OPERATIONAL EXPERIENCE WITH SMALL VOLUME PROVERS

Class # 4110.1

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Introduction

Over several decades, the Small Volume Prover (SVP) has become a common and vital piece of equipment throughout the pipeline industry. There are many available publications that explore the functionality and method of operation for the SVP. The primary focus of this document is to highlight the author's experience with the SVP. The majority of the document will address the technical operations and advancements made to the SVP over time, as well as the calibration methods and proper maintenance of the devices.

SVP's have progressed into being the industry standard in custody transfer applications. They have shown to be extremely accurate as well as efficient in both stationary and portable applications. They can operate across an extensive variety of fluids and an equally broad span of flowrates. This is especially impressive considering the compact size of the SVP, which demonstrates their claim of efficiency. The size comparison to a traditional pipe prover (foot print) can be a significant factor when considering the implementation of an SVP.

Definition of a Small Volume Prover

The SVP is defined in **API MPMS 4.2** as "*a unidirectional prover with captive displacer*". For quite some time, the only real criteria to be considered an SVP was simply any prover that collected less than 10,000 pulses per pass. This has since become an outdated method of classification. With technological advancements have come great changes in meter design, operation, and output. The result has been meters that, regardless of prover volume, are unable to generate 10,000 pulses. One example is the helical turbine. Many large barrel provers still cannot accumulate the minimum amount of pulses required, but are not classified as an SVP. To explicate the established definition, an SVP should be defined by its displacer and detector switches.

Operation

The evolution of meters over time goes hand in hand with that of the SVP. The most current/common incarnation of the SVP uses machined optical switches, which represent the volume to be measured, in conjunction with the internal displacer (sphere or piston/shaft). As fluid travels through the prover, the displacer is mobilized, activating a primary and secondary switch which controls the operation of very precise pulse counters. All data is collected electronically and transmitted through computer software that handles calculation and makes the necessary corrections. Detailed operation procedures are highlighted in **API MPMS 4.8**.

Characteristics

Most vital to the accuracy of the SVP are the detector switches combined with the pulse interpolation system. The switches may represent one or multiple volumes for a single prover and must be repeatable within .0001 of an inch. This precision makes it possible for the volume to be so small without degrading the accuracy. Optical detector switches are very popular for their high speed and are, despite being plastic and relatively delicate, considerably low maintenance. Regular maintenance can ensure an extensive lifespan of the detector switches.

Electronically speaking, the other half of this process is the pulse interpolation system. Pulse interpolation is only necessary when accumulated pulses are less than 10,000. Meters that generate more than 10,000 pulses per pass do not require pulse interpolation. Being that the former is most often encountered when dealing with the SVP, pulse interpolation has become viewed as mandatory for effective operation. An example being double chronometry pulse interpolation (**API MPMS 4.6** details this method). This allows pulse resolution to 1 part in 10,000 (i.e. out to 5 significant digits). This is still limited by stable pulse output; best results are obtained from meters with more uniform pulse emission. Subsequently, higher pulse output results in better resolution.

Other common traits today's SVPs share are their precision machined barrel, piston, and shafts. This allows the flow chamber to be compact while also minimizing error, but must be carefully inspected for any signs of damage or wear. If any of these parts need to be repaired or replaced, a new water draw or calibration of the prover must be conducted.

Detector Switch Maintenance

Though these optical switches are typically low maintenance, malfunctions do occur and are usually attributed to electronic failure or breakage. In the past, replacing switches could be a troublesome chore, not to mention it typically required that the prover be recertified by a new water draw. Replaceable switches have been developed that now allow for significantly shorter down time, which translates directly into dollars saved. With this development, switches can be interchanged with great ease and even retain accuracy to the point that a water draw is no longer necessary upon a new switch installation. This improvement to the switches has been tested on multiple occasions both in our lab as well as in the field. When compared between waterdraw or prover bump methods, no discrepancy in volume could be detected. The results of such tests have proven satisfactory not only in our company but also in leading oil companies within the industry.

Seals

The SVP is capable of handling many different fluid applications largely due to its Teflon based elastomer seals. These seals hold up under high pressures and flowrates as well as large fluctuations in temperature that may be present throughout operation, whether attributed to seasonal or product changes. They can be subjected to many different products ranging from very viscous, unrefined products to light hydrocarbons sometimes characterized as "dry" products in the industry without compromising seal integrity. The biggest threat to the seals, and even the machined components within the flow tube, is extreme exposure to abrasive materials within the product lines. However, great measures are typically in place to minimize or eliminate this concern.

