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GUIDE TO TROUBLESHOOTING PROBLEMS WITH LIQUID MTERS AND PROVERS

CLASS # 4060

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INTRODUCTION

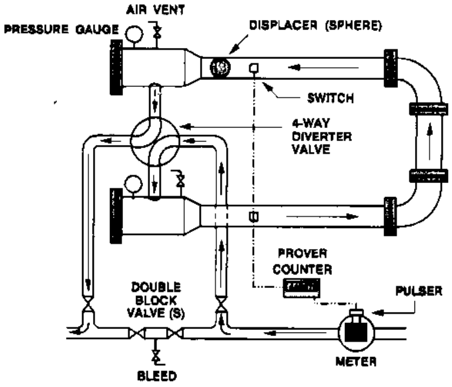
As one of my true and trusted friends says, “Counting is easy, but measuring is not so easy.” What he means by this is, without establishing any rules you and I could agree on how many tanks there are in a tank farm. The difficulty comes in when we start to try and agree upon how many barrels or cubic meters are in the tanks.

Measurement becomes more difficult when the things that we rely on to do the measuring, meters and provers, are not predictable in their performance. When this happens, quite often the reason for the unpredictability is not apparent. However, because of the value of today’s liquid hydrocarbons, the problem must be corrected in a timely manner. Therefore someone must analyze the situation and eliminate each possible contributor to the problem until only one remains. This process is called troubleshooting. That’s what we will be talking about in this paper. Because of space constraints and knowledge limitations, especially the later, this paper is not an exhaustive list of problems and solutions. But, hopefully we will discuss something that might be of some help to some people. We will start with the different type of provers in use today.

METER PROVERS

Meter provers can be divided into three basic types with differences in each type. These three types are: Tank Type Provers, Master Meter Provers and Pipe Provers. Because of the relative number of each in service today, we’ll start our discussion with the most used type, the pipe prover. The pipe prover can be divided into two basic designs: the Conventional Pipe Prover and the Small Volume Prover (SVP). In some cases a pipe prover may be a conventional pipe prover in one case and a SVP in another case. This is because of the definition of a conventional pipe prover. A conventional pipe prover is a prover with a large enough volume to deliver at least 10,000 unaltered pulses to the proving counter while the displacer is between the two switches. (See Figure 1) For example, a portable pipe prover having a volume of 2.43876 barrels proving a meter that delivers 8400 pulses per barrel will deliver over 20,000 between switches. This is clearly a conventional pipe prover. However, using this same prover to prove a turbine meter that produces only 1000 pulses per barrel would produce only about 2400 pules between switches. In this case the prover would, by definition be a SVP.

Figure 1 Conventional Pipe Prover



Pipe provers are also divided into two basic designs. They are either bi-directional or unidirectional. In the bi-directional design the displacer, usually a ball or sphere, travels first in one direction and then, when the 4-way valve is reversed, in a reverse direction back to its original position. The unidirectional design allows the ball to travel in only one direction.

To further complicate things, there is another division in prover design. This division is because of the displace type used. Today's pipe prover generally utilizes a sphere or ball as a displacer. However, in some cases a piston is used as a displacer. Therefore we have sphere type and piston type pipe provers. Each of the designs may be either a conventional or a SVP. Despite all these variations, we'll discuss the things that all pipe provers have in common.

Prover Detector Switch Problems

Regardless of the type of prover, a detector switch is used to start and stop the proving run. Every prover switch must be able to detect the presence of the displacer to within very close tolerances. And, it must do this every time in a repeatable manner.

The switches are mounted on a flange which is welded to the prover pipe. In the center of the flange a hole is drilled through the pipe wall to allow the detector probe to protrude into the prover. (See Figure 2)

Detector switches should be checked on a bench before being installed in a prover. After testing and installation, switches generally work well for a long period of time. However, it is a good practice to replace the switches before a prover calibration. This is especially important if the prover is only recalibrated every five or so years. The reason being, if a switch fails, a lot of people think that the prover must be recalibrated after a switch is replaced. This can be very costly.

A typical failure will result in a faulty switch either not starting or not stopping the prover counter. If the sphere interchange in operated or the 4-way valve is switched and the prover counter fails to start after a reasonable time period, the first switch, "A" may be suspect. It will generally be confirmed as the problem if the prover counter starts when the displacer hits the second switch, "B". Further confirmation will be given if the counter continues to count long after it is expected to stop. In the case of a unidirectional prover the counter may continue to count even though the interchange sequence has started. For example, if a total of 20,000 pulses are expected between switches and the counter is still counting after 25,000 pulses, it is reasonable to assume that switch "A" is faulty.

