Title: Flow Meter Proving by E.L. Upp

FLOW METER PROVING

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INTRODUCTION

To determine how well our plants are operating we must make measurements of the process variables plus the inputs and outputs to the process. In a number of cases this means some type of fluid flow measurement is involved. In past years this flow measurement received little attention except during a plant shutdown or during periodic tests of the readout equipment. This was sufficient for routine control signal equipment, but as we attempted to improve plant efficiencies; or found fuel costs skyrocketing and needed to get a closer reading of these costs; or were doing a closer check on our material balances, we found that we needed and could afford to have improved accuracy in our flow measurement.

THE FLUID CONSIDERATIONS

Good flow measurement begins with the proper installation of the flow meter. Before we begin to consider the possibility of flow meter proving, the installations in question should be reviewed to make sure the fluid has been prepared for measurement; it is single-phase, non-pulsating, with known pressure, volume temperature, composition relationships. If we fail any of these tests the fluid must be prepared before trying to work on the accuracy of the meter system as a whole. As an example, fluids may require the addition of heat or pressurizing to maintain them in a single phase with known PVT relationships. If these prob-lems cannot be worked out, then the use of proving techniques will be a disappointing expenditure of time and money.

THE FLOW CONSIDERATIONS

All flow meters have recommended installation requirements such as length of straight pipe upstream and downstream of the meter, limitations of their use in terms of temperature and pressure extremes, requirements of proper flow profiles which may require such things as straightening vanes and allowances for removal of liquids from gas measurements and vice versa. Once again, if these are not inspected for compliance and changed, if necessary, no amount of flow meter proving will straighten out this flow measurement problem.

THE METER CONSIDERATIONS

The various types of flow meter signals that are produced by primary elements must be read by instrumentation. This, in turn, is either recorded and interpreted by people or fed directly to computers and thereby converted to flow measurement. As an example, on head devices such as orifices, nozzles and venturi's, the reading may include differential, temperature, static pressure and specific gravity. Here again, each individual part of the system such as the primary device, or the transducers, or recorders on the measured variable, should be individually calibrated before a system proving is attempted.

THE METERING SYSTEM

In summary, then, any fluid flow meter system must be reviewed in its individual components before we attempt to make a proving of the system as a whole. Proving a system without these considerations will be of little value other than at the exact conditions of proving.

WHAT IS PROVING?

The term "proving" in flow measurement means a throughput test and comes to us from the liquid measurement people who developed the mechanical displacement prover (now termed the "pipe prover") for proving turbine and positive displacement meters on crude oil and petroleum products. Prior to this development, we had critical flow and low flow provers used on PD meters on gas, but these had relatively limited use. On the other hand, "proving head meters" was never done. We substituted mechanical inspection of the devices for the throughput test. Proving is the checking of the throughput of a meter versus a standard de-termination of volume from another device. The purpose of all testing and proving is to establish a meter's performance accuracy to some tolerance. This tolerance is dependent on the basic accuracy of the standard used plus the conditions of the test. The allowable proving tolerance is dependent on the value and quantity of the product handled. Because of this, some metering installations cannot justify an extra few dollars in cost. This same "cost consideration" is reflected in the degree of "accuracy needed" and operations and maintenance money available to be spent in obtaining and maintaining the "accuracy." Here, then, are several of the influences that affect our measurement testing and proving: Present practice, standards, accuracy desired, and economics of the measurement job. There is wide diversity of opinion as to which influence is the most important, and this is as it should be since no one measurement job is identical to another. With these factors in mind, let us get more specific in terms of proving liquid and gas metering devices.

LIQUID PROVERS

Liquid provers of most use to the process industry are the pipe provers. They allow the in-place testing of the meters that includes the fluid and the flow effects in testing the system as a whole. These provers are covered in the American Petroleum Institute Manual of Petroleum Measurement Standards. The appropriate chapters are: 4 (Provers), 5 (Meters) and 12 (Calculations). These original provers shown in Figures 1 and 2 are continuing to evolve as improvements are made in their design. This includes better block valves and valve seal materials for different fluids, better displacers, improved detector switches, better flow-reversal systems, reduced size requirements and improved electronics.

