## June 2005

# Part 2 –
# Small Volume Provers
# History, Design, and Operation

By Diane Lee

This is the second part in a series of articles on small volume provers (SVPs). Part 1 of the series identified the various types of pipe provers, which include conventional pipe provers and SVPs. Part 1 also included definitions of the types of provers and components associated with SVPs. The reader is encouraged to reference Part 1 for terms and definitions that are used in this article on SVPs. Part 1 of this series is available on the NIST Weights and Measures Division website at www.nist.gov/owm. This article, Part 2, of the series addresses the history, design, and operation of small volume provers.

***History***

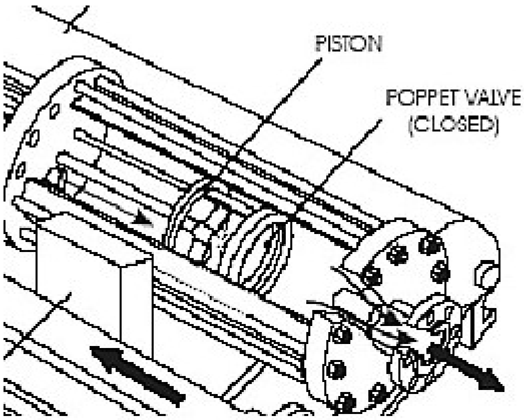
The first pipe provers were used in the early 1950s. One of the first pipe provers was a mile in length and linked two oil refineries in dispute over the measurement accuracy of the flow meters. The refineries were unable to independently verify the accuracy of the meters so the length and diameter of the pipe were estimated and the time for a displacer to travel the distance was used to calculate the volume and verify the accuracy of the meters. Since then many manufacturers have improved on the design of these provers. In the late 1960s to meet the requests for precision test equipment to calibrate small flow meters, a pipe prover called a "small volume prover" was developed that used an electronic pulse-counting technique called double chronometry. In the late 1970s and early 1980s further modifications, which included the replacement of reed switches with optical switches, were made that allowed the SVP to be used more readily in trade. In 1996 changes were made to the terminology in NIST Handbook 44 "Liquid Measuring Device Code paragraph N.3.5. in order to allow the use of SVPs, and in 1997 NIST Handbook 105-7, "Specifications and Tolerances for Dynamic Small Volume Provers" was published.

***Design***

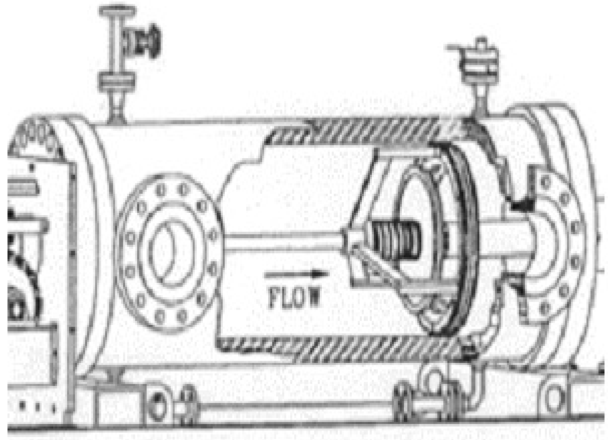
The basic design of SVPs include a precision bore cylinder, a displacer, a means of positioning and launching the displacer upstream of the calibrated section, a displacer detector or detectors that allow fluid flow while the displacer is traveling from one position to the opposite position, a pressure measurement device, a temperature-measuring device, instrumentation with timers, counters, and pulse interpolation, and provisions for proper venting. SVPs come in various sizes based on the connection and flow rate capabilities. The measuring section of some common sizes are 20 L (5 gal), 40 L (10 gal), 60 L (15 gal), 120 L (30 gal), 250 L (65 gal), and 318 L (84 gal). The following are diagrams with descriptions of the basic components of the SVP.

*Precision Bore Chamber:*

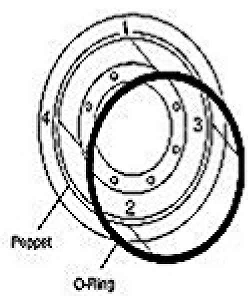
The precision bore chamber has a known volume, which is verified in a laboratory using a water draw procedure. This component of the SVP houses the piston and the poppet valve (also called a flow-through valve). See Diagrams 1, 2, and 3.




