SMALL VOLUME CAPTIVE DISPLACEMENT PROVERS FOR NATURAL GAS LIQUIDS

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Introduction-

Natural Gas Liquid service was among the first applications for CDP or Captive Displacement Provers. CDP’s formerly called SVP's or Small Volume Provers are used widely in natural gas liquid services.
This paper will be focusing on operation and history of CDPS and thier advantages over the conventional type of Provers.

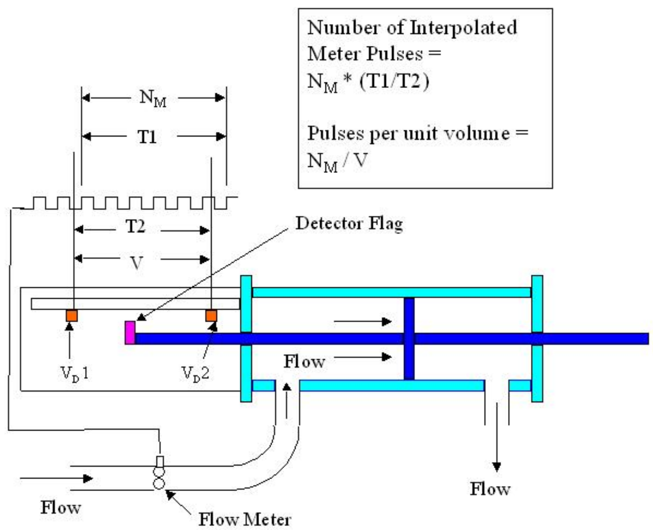
History of Small Volume CDP Provers-

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 1970's in order 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 now known as the CDP.

Mr. Ed Francisco, who was the owner of Flow Technology, Inc. back in the 1960's was contacted by NASA to help with proving of 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 period. Double chronometry for API meter proving as described in API 4.6 is simply a method of resolving meter pulses to a resolution of +/-1 part out of 10,000 without the need for actually counting 10,000 meter pulses during a meter proving.

The double chronometry technique is a simple process. The time for the volume displaced and the time period for the whole meter pulses collected during that time period are timed separately with high frequency time bases. The whole meter pulses collected during that time period 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) * number of whole meter pulses. Modern computer time bases currently utilized in flow computers and other double chronometry devices utilized for flow proving use time bases at least 1 mHz frequency providing an uncertainty of far better than the 1 part out of 10,000 as required.



Definition of Captive Displacement Provers (CDP's)-

With the advent of some low frequency pulse output meters, such as helical turbines, even very large volume sphere Provers cannot accumulate 10,000 meter pulses in a Prover pass. The old definition was no longer applicable, as it could be any Prover, depending on the meter type being used.

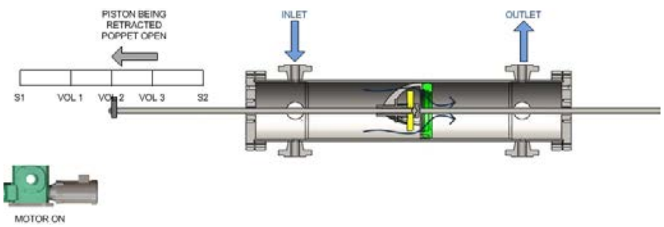
Definition of Small Volume CDP's-

With the introduction of low pulse output meters, such as helical turbines, even very large Provers could not meet the requirement of 1 part out of 10,000 by using conventional Prover counters, making the old definition of Small Volume Provers obsolete Because of this development, the API measurement manuals needed to re-define Provers. To avoid confusion, it was determined to define a Prover by the type of displacer and switches it uses. The number of pulses collected determine whether pulse interpolation is necessary must be used. The newly published API Chapter 4, Section 2 refers to a CDP as a unidirectional Prover with captive displacer.
A Prover having a captive displacer has an attached shaft or rod, which moves with the displacer. The displacer is normally attached to a shaft or rod that passes to the outside of the Prover and is used to move it to the

upstream end of the measuring section. This shaft may also be used to detect the position of the displacer and to activate the detector switches.

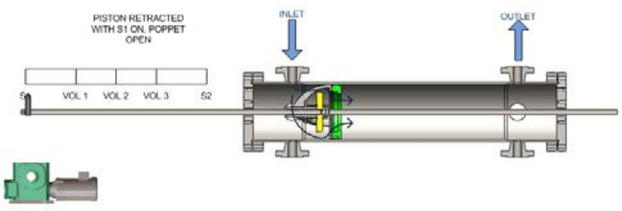
Operation of CDP-

The basic operation of CDP's is very similar in regards to the measurement.

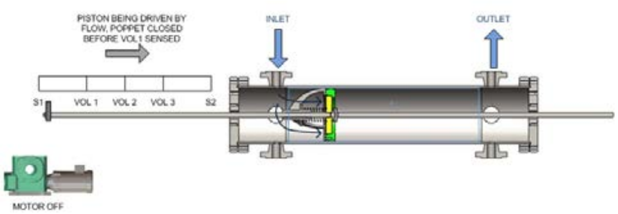


In standby, the piston resides in the downstream position, with the piston poppet valve held open by fluid flow through the Prover

When a prove command is generated by the host flow computer, a signal is sent to the CDP controller, which sends signals to the drive control (Motor, Hydraulics etc.). to start causing the drive assembly to pull the piston assembly to the upstream position.



When the drive assembly has pulled the piston to the upstream position and contacted the upstream switch S1, (Figure 2) a signal is sent to the Prover Controller, which Releases the drive mechanism , releasing the piston shaft, allowing the piston valve to close, starting the prove pass.



