to convert the mass measurement to a volumetric measurement for comparison to the meters registered volume.

Gravimetric test measure tank proving in a test lab environment is one way that displacement type prover manufacturers use to verify the volume of the measurement area of each size prover. When completing a water draw certification for a displacement prover, the weighted amount is determined by the amount of fluid registered between detector switch one and detector switch two. Once the weight of the distilled water is found, the temperature and pressure of the water in the prover body are used to convert to a certified volume amount. (Refer to API MPMS Chapters, 4.9.4, and 12.2.4).

Figure 5: ISO 17025 Certified gravimetric water draw test stand – Flow MD – Phoenix, AZ

Critical Characteristics of Gravimetric Type Provers

- Multiple scales and containers are used for larger volumes
- Precise temperature and density are required to convert the mass measurement to volume.
- For larger volumes, the containers are drained and used to maintain a continuous flow.
- Water is the median used in most cases for this type of testing.
- Well maintained tanks require little maintenance costs.

5.3 The **master meter proving** solution has been applied for years and the operational requirements are covered in API MPMS Chapter 4.5. A Master meter proving requires the use of a higher accuracy meter (verified to a higher accuracy level than the meter under test) installed in series on the pipeline along with the meter being verified. There will be a pulse counter system that allows the user to gather flow information over greater time intervals and allows the user to gather as many pulses as they desire. The master meter volume registered is then compared with the test meter volume register and a new meter factor can be calculated from the comparative totals. A second verification of the master meter proving is required to assure that any changes applied had the desired result.

Figure 6: Master Meter Test Cart

Critical Characteristics of Master Meter Prover

- A proving device should preferably be 10 times more accurate than the device being proved. Avoid using an equally or less-accuracy device to "prove" a similar, less-accuracy device.
- Measurement errors form the normal operation of the master meter will be transferred to the test meter
- The Master Meter accuracy could be affected by liquid viscosity, flow rate, temperature or pressure;
- Master Meters are usually designed for a specific fluid type and can't be used on a range of fluids

5.4 The **conventional pipe prover** (ball / sphere type) is covered in API MPMS Chapter 4, Section 2 and can be designed for unidirectional or bidirectional operation. The pipe prover was designed for all levels of flow but gained the greatest acceptance in the industry in larger pipelines where other prover types were unable to handle the higher flow rates. Despite involving a much larger footprint than other types of provers, the pipe prover is a very simple design. The criterion for a unidirectional pipe prover is a minimum sphere velocity of 1 foot /second and maximum sphere velocity of 5 feet/second. The bidirectional pipe prover design sphere velocity must be between 0.5 feet per second and 10 feet per second, but in either design, the prover must allow for the counter to accumulate of 10,000 pulses between the two required detector switches. (Check API MPMS Chapter 4.2, Appendix B). Pipe provers come in multiple sizes and designs, flow rates, and sphere velocity calculations that affect the overall footprint of the individual device.

Figure 7: Examples of Pipe/Ball Provers

The key components of a pipe prover are the U shaped smooth lined uniform circumference pipe, the four-way diverter valve system, the inflatable prover ball or displacer sphere, the ball launching chamber(s), the two detector switches and a meter pulse generating proving counter.