Prover seal life depends heavily upon the amount of harsh particulates that may be present in the fluid and the frequency of the proving cycles. Use of cleaner products should yield roughly 40,000 to 50,000 proving cycles before a seal change may be necessary. This is based on a test conducted to count the average cycles of two provers between seal changes.

Leak Testing

Leaking seals can adversely affect accuracy. Manufacturers have developed fairly efficient procedures for leak detection, but these measures must be conducted in a shop setting and are almost exclusively designed for use with water. Though these tests can work in field applications, they can prove difficult to verify especially when conducted using hydrocarbons. Field conditions often change regularly with the environment, taking many elements out of our control, which increases the chance of inaccuracies.

Over the years, a second method has been used and successfully proven for indicating seal leaks in the field. Begin by proving at one flowrate to establish a correction factor then change the flowrate by fifty percent and reprove. Upon completion of the second proving, the percent of change between correction factors should be equal to the change in flowrate percentage. This method should prove quite precisely provided the issue is solely due to leaking seals. Of course a leak between the meter and prover will have the same effect. By changing the flowrate, the flow time between switches is doubled thus magnifying the error. It should be noted that for this test to work correctly, both flow rates must also be within the manufacturer's suggested flow range of the meter.

Minimum Pulse Output

The minimum number of pulses required to indicate an acceptable meter proving is a topic full of debate and speculation. Through much field testing and research throughout the industry, a general consensus was reached that 300 pulses was an acceptable threshold for meter proving. Through our own testing at Coastal Flow, we have found 100 pulses to be acceptable because no significant difference in meter factors could be recorded. This led us to implement a 100 pulse policy within our company. That being said, the understanding of pulse output continues to vary between specific field applications. Contributing factors include meter type, pulse output resolution, materials, pulse fidelity, and the stability of the flowrate. These are the factors that dictate the number of pulses output to the SVP. They do not represent the minimum pulses required for the SVP to be effective.

Meter Proving Experiences

As stated, the SVP is applicable to many different meter types, despite the first SVP being designed for turbine meters specifically. As time has passed, SVPs have proven quite effective proving Coriolis, displacement, and even ultrasonic meters. The SVP has been cast into a negative light by some detractors by claims of inaccuracy or difficulty achieving acceptable repeatability. This however is usually due to the fact that the smaller volume of the

SVP makes it possible to see errors that may not be apparent when using a conventional prover. It is our position that the SVP allows for recognition of potential problems and preventative steps to be taken before a minor issue can become a big problem.

In applications involving electronic based meters, most manufacturers do recommend different flow rates than what are applicable to mechanical meters. Repeatability has been an issue in itself being that electronic based meters have inherent difficulties with repeatability in tests conducted with SVPs. This issue can usually be resolved by using multi pass proving runs, either by summing or averaging passes. This method is detailed in **Chapter 4, Section 8, Annex A.5**. In regards to Coriolis meters, cases where averaging multiple passes do not help, it can be attributed to zero instability. This is an issue that can be caused by several different factors that are not exclusive to installation and flow process.

<u>Waterdraw</u>

The procedure utilized to calibrate and certify the SVP. Several methods can be used to yield an acceptable water-draw calibration of an SVP. Acceptable, defined as, meeting minimum standards set forth within **API Chapter 4 Section 9**. The three methods being volumetric, gravimetric, and master meter have all been proven successfully in lab and field applications, but are not necessarily created equal. Typically, SVPs are water drawn every three years, although it is not uncommon that contractual agreements between companies may dictate the frequency of calibrations.

At first the initial results came under some skepticism when testing the SVP. This led Coastal Flow to begin conducting waterdraws on our provers more frequently than required by API standards. This increased frequency did come with other challenges, primarily finding a third party that could meet the demand at a reasonable price. It was decided in time that the best course of action was to obtain the necessary equipment and conduct the tests ourselves. This decision not only increased our customers' confidence in the SVP, but also led us to improving the waterdraw process. The NIST uses a gravimetric method to calibrate test measures (cans). By essentially using the same method for a waterdraw we can produce the same results as a volumetric test. The benefit to this is that the gravimetric calibration has shown improved repeatability between runs as well as draw to draw.