**Precision Bore Chamber & Displacer**
*Diagram 1*




**Precision Bore Chamber & Displacer**
*Diagram 2*

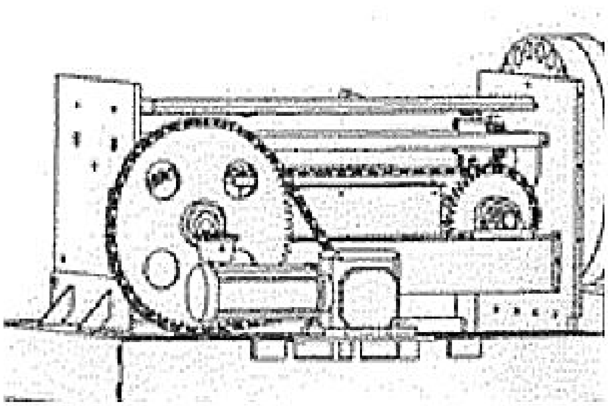



**Poppet Valve**
*Diagram 3*

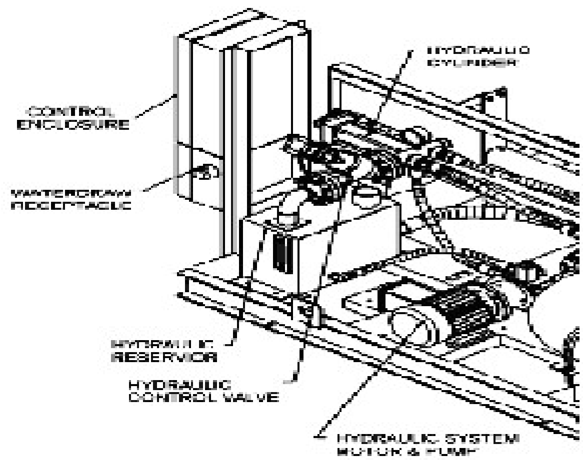
*Displacer:*
The displacer can consist of a piston or a sphere or ball. The displacer moves with the same flow as the liquid between two detectors, and the time it takes to travel between the switches will give a measure of flow rate. The displacer is made of material that is appropriate for the prover's operating pressure, temperature, and the desired resistance to degradation by the liquid that is being metered. The displacer is typically of a piston type for small volume provers. The design and components discussed in this article and illustrated in the diagrams below are of the piston type. See Diagrams 1 and 2.

*A Valve Arrangement that Allows Fluid Flow While the Displacer is Traveling from One Position to Another:*
The poppet valve or flow-through valve is a valve located inside the piston displacer, that, when open, allows product to flow through. During movement of the displacer from upstream to downstream, the valve is closed. The valve is open when it moves from downstream to the upstream position.

*A Means of Positioning and Launching the Displacer Upstream of the Calibrated Section:*
Diagrams 4 and 5 show two types of means used to position and launch the displacer. Diagram 4 shows a chain drive mechanism and Diagram 5 shows a hydraulic mechanism. In Diagram 4 the standby mode for the piston is downstream with the poppet valve open. The chain mechanism pulls the piston to the upstream position, the piston is released, and the poppet valve closes to start a proving run. In Diagram 5, the piston is upstream in the standby mode. When the hydraulic control valve opens and releases the hydraulic pressure, pressure from the pneumatic spring plenum closes the poppet valve to begin the run.



**Chain Mechanism**
*Diagram 4*




**Hydraulics**
*Diagram 5*

*Detectors:*
The detectors are optical sensors or electrical switches used to start and stop counters and determine the calibrated section of the prover. A piston displacer will trip the optical sensors as it travels the length of the calibrated section of the prover (precision bore chamber). See Diagram 7.