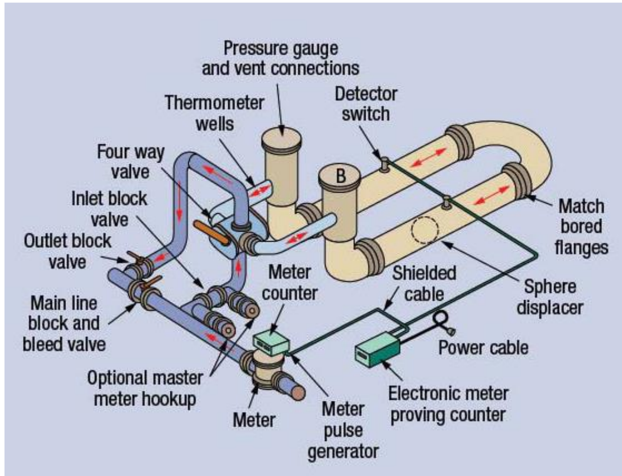

Figure 8: Standard components in Pipe/Ball Prover

Before the proving operation starts, a required proving flow rate must be established. The proving pass is started when the four-way valve actuates to launch the prover sphere into the flow pipe. It then travels through the pre-run area until it reaches the u-shaped measuring section of the pipe. When the sphere contacts the first mechanically actuated detector switch, the counter is started, and the sphere continues to travel until the second detector switch is activated, at which time the counter is stopped signifying a complete pass in a unidirectional prover. The sphere continues to travel until it reaches the other launch chamber where it remains until the start of the next proving pass. If bidirectional, the four-way valve will again actuate to start the pass in the opposite direction and when concluded will be a single pass registration. The flow pulses accumulated from the test meter are then compared with the pulses generated from the accumulated volume between the detector switches on the prover. The proving passes are continued until sufficient passes are completed and the multiple pulse totals can be compared with sufficient repeatability to satisfy the requirements as specified in API MPMS Chapter 4.8, Chapter 9.3, and Chapter 13.2.

Critical Characteristics of Conventional Pipe Prover

- Ball provers require to launch and receive chambers and long pre-run distance;
- Possible high pressure drops with Ball Provers;
- More difficult calculations to correct for temperature and pressure;
- Appreciable uncertainties due to mechanically activated detection switches;
- Large and expensive to install.
- Sphere materials must be compatible with the product, a
- Appreciable uncertainties due to mechanically activated detection switches and detector switch might be sensible to vibrations;
- Difficult to maintain and service

<u>5.5</u> The **Uni-direction Captive Displacement Prover or small volume prover** is a device that is also covered in API MPMS Chapter 4.2. This type of prover with insufficient reference volume to accumulate 10,000 pulses in a single run requires pulse interpolation software to calculate the 10,000-pulse requirement to satisfy a proving pass. One of the most significant design changes compared to a pipe prover was relocating the detector switches to the outside of the measurement pipe and installing them on a switch bar. This allows for higher quality switch activation and easier access for service. The most significant advantage of the design is the ability to verify meter accuracy faster over a larger flow range with a 1200 to 1 turndown and considerably reduced footprint for installation. The major components of the UDCDP are the prover body, prover frame, piston assembly, optic switches, puller assembly, drive system, drive shaft, and controller. For the complete proving operation there is a need for a flow computer or proving software that received the raw data from the prover and meter under test and per API MPMS Chapter 12.2 requirements calculate the data and generate a proving report.

Another tremendous advantage of UDCDP's has when used for dry LPG's meter proving is the low friction seals allowing for smooth operation during proving. With the LPG's, the Pipe/Ball Prover is susceptible to squealing and lunges in the moving of the ball due to minimal to no lubrication capabilities of the product.