PROVER OPERATION

It is easier to understand the prover as a calibrated bucket. Hydraulic labs around the country have for years used calibrated tanks or a weigh scale for calibration work. The procedure is to establish a rate of flow by volume or weight of liquid that is first passed through the meter under test and then collected for weighing or volume determination. The length of time that the flow is continued into the standard is accurately determined. The weighing is done on a carefully calibrated scale, or the volume is determined on a calibrated seraphin type volume tank that has been calibrated by some standard organization (usually the Bureau of Standards). There are procedures that must be carefully followed or errors can enter into the tests. Several sources of errors can affect the results obtained. First, flow should be carefully regulated so that variations do not occur during a test. Second, the fluid parameters of density, viscosity and composition must be carefully determined. This is particularly true if the test fluid is to be different from the fluid the meter will eventually measure. Third, the conditions of the volume measuring device, such as temperature and pressure, must be determined and its volume corrected for any differences between its calibrated conditions and the conditions of the tests. Normally, these conditions are closely controlled so that the magnitude of the correction is minimized. This is necessary for greatest repeatability and accuracy in laboratory work. These same criteria apply to the use of a mechanical displacement prover in the field.

COMPACT PROVERS

The latest development in the area of provers is the so called compact prover (see Figures 3 and 4). This prover has the most interest to the process industries and has expanded the possibilities of prover use too much smaller meters and for fluids that previously would have been difficult to test. These provers have been available since 1977. Tests and evaluations have been run by a number of companies on various fluids such as water, crude oil, ethane-propane mixes, and LPG. Continual development has taken place, to the point that national and international standards are being written and are in the final stages of approval. The stated advantages of these units are: The reduced size and weight, coupled with cost reduction, and increased range of testing with a single prover. These units use a faster cycle of test, which, along with its reduced bulk, minimizes temperature stabilization problems. There is an increased requirement for precision displacer-sensing and an interpolation technique to allow higher resolution of the meter pulses being tested. This puts a demand on the electronics to assure equivalent accuracies to present provers is maintained. There are several manufacturers in the marketplace with other manufacturers in the final stages of development. It is not my purpose to get into a detailed description of these units, which have been well covered in recent trade magazines and trade shows, but rather to show the anticipated influence they will have in flow measurement accuracy.

APPLICATION OF PROVERS

For plant application of a prover, there are several criteria. If there is sufficient need and economic justification, then it is possible to install a prover at each major measurement installation. This has become a standard in large liquid pipeline meter installations. An alternate to this is to use a portable prover to test meters in a general area. Where there is less economic justification, a centralized prover can be installed, where master meters can be periodically tested and these master meters used to test plant meters. The last possibility would be to use a master meter that has been tested by someone at a test location. Each of these methods would have a slightly larger tolerance than the previous method, since it is one step further removed from the standard prover use.

COMPACT PROVER APPLICATIONS

As mentioned, they are much smaller than standard provers, which allows them to be portable. This increases the usefulness of units for many meters around a plant can be tested with unit. It reduces the cost of using individual provers for each flow meter performance check. They are made to have increased rangeability so that one prover may be used for a large number of different sized meters. Here again, this is an advantage to the plant operator. The available accuracies of these provers have been shown to be equal to standard provers (some manufacturers claim "better" rather than equal to) which is in the tenths of a percent rage. It is my estimate that within the year we will see a reduction in price that will come as the competition increases. A number of evaluations have been run by process plants in the last five years, and it is possible to find other users with experience in their use in measurement stations. I hasten to caution you that the units available today have been improved to the point that some "bad evaluations" of a few years back may turn out differently if rerun today. The major advantage that these units allow is the test of an actual throughput versus a standard that minimizes flow measurement errors that might be peculiar to a given installation. These peculiarities may come from piping effects (creating a non-standard profile to the meter or from the fluid characteristic), creating an unusual pattern in the meter. These items may not be sufficient to create errors outside the normal tolerances given in standards written about a particular meter, but the prover will allow you to reduce these tolerances by as much as a factor of 10 if the error is in the flowing volume and is caused by the meter installation or some fluid characteristic. Provision must be made for disposal of the fluids left in the prover system after a test. It is of particular importance on fluids that are toxic, too valuable to send to waste, or that can contaminate the next fluid to be tested. These limitations must be considered in the application of the prover.