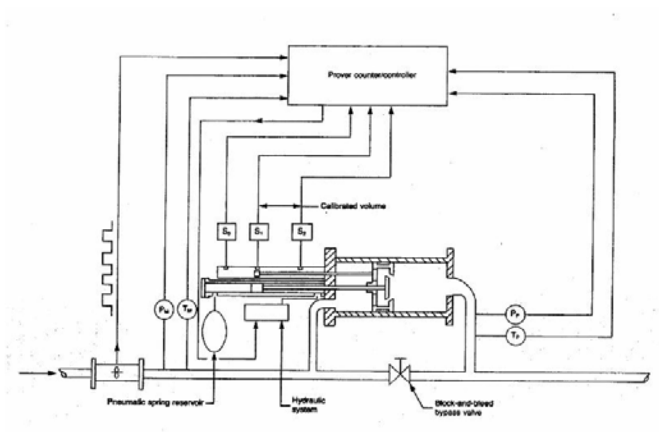
After closure, the piston travels downstream synchronous to the fluid flow. The flag actuates volume switches 1, 2, and 3 in that order, sending the signals to the Prover Controler which stores the information and sends signals from the selected switch pair to the host flow computer. Piston then continues downstream to the standby state until another run command from the host flow computer.

The main characteristic of a small volume CDP is external optical switches actuated via the shaft attached to the piston.

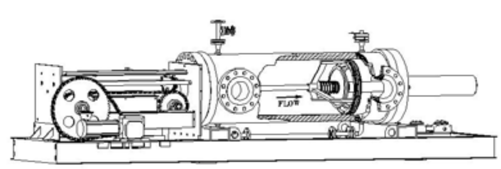
Development of CDP Provers-

CDP Small Volume Provers have gone through a progression of design changes. Currently, there are 3 basic CDP types available. Following are the types and the sequence of design. It is not the intent of the author to critique the designs, but to point out the design differences. It is extremely important to properly size the CDP to the meter type and application, and to operate the unit per the manufacturer's recommendations. Regardless of the design of the Prover, improper application will not provide adequate results

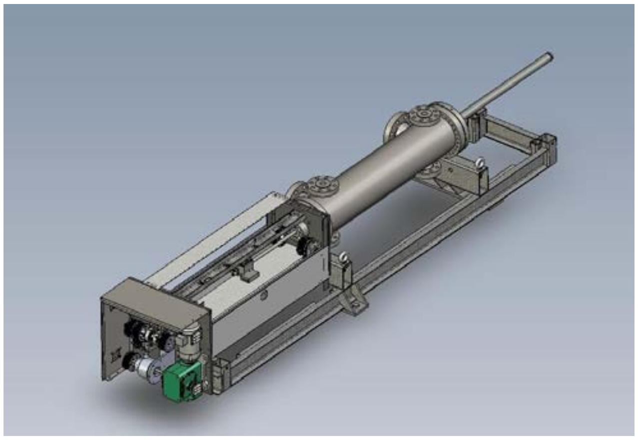
First Generation of CDP small volume Provers utilized a single shaft arrangement using hydraulic piston return mechanism, and required a spring plenum to balance line pressure because of the single shaft arrangement. This Prover had unequal upstream and downstream volumes. It was the first flow Prover to utilize high precision optical switches and the flow-through piston design.



The second generation CDP small volume Provers utilized a double shaft arrangement which provided equal upstream and downstream volumes. It utilized a chain drive arrangement which returned the piston, and de-coupled from the piston shaft to make a proving stroke.



The Third Generation CDP has a drive system utilizing timing belts for the return of the piston. The drive mechanism utilizes a clutch to de-couple the drive, allowing for very smooth operation, minimizing shock and flow perturbation. It also utilizes the flow through piston design and high precision optical switches.



Advantages of CDP Provers in NGL service-

Long life: A precision machined stainless steel flow tube with hard chrome plating has an indefinite life. The author is aware of some CDP Provers installed in the late 1970's that are still in daily service.

1. **Smooth operation:** NGL service, especially in some products is extremely dry, and provides no lubrication. The smooth precision bore coupled with filled PTFE material seals provides very smooth operation and long seal life. Many older pipe Provers chattered or squealed as the ball traversed through the Prover tube in dry NGL service.

2. **High precision:** The volume switches in a CDP are normally external optical switches, and have a repeatability of 0.0001 inches or better. These switches are precision calibrated, and can be changed and retain the same volume within very tight tolerances. Some new developments, such as laser switches with a switch bar with fixed precision holes defining the volume completely eliminate the need for re-calibration in case of a volume switch failure. Volume calibration by the gravimetric technique as defined in API 4.9.4 which is currently used by most CDP manufacturers has an uncertainty of from 10 to 20 times better than the +/- 0.01% as required by the API Measurement Manuals.

3. **Cryogenic or low temperature operations**: The newer generations of CDP's are capable of operating to temperatures of negative 169 Degree C with Stainless Steel wetted parts (parts in direct contact with fluid) material and new polymer technology.

Other advantages-

1. An extremely wide operational flow range of at least 1200:1 because of the extremely smooth operation, and superior fluid compatibility, which is very important in natural gas liquid service.

2. CDP's require less real estate to install in fixed installations, and are ideal for portable proving of natural gas liquids due to the much smaller size and ease of installing on trailers or trucks.

3. CDP's are also ideal for proving mass meters such as Coriolis meters. When using the Provers volume and a density meter coupled to the Prover, the mass of the proving system can be compared with the mass output of the meter for a direct mass proving. CDP's can be factory equipped with densitometers.

4. Shorter Proving time.
   The small measurement volume and shorter stoke requires less time for Proving meters.

Conclusion-

Small Volume CDP Provers are an ideal choice for proving Natural Gas Liquid meters because of the long history of use in NGL service, the accuracy of proving, and repeatability of volume, ease of operation, ease of installation, portability, and long life.