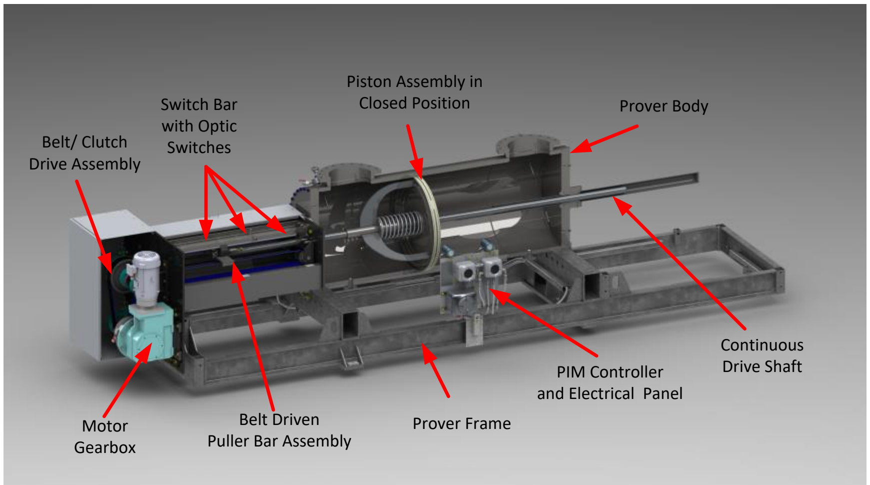

Figure 9: Standard Components for Flow MD UDCDP

The operation of the UDCDP is nearly fully automated. Once the valves are aligned to direct flow through the prover and the required flow rate is set, the flow computer outputs a signal to the UDCDP controller to begin the proving run. That signal engages the drive system drawing the piston shaft to the upstream position in front of the first optical switch. Once the electronic clutch releases the piston the product flow velocity will close the piston and begin the travel downstream through the certified measurement section of the prover's flow tube. The certified measurement for calibration begins when the optic flag mounted on the external portion of the drive shaft, activates the first optical switch and continues the travel downstream until the second optical switch is contacted signaling the end of the first pass. Simultaneously, when the first optical switch is contacted, a signal is transmitted to the flow computer to start the interpolated signal prover counter and the counter for the meter under test. This begins the pulse accumulation from the meter and the controller. When the second optical switch is activated a signal is sent stopping the pulse counters, signifying the end of the next pass. This process continues until the set quantities of required passes are complete. During this process, the flow computer is receiving pressure and temperature information from transmitters installed downstream as well as the temperature of the switch bar on the prover and upstream by the meter in the pipeline. Once the multiple pass information is processed it will be compared for sufficient repeatability to satisfy the requirements as specified in API MPMS Chapter 4, Section 8; Chapter 9.3; and Chapter 13.2. The API proving reports can then be generated automatically as required.

Critical Characteristics of Uni-Directional Captive Displacement Prover

- Can be used in situations where it is possible to collect less than 10,000-meter pulses in a prover pass, by utilizing "Double Chronometry" or pulse interpolation.
- Designed with an internal piston to displace the volume and externally mounted optical detector switches.
- Precise external optical switches are easily serviced.
- A small amount of liquid required for a volume water draw test.
- Piston and Poppet assemble is designed for fail-safe operation not to disrupt the flow.
- Prover allows for accurate measurement of flow meters with a wide variety of fluids. The repeatability of a prover will be better than 0.02% as stated in the API guidelines.
- Has a 1200 to 1 turndown ratio allowing use on multiple size meters.
- UDCDP pulse interpolation is completed in the flow computer or another type of computing device that are part of the proving system.

6. The Industry Acceptance of the UDCDP: With a smaller certified volume and faster operational sequence the UDCDP attained the highest level of acceptance for meter verification in the liquid oil and gas industry. As the industry continues to grow, the UDCDP has kept pace with the growth by offering larger sizes with a maximum flow range to 24,500 GPM (35,000 BPH or 5,564 M^3H). With the standard of 1200 to 1turndown, each prover size can be used to calibrate multiple size meters making it a very economical choice. With higher flow rate proving capabilities and significantly smaller certified volumes, the UDCDP can usually complete a multi-pass proving of a meter in the same amount of time it takes to make a single pass with its predecessor the Pipe/Ball prover.

The other major changes to the UDPDP are the higher (450ºF or 232ºC) and lower (-262ºF or 162 ºC) operational temperature specification to continue to meet industry needs. The design for high temperature and cryogenic temperature UDCDP is now a reality.

Another advantage the UDCDP over its predecessors is the installation footprint that can be 10-30 time smaller in area. The larger footprint when comparing the overall capital expense of total installation and commission cost makes the UDCDP a better economical choice especially with larger meters from 6" through 16" meters with high flow rates.