As with any field application in the industry, circumstances and environments are not always ideal. Each of these processes are susceptible to error and great care must be taken to ensure all related test equipment is accurate and of good quality. One obstacle these first two methods present is that they do rely on quite a few moving components and any variation on any one of them could result in a failed test. The master meter method can address this concern by eliminating the need for some equipment such as the can and scales. Though it is not necessarily more or less accurate, it is typically more compact being that it works in tandem with a master prover to conduct the test. This method is detailed in **API Chapter 4** "Proving Systems," **Section 9** "Methods of Calibration for Displacement and Volumetric Tank Provers," **Part 3** "Determination of the Volume of Displacement and Tank Provers by the Master Meter Method of Calibration". The advantages to this method include eliminating the need to clean the field prover, do not necessitate the use of water, and allow an opportunity to verify the prover under operating conditions. The master meter method is, however, bound by the accuracy of the master prover and the performance of the master meter. Choosing a master meter should be done with the utmost discretion.

After years of testing each of these methods both in field and lab settings, we are confident that the following recommendations will improve the results of any test conducted no matter the method applied.

- Conduct waterdraw with only one test measure. More than one can increases the amount of equipment and time thus increasing uncertainty and the possibility for error.
- Test with minimal inventory. This pertains to the volume of water in the hose between the prover and the can. As this volume increases, so does the chance of an error occurring.
- Minimize the associated volume. Associated volume is a reference to the volume of water in both the upstream and downstream piping connecting the meter and prover. When possible efforts should be made to eliminate this area altogether. Typically this is done through installing blinds.
- Eliminate as much air from the process as possible.
- Stabilize air and fluid temperatures.
- Perform five consecutive prover runs with 0.02% or better repeatability instead of the required API minimum of three. This reduces uncertainty and may expose apparent issues not evidenced by three runs.
- Obtain the highest quality of water possible. Hydrocarbon free de-ionized water will yield better test results.
- If possible select a master meter with a proven history of good repeatability and linearity.

Crude Oil Applications

The SVP has been in service for many years with great success even in crude applications. The largest obstacle when dealing with any unrefined product is the presence of debris and trash within the fluid. As previously mentioned, this can significantly shorten the life of the prover seals. However it is important to note that contaminants can adversely affect any prover operation. It would also be beneficial to select a chrome lined stainless steel tube which would offer increased durability against harsh contaminants. Even under the most extreme conditions our full expectation is that the SVP will exceedingly surpass performance and longevity of any other prover in the industry.

API Standards

Portions of this paper reference the **API Manual of Petroleum Measurement Standards.** Over time these documents are updated and revised. The SVP has continued to evolve along with associated field equipment necessitating such revisions.

It is strongly recommended, whether a SVP is already in service or under consideration by your business, that you familiarize relevant personnel with these standards. Though portions of the older editions may be outdated in regards to small volume provers, they can provide good insight into the evolution of the equipment as well as procedures. As technology continues to advance more rapidly than ever, we also encourage that current or potential users closely monitor and stay up to date on future editions/revisions of these standards.

Conclusion

After countless man hours and years of extensive testing, Coastal Flow Liquid Measurement has observed the progression of these machines. We have also experienced first-hand the difficulties with introducing new test equipment into the industry, however each adverse encounter proved to be miniscule as our knowledge and understanding of measurement increased. We view such adversity as a learning opportunity and continue to be impressed by the capability of the SVP as we apply that knowledge in the field. At Coastal Flow Liquid Measurement our confidence is cemented in the SVP so much that we promote it as the most effective and efficient prover technology available in the industry.

Sited References

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 2 “Displacement Provers” (March 2011)

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 6 “Pulse Interpolation” (October 2013)

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 8 “Operation of Proving Systems” (September 2013)

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 8 “Operation of Proving Systems” Annex A.5 “Multi Passes per Run” (September 2013)

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 9 “Methods of Calibration of Displacement and Volumetric Tank Provers”, Part 2 “Determination of the Volume of Displacement and Tank Provers by the Water draw Method of Calibration” (December 2005)

American Petroleum Measurement Standards Chapter 4 “Proving Systems”, Section 9 “Methods of Calibration of Displacement and Volumetric Tank Provers”, Part 3 “Determination of the Volume of Displacement and Tank Provers by the Master Meter Method of Calibration” (July 2009)

American Petroleum Measurement Standards Chapter 12 “Calculation of Petroleum Quantities”, Section 2 “Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors”, Part 3 “Proving Report” (March 2009)