In a case where the prover counter starts when it is expected to start but continues to count long after it should have been gaited off by the switch "B", that switch is probably the problem. To confirm this on a bi-directional prover, reset the counter and reverse the valve. It the prover counter does not start when expected but does start when it hits switch "A", switch "B" is the problem. The reason for any switch failure is either mechanical or electrical.

A mechanical problem may only require a tap on the switch flange with a small hammer to free a sticky plunger. This will often fix the problem and return the prover to service. If this fails, the problem may be electrical. Because of the extremely close tolerances for most switches on SVPs, you should consult your vendor if you have a problem.

If you suspect electrical problems, check the wiring connections at the switch. If the connections appear to be good, a multimeter may be connected to the switch, the selector set for ohms and a run started. If the displacer his had time to move past the switch and no deflection has been seen on the multimeter, the switch will probably need to be replaced.

Figure 2 Typical Prover Switch

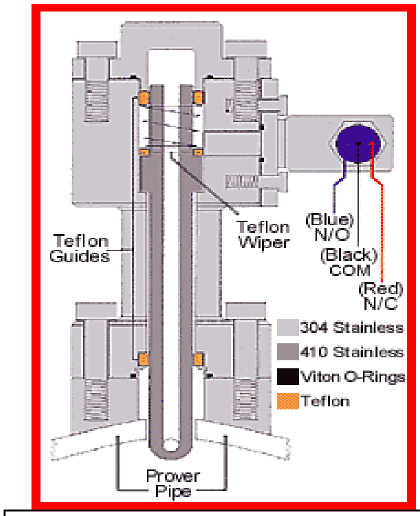


Figure 2 compliments of Meter Engineering Inc.

Displacer Problems

The job of the displacer is to divide the flowing liquid into different segments and prevent leakage from one segment to the other. In order to do this the sphere must be larger than the inside of the pipe, generally 2 to 3%. Spheres are inflatable, so that they may be sized properly. Because the sphere is oversized, it forms a wide seal around the entire pipe circumference. The width of the seal should be wider that the width of the hole in the pipe that the switch probe protrudes through.

Before a water draw and at regular intervals thereafter, the prover displacer should be inspected. Since I mentioned water draw, a word of caution is in order here. Always water draw the prover with the same size sphere that it will operate with. Never over inflate the sphere for water draw and then reduce the size for operations. If the prover volume will not repeat to within tolerance with a sphere inflated to 3% larger than the inside of the prover pipe, the prover barrel has a problem that **must** be fixed before the prover can be used.

Scratched, blistered, oversized or undersized spheres will cause problems. If a sphere is cut, undersized or misshaped it may not form a good seal that completely covers the switch hole in the pipe as the sphere passes. Undersized spheres may not be large enough to cause the switches to make every time. This condition could be sporadic especially if the sphere is not completely round. The most serious thing that may happen is fluid slips past the displacer during a proving pass. Of course, this will cause the meter factor to be erratic and wrong. This will invalidate the proving result.

If the displacer is oversized it may also cause problems. It will always cause a higher than necessary pressure drop across the prover. This may slow the meter flow rate while the meter is being proved, which may result in a lower meter factor. An oversized sphere may also cause the travel of the displacer to be erratic as it passes though the barrel of the prover. It will take a series of short jumps through the prover rather than moving smoothly. This can be seen by watching the pressure gauges. The upstream gauge will increase in pressure as the displacer stops and decrease in pressure as the displacer jumps. This happens more frequently at low flow rates with fluids having little or no lubricity.

The piston in a SVP also has seals that must not allow any fluid to pass by them during a proving pass. Most SVPs have a leak interlock system that will abort the proving if any leakage is detected. If the proving fails due to a piston seal failure the operator should check: the piston seal indicator flag to be certain it is tight and not stuck, the vertical seal adjustment on the seals switch, the intrinsic safe wiring circuit, the relief valves for leakage and the piston seal for damage.

In order to ensure proper sizing of the sphere, a sizing ring, usually supplied by the prover vendor, should be used. Periodic displacer inspection is required because the displacer is in a hostile environment where it is exposed to hydrocarbons under pressure. It may sit in the prover barrel for extended periods of time, which may cause the displacer or piston seals to lose their shape. It may also be exposed to volatile fluids which, in some cases, may permeate the surface of the displacer or piston seals and cause "blisters". Also, a displacer or piston seal may become cut or nicked by objects in the flowing stream. The prover will experience repeatability problems if any of the above occurs.