PROVING LIMITATIONS

Proving does not eliminate other errors in flow measurement that might come from such items as the calculation for reducing flowing conditions to base conditions, or two-phase flow errors, or totalizing errors. The reason is that a proving simply checks the volume being measured at line conditions versus a known volume (the prover) at the same conditions for a short duration. These flowing volumes can then be erroneously reduced to base conditions and we would still have a flow measurement error undefined by the proving. In the second case, with two-phase flow the prover cannot be used since the two phases give an undefined volume to compare. Once again, it is of value to point out that meter proving will not resolve metering problems that are outside the prover's ability to check volumes. The standard and compact provers have been used to a limited degree on gases such as ethylene and carbon dioxide in the dense fluid range, but these applications require special attention since the major problem is in the determination of the density of these fluids at the points of their volume measurement.

GAS PROVERS

In the area of gas measurements, standards are being written for the use of critical flow nozzles that will allow a similar type of test (see Figure 5). This device operates on the principle that the mass flow per unit area reaches a maximum at the velocity of sound in the flowing gas. Hence, with knowledge of the area of device, the density of the gas and the speed of sound in the gas, we can calculate a flow rate providing flow is critical or choked in the throat. This takes place with an approximate pressure drop of 50 percent between the upstream and the throat of the nozzle. Thus, a flow nozzle operating at critical flow conditions will pass an amount of gas that can be calculated based on the static pressure, temperature, time, and the proper critical flow functions. In the circle arc venturi nozzle, the pressure drop of 50 percent in the throat can be recovered by use of a cone-shaped recovery section so that the permanent loss across the device is only five to ten percent of the upstream pressure. This limits its usefulness in some applications since this pressure drop may require that the gas used in a test be vented from the process to a flare.

The data indicates that this device properly used on gases with known critical flow functions can be used to an accuracy in the range of .2 to .3%. These gases include air, argon, carbon dioxide, methane, nitrogen, oxygen, superheated steam, and some natural gas mixtures (see Reference 1). An alternative method of applying the device is to use a central test facility and bring the plant meters to this point for test. This might be on an air system where the disposal of the gas would not create a problem; however, to a degree we are defeating the purpose of a meter proving by removing the meter under test from its normal installation. The critical flow nozzles have been used mostly for testing natural gas meters either on-site or at a central test facility.

MASTER METER PROVERS

The last type of meter proving that is used is the master meter test. In this case, a meter whose calibration has been determined against a standard may be taken into a plant, installed in series with the process meter, and comparative readings taken. One difficulty encountered with this system is the effects on the calibrated meter of moving it from installation to installation and the effects this has on the stability of its calibration. For this reason we have a tolerance in this method of ±.5% at best. Another method of using a master meter is to combine it with a prover system in which the master meter, such as a turbine, is made part of the prover skid. The master meter is tested against a prover and then run against the process meter. This is necessary when the process meter has a low resolution output and sufficient volume counts cannot be taken during the short period of a prover run. Some meters have irregular count rates such as some positive displacement and vortex shedding meters, and the longer test period is necessary to obtain a useful test. This is commonly done with smaller process meters. Proving allows the master meter test to be reduced in tolerance to the .2% range, but is considerably more expensive since the prover is required.

INSTALLATION REQUIREMENTS AND COSTS

In each type of proving, specified piping must be installed to allow the installation of the proving systems. This is more difficult with old systems, but can be allowed for as new systems are installed, but in each case, additional piping and valving will be required that will add to the cost of flow measurement. If we use the compact provers, which run in the range of $50,000 to $100,000 or more depending on size, we will add to our capital costs as well as the maintenance costs necessary to use the device. The use of the critical flow prover on gas will not be as expensive as the compact provers since a set of these nozzles may be purchased for several thousand dollars. However, the cost of disposing of the gas used in a test may be significant. The use of the master meter is not in the cost of the master meter but in the calibration necessary to establish its accuracy. The calibration can be done by your own people and facilities or could be done under contract by several testing agencies on a periodic basis.

COST EFFECTIVENESS

Balanced against the installation costs will be the value to you of reducing your material balance in a plant. Depending on the value of the fluid handled such as ethylene, users have justified spending several hundred thousand dollars for permanent provers at each flow measuring station in an attempt to reduce loss due to flow measurement uncertainties. On the other hand, flow measurement of water inaccuracy costs may not allow any more than a physical inspection of a meter.

CONCLUSIONS

The main message is, then, that there are methods of proving meter throughputs that go beyond the types of testing we have done in the past and that will allow a reduction in the normal tolerances that we have assigned to flow measurement. The economic justification for making such an installation will have to be worked out for each flow measurement system.