Criteria	Bi-directional Ball Prover	Flow MD SVP
Turn down	5 to 1	1200 to 1
Displaced Volume	100 pulses b/t switches = 56.76BBL 1050 pulses b/t switched= 90.91BBL	75 gal (1.78 BBL)
Dimensions	Approx. 70 ' x 16' x 15'	FMD90 16' x 4.5' x 5.5'
4 Way Valve	yes	no
Pre run Length	29 feet of 30" pipe on each side	1'
Approx. Distance between Switches	54 feet of 30" Pipe b/t switches	3.5'
Type of Displacer	Use a liquid filled prover ball (pressurized + 3-6% pipe size)	Self seal piston design (Open until proving)

Table 3: Comparison of Pipe/Ball Prover vs. UDCDP 12,500 BPH (1,897 M^3H)

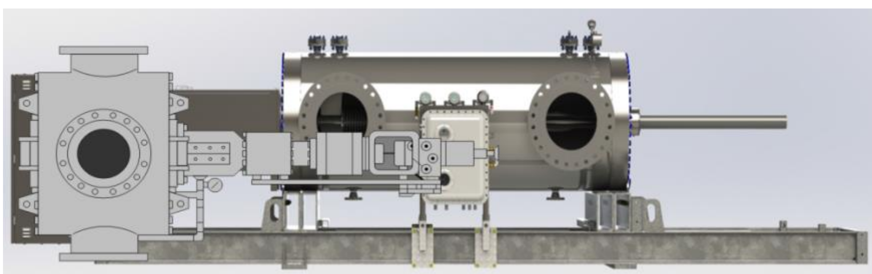

Figure 10: UDCDP sized for 28,800 BPH (4,500 M^3H)

compared to the 4-way valve for the same flow rate in a Pipe/Ball Prover.

The other major developments in the UDCDP is the design changes to the electronics that now can continuously verify the certified volume after each prover pass, and a continuous self-diagnostic of the health of the complete prover system.

7 UDCDP Designed for Mass Proving As the use of Coriolis Meters (designed to measure mass first and density second) continue to expand in the liquid oil and gas market, the required volumetric proving can become a challenge. First, the Coriolis Meters have very little influence for measuring mass since the movement of the fluid inside the tube causes the time phase shift from the inlet to the outlet electronic measurement coils which are a direct relationship to mass flow. Since the density measurement is derived by the vibrational frequency of the tube, changes in the weight of the tube will change the density of the output. When using the Coriolis meter for volume measurement the standard calculation of mass / density = volume is utilized. Therefore, if product buildup on the walls of the tubes occurs, this product usually has a different density than the product in liquid state inside the tube during flow causing possible errors in the volume output.

This is where the UDCDP with the option for an installed Densitometer and a Pycnometer can be used as a complete Mass Prover solution. This system allows the verification of all the parameters of the measurement uncertainty for a Coriolis meter. Also, note the temperature and pressure of the measurement is verified as part of the required parameters as with all proving calculations.

Figure 11: Standard Mass prover design

8 Groups and Agencies that Govern the Proving Processes: The American Petroleum Institute (API), International Organization of Legal Metrology (OIML), and National Institute of Standards and Technologies (NIST) oversee the meter proving process generally. There are global requirements and regional requirements to be aware of and the specific regulations or standards for each country, province, state or city where measurement equipment and measurement verification devices are used must be considered. Noted below in the reference sections are documents that should be evaluated when proving meters and for the operation and design of verification equipment and systems.

8.1 Where does a Prover Device fall within the Agency Approvals?

Within API MPMS Chapter 4 there is noted an overview of Hierarchy in proving products.

Liquid metering systems designed and operated in conformance with **API's *Manual of Petroleum Measurement Standards*** typically have one or more of the following levels of hierarchy as shown below.

- ***Level 1.*** Primary standards involve mass, volume, and/or density standards developed and/or maintained by National Institute of Standards and Technology (NIST) and/or other national laboratories to calibrate secondary working standards.
- ***Level 2.*** Secondary working standards include mass, volume, density, and/or weighing systems maintained by NIST and/or other national laboratories to calibrate field transfer standards conforming to Chapter 4.7. Secondary working standards may also be maintained by state and other certified metrology laboratories to calibrate field transfer standards. These additional secondary working standards, however, increase uncertainty in the final custody transfer quantities.
- ***Level 3***. Field transfer standards conforming to API MPMS Chapter 4.7 are devices used to calibrate meter provers in compliance with API MPMS Chapters 4.2, 4.3, and 4.4.
- ***Level 4***. Meter provers in compliance to Chapter 4 can be used to determine meter factors that correct the indicated volumes of meters.