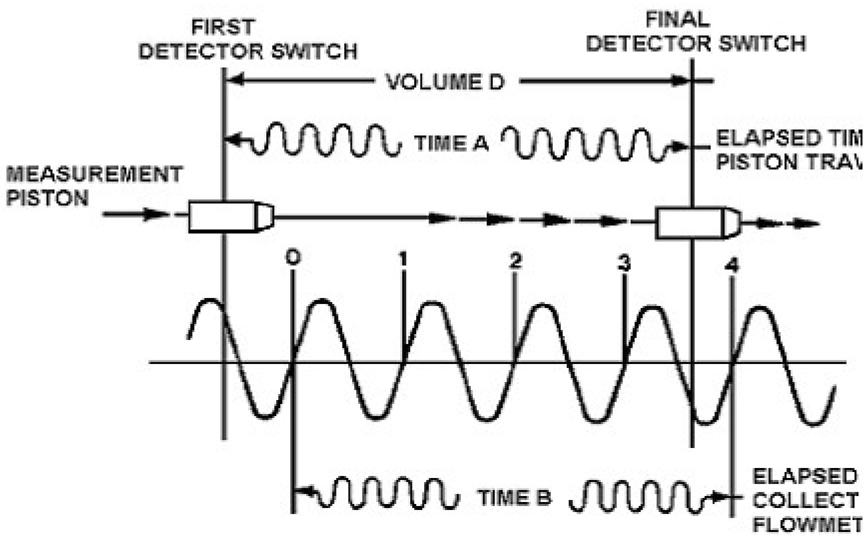
*Pressure and Temperature Measurement Devices:*
Temperature and pressure measurements are made during the proving run. Liquid is passed through the meter and prover until the temperature and pressure are stabilized.

*Instrumentation with Timers, Counters and Pulse Interpolation (see Diagram 6):*
SVPs require the use of an operating computer that is capable of dual chronometry pulse interpolation. Pulse interpolation is a pulse counting technique used to calculate the total number of meter pulses between two detectors, including fractional pulses. As discussed in Part 1 of this series, a conventional pipe prover requires a minimum of 10,000 unaltered pulses to ensure an accurate test. This minimum is based upon the assumption there is a potential error of 1 pulse each time a detector is passed, which equates to a 2-pulse error per run. The value of 2 pulses per 10,000 equates to a potential 0.02 % error. SVPs require less than 10,000 pulses, which would equate to a potential error greater than 0.02 %. To enhance the meter's pulse output, SVPs use pulse interpolation for fractional meter pulse counting. To interpolate fractional meter pulses or to mathematically interpolate partial pulses, the method most widely used is double chronometry. Double chronometry pulse interpolation increments time precisely to 0.000001

parts per second. A high frequency master oscillator operates two time counters referred to as Time A and Time B. Time A starts when the first detector switch is tripped, and Time B starts with the leading edge of the first flow meter pulse after Time A has started. Time A is stopped when the final detector is tripped and Time B is stopped with the leading edge of the first flow meter pulse after Time A has stopped. Using the ratio of Time A and Time B allows for counting of a fraction of the flow meter pulse.

$$K = \frac{Time\ "A"}{Time"B"} x \frac{C}{D}$$

K = K-Factor, or counts per unit volume, from the flowmeter
A = Time for displaced volume
B = Time for whole meter pulses
C = Total number of whole meter pulses
D = Displaced volume




**Double Chronometry**
*Diagram 6*

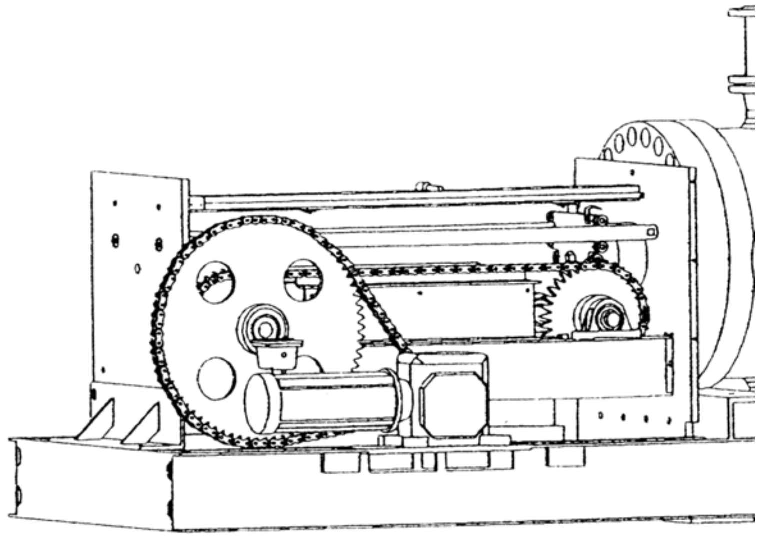
***General Operation***
The precision bore chamber is the measurement chamber of the SVP. The precision bore chamber has detector switches, and the volume between the switches is a known value. The displacer, traveling at the same rate of the liquid, trips the detectors and a measure of flow rate is determined.

*SVP with Chain Mechanism (see Diagram 7 below)*
1. The piston is downstream and stationary in the standby mode, and the piston's flow-through valve, which is also called a poppet valve, is open allowing the fluid to flow through the piston.

