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Part 3 - Small Volume Provers (SVPs): Mathematical Determination of Meter Performance Using SVPs

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This is the third in a series of articles on small volume provers (SVPs). Part 1 identified the various types of pipe provers, which include conventional pipe provers and SVPs and associated components, and definitions of the types of pipe provers. Part 2 addressed the history, design, and operation of small volume provers. This article, Part 3, addresses the mathematical determination of meter performance using SVPs. Please reference Parts 1 and 2 on the WMD website at www.nist.gov/owm.

Calculating Meter Performance

Calculation of meter performance when using SVPs is mostly automated. These provers are typically connected to a pulser driven by the meter and to a prover controller, which can be a computer that is capable of dual chronometry pulse interpolation. Dual chronometry, as described in part 2 of this series, enhances the pulse output by mathematically interpolating a fraction of a flow meter pulse. The use of a "K-Factor," a number that represents the approximate number of pulses a given meter generates per unit volume, along with correction factors for temperature and pressure, and other prover data allows the controller to calculate a "*meter factor*" that will account for measurement error.

K-Factor

There are two K-factors to consider when the prover controller determines the accuracy of a meter: the **"meter base K-factor"** and the **"proving K-factor"**. As noted above, the K-factor establishes a relationship between the pulses generated by the meter and volume shown by the indicator. It is important that the prover controller (computer) doing the calculation of the meter factor use the same K-factor as the indicator or that the relationship between the pulses it and the indictor receives is known if they do not receive pulses from the same source.

The ***meter base K-factor*** is the coarse calibration factor used with the flow computer, which is typically supplied by the meter manufacturer. The ***meter base K-factor*** is used in the flow computer's calculation of the quantity of liquid delivered, so it must be considered during the testing of a meter. The ***proving K-facto***r (PKF) is used to calculate the correct ***meter factor*** based on the pulses it receives while a known amount of liquid passes through the SVP.

Pulses from Same Source

When both the flow computer and the prover controller receive pulses from the same source, the ***meter base K-factor*** is equal to the ***proving K-factor***. This practice is common and there is no reason to calculate a *proving K-factor* in such instances; however, it should be confirmed that this is the number entered into both units or inaccuracies may result.

Pulses from Different Sources
The prover controller may receive pulses from a different pulser than the flow computer. This occurs when a separate pulser is hooked up to the meter for proving or when a mechanical register, which has no pulser, is tested with an SVP. In some cases, when the pulses used by the prover controller are provided by the flow computer, they may already be corrected by some factor, either a *meter factor* or its reciprocal known as a ***"meter accuracy factor".*** In these cases, the operator must determine the *proving K-factor,* which is counting the pulses as product passes through the meter. First, a pulse counter must be attached to the pulse source, then both the flow computer and the pulse counter are set to zero. A volume of product equal to at least 10,000 pulses must be passed through the meter.

The method for determining the *proving K-factor* is basically the same for all types of SVPs and installations, but the calculation must be modified according to the method of correction used by the flow computer and where the pulses are being picked up. There are several different calculations to determine the *proving K-factor* for the various flow computers, so the operator must consult the specific instructions for the flow computer in use. The following are calculations for determining the *proving K-factor* with many types of flow computers.

Example 1:
Meters equipped with mechanical registers OR
The prover controller receives pulses from a source different than the flow computer, and the flow computer provides an indication of volume that has not been corrected with a *meter factor* or *meter accuracy factor*:

(These computers divide the total number of pulses received for each run by the gross indicated meter volume.)

$$PKF = \mathrm{RIP} \div \mathrm{GMI}$$

where:
RIP (Raw Input Pulses) = pulses received directly from the meter; and
GMI (Gross Meter Indication) = meter indication without automatic temperature compensation (ATC)

Example 2:
The prover controller receives pulses from a different source and the flow computer provides an indication corrected using *meter accuracy factors* OR
The pulses received by the prover controller are provided by the flow computer and have been corrected using a *meter accuracy factor*:

$$\mathrm{PKF} = \mathrm{IP} \div (\mathrm{GMI} \times MAF)$$

where:
IP = Input Pulses;
GMI = Gross Meter Indication; and
MAF = Meter Accuracy Factor

Example 3:

The prover controller receives pulses from a different source and the flow computer provides an indication corrected using meter factors OR
The pulses received by the prover controller are provided by the flow computer, but have been corrected using a meter accuracy factor:

$$PKF = (IP \times MF) \div GMI$$

where:
IP = Input Pulses;
MF = Meter Factors; and
GMI = Gross Meter Indication

The *proving K-factor* should be determined 3 times to obtain an average. The *proving K-factor* used in the calculation of the meter factor is the average of three runs. Agreement of the factors to within +/- 0.01% indicates that the pulser/counter system is operating correctly. The *proving K-factor* should be entered into the computer prior to the run

Temperature and Pressure Corrections
Corrections must be made for temperature and pressure because the flow meter usually operates at conditions that are outside the standard reference conditions to which the SVP was calibrated. Temperature and pressure are automatically measured during testing and this information is relayed to the prover controller. The prover controller makes corrections for the temperature and pressure effect on the prover volume (correction for the effect of temperature and pressure on the steel prover parts) and the effect of temperature and pressure on the liquid volume.

Calculating Meter Error from Proving Data
The prover controller calculates the meter error from a ratio of the *corrected prover volume* (CPV) to the *corrected meter volume* (CMV), which is referred to as the *new meter factor* (MFn).

$$MFn = CPV \div CMV$$

where:
CPV = (Certified Prover Volume) x (Temperature and Pressure Corrections for the prover volume and liquid volume);
CMV = Average Number of Pulses x ([*Ctlm* x Cplm] ÷ PKF);
Ctlm = corrections for effects of temperature on the liquid in the meter; and
Cplm = correction for the difference in liquid volume as a result of the difference in pressure between the meter and the prover (compressibility correction factor for the meter)

The *new meter factor* is the factor that should have been programmed in order to have the flow computer indicate the true or corrected volume. If the meter is equipped with a mechanical register, the *new meter factor* multiplied by the meter registration will equal the true unit of volume.

The meter error in terms of percent is calculated by comparing the *new meter factor* to the previously programmed value of the *meter factor* (Mf).

Meters equipped with mechanical registers of flow computers:

$$\text{Meter Error in \%} = (1 - MNn) \times 100$$

Meters equipped with other flow computers:

$$\text{Meter Error in \%} = (\text{Programmed Meter Factor} - MFn) \times 100$$

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The next article in this series will address the use of SVPs in testing commercial measuring devices.