Traceability Pyramid of Standards

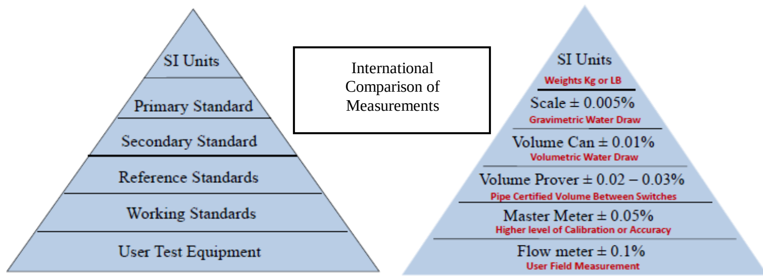

Figure 12: Pyramids of Traceability for Working and Operational Standards.

These traceability standards (Listed in Figure 12) can be used for all liquid measurements in the global market. Starting with the meter on the bottom to the SI weights on the top. Each level requires a minimum of two times better accuracy of certification.

The Captive Displacement Volume Proves lies in the middle of the Traceability Pyramids illustrated above. What this means is the prover devices that have higher uncertainty can and are used to verify each other. In the world of Captive Displacement Provers, the Volume Can and the Scale Can Provers are used for Volumetric and Gravimetric Prover verification respectively. Certification of a Prover is noted in the API MPMS Chapter 4 and OIML R119 documents and is required every 1, 2 or 3 years depending on the service.

With the field use of a master meter used in volume certification of a ball prover, the UDCDP becomes in most cases a critical part that the Pipe/Ball Prove field certification as noted in Figure 12.

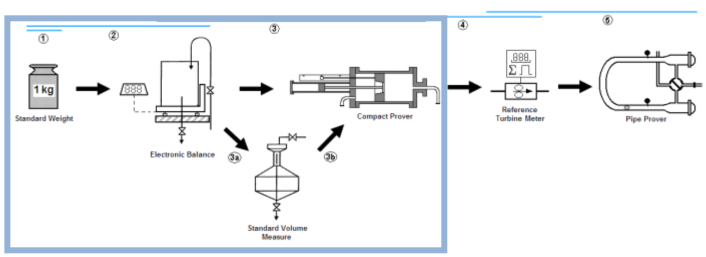

Figure 13: Field Water Draw UDCDP in 3 Step Process or Ball Prover is 5 Step Process

Although capable of being certified by a volumetric can for the water draw, one of the greatest advantages of the UDCDP is the ability to be field certified gravimetrically with the use of electronic high precision balance (scale). The largest UDCDP designed at this time has a 4 BBL certified volume which can be gravimetric water drawn with a scale and a tank that can handle a weight of 1500 lbs. Manufacturers of UDCDP have recognized the importance of accurate volume calibrations and have employed the gravimetric method in their final acceptance testing for years. There is documentation in an ISHM Paper (Reference 13 below) that the comparison indicates the gravimetric method has a significant improvement (decrease in value) in uncertainty over volumetric water draws. The values also show an improvement that is much greater than an order of magnitude (a factor of 10) better than the volumetric method.

9. Summary: There was a great deal of information provided in this paper. The idea was to supply enough information that would substantiate the use of a UDCDP as an acceptable and viable proving device from both an economical and qualitative perspective for the liquid Oil and Gas Industry. As the industry changes from the original technology (Turbine and PD) to the newer technologies (Coriolis and Ultrasonic) for metering liquid products the UDCDP will continue to be the operative choice for the future. There are many options for using a proving device and all influences like accuracy, flow rates, measurement turndown, environment, installation, and operational costs, local agency acceptance should be part of that decision. There are applications for every type of proving device and hopefully, the information provided here has supplied guidance to help make those decisions.

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