2. To begin the operation, the motor pulls the piston upstream. The piston is then unlatched from the chain drive return mechanism and the flow-through valve closes by spring tension and travels with the flow of the fluid.

3. The piston trips the first optical switch, sending a signal to the computer, which starts the timing sequence. The second optical switch is then tripped, sending a signal to the computer, which stops the timing sequence.

4. After passing the second optical switch, the piston shaft is stopped by a mechanical stop and the flow through the prover pushes the perimeter of the piston further downstream opening the flow-through valve that allows the flow to continue.



**SVP with Chain Mechanism Operation**
*Diagram 7*

*SVP with Hydraulics (see Diagram 8 below)*

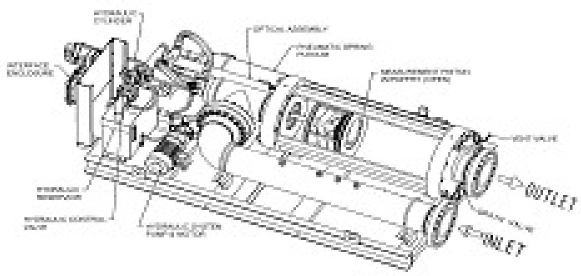
1. To begin the operation, the displacer is typically upstream in the standby position, with the poppet valve open and held in place by the hydraulic pressure.

2. The hydraulic control valve opens and releases hydraulic pressure; the pressure from the pneumatic spring plenum closes the poppet valve, and the piston begins to move downstream at the process flow rate.

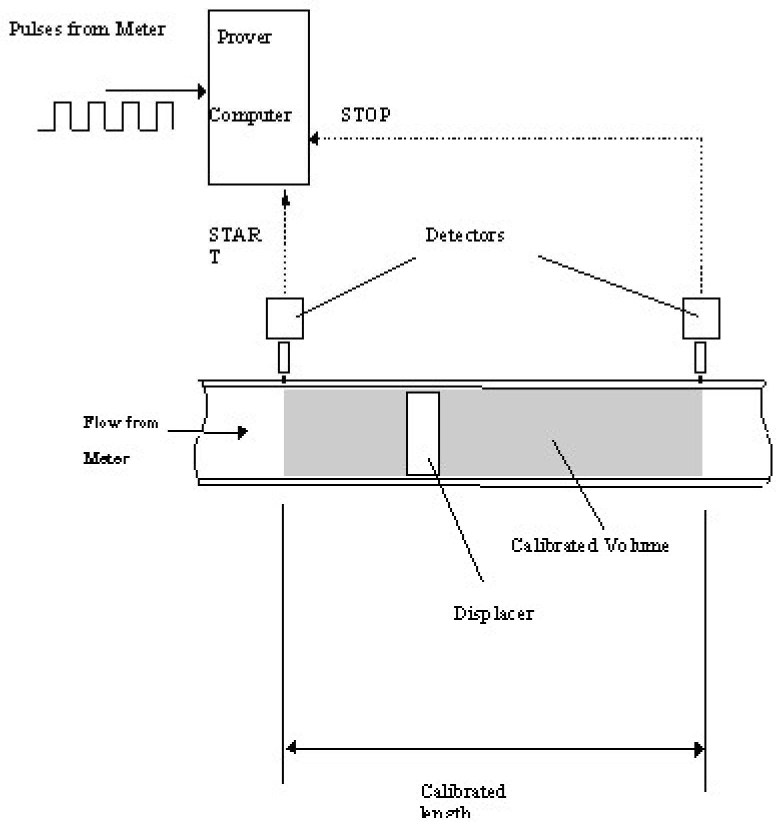
3. The piston, as it moves downstream, trips the first optical switch and the timing sequence begins. The second optical switch is then tripped, and the timing sequence is stopped. These volume signals are instantly sent to the operating computer.

4. When the second optical switch is tripped, the hydraulic control valve closes. The hydraulic pressure builds and begins to push the actuator piston upstream, opening the poppet valve, allowing the process fluid to flow through the piston.

5. The piston then moves back to the upstream position.




**SVP with Hydraulic Operation**
*Diagram 8*




**SVP Operation**
*Diagram 9*

We extend our thanks to Marathon Ashland Petroleum and Emerson Process Management for their assistance in the preparation of this article.

The next article in this series will expand on the operation of the SVP in the field and the mathematical determination of the meter performance.