Coating Problems

Most pipe provers are internally coated with a thin layer of hard slick material. This does a couple of things. First it reduces the friction of the sphere as it travels through the prover barrel. And, secondly it reduces wear and corrosion and may fill some small imperfections in the pipe wall that otherwise would allow some slippage during proving. Over time this coating may wear off especially in the bottom sections of provers used in crude oil service. This is most prevalent where sand or other particulate matter is present in crude oil at a lease location. As this wear continues, at some point longitudinal grooves will be formed in the bottom of the prover pipe. This will allow leakage past the sphere during provings. When this happens the meter factor is wrong. Someone is losing and someone is winning. This leakage may go undetected until the next time the prover is water drawn. And, if you let allow the sphere to be inflated to 7% to get a number and then deflate the sphere to 3%, the inaccuracy will continue on and on.

The coating should be inspected as part of a regular prover inspection routine. A visual inspection can be done by simply draining the prover, opening it up and shinning a light as far as you can see into the prover barrel. This may not tell you a lot, especially if you have a folded pipe prover. A more complete inspection should be done using a bore scope to inspect the inside surfaces of the entire prover. If coating damage is seen, the prover must immediately be removed from service, recoated and recalibrated.

Leaking Valves/Interchanges

As we all know, there can be no leakage, internal or external, between the meter and the outlet of the prover during proving. This supposes that the prover is properly installed downstream of the meter. Leakage points may involve only a single block valve in the mainline and a 4 way valve on the prover, as in Figure 1. In this case checking a valve for leakage is a fairly simple task. However, the drain from the bleed valve, on the mainline block valve may become plugged with paraffin or in some cases heavy crude. When this happens, unless the plug is cleared, the operator assumes that there is no leakage. Big mistake.

In the case of a bank of meters tied into a single prover, there are a number of valves that must be checked. If the prover is downstream of the meters, each of the prover inlet valves must be double block and bleed type. Whenever any one of the meters, in the bank is being proved, the bleeds on the other meters prover inlet valves must be checked for leakage.

The prover diverter valve or sphere interchange must be checked each time the valve or interchange is moved. A valve is only subject to leaking when it is closed. That means check it every time it is closed.

Another thing that can happen is the 4-way valve operator works so slowly that the sphere hits the first switch before the valve is fully closed and sealed. This form of leakage may not immediately be obvious and is very rare, but has happened. It resulted in a meter factor that was 2% low.

Meter Problems – Displacement Type Meters

First, let's discuss those things that cause a meter to under register causing the meter factor to go up. When a meter factor goes up it means that there is more liquid getting through the meter without being metered at this proving than at the last proving. This is called “Slippage. Slippage occurs as the mechanical parts in the meter wears. Over speed, dirty fluids and pulsation will all increase the rate at which the meter wears.

Two things happen as a meter wears. First the clearances in the meter increase which allows more liquid to slip through the meter without being measured. And, secondly friction between worn parts that are not designed to touch, slows the meter rotation, causing the pressure drop across the meter to increase thus increasing slippage.

One exception to this is the horizontal rotor sliding vane meter. As wear occurs on the parts that hold the blade up off the bottom of the measuring chamber, the blade to housing clearance is decreased. This decreases slippage and lowers the meter factor.

Worn bearings are a chief contributor to meter factor increase. In the case of the vertical sliding vein meter, as the thrust bearing wears, the rotor will drop until it contacts the bottom of the meter. This will increase the friction and cause more slippage. Rotor bearing wear will allow the rotor to rock on the vertical shaft resulting in the rotor occasionally touching the bottom of the housing. This periodic touching will increase friction at irregular intervals which will show up as poor repeatability during proving.

In the case of the bi-rotor meter, bearing wear is less significant than timing gear wear. The two rotors are kept apart as they turn by a set of timing gears. As the teeth on the gears wear down, the rotors will start to touch causing at first only periodic increases in friction resulting in poor meter repeatability. Of course if the condition is allow to continue the fiction will increase continually with a resulting increase in meter factor.

Changes in viscosity will cause changes in the way a displacement type meter performs. The operating principal of dividing the flowing stream into a number of pieces and then counting those pieces, means that something is segmenting the stream. This segmenting requires that small portions of the stream must be momentarily isolated. These isolating members, either blades or rotors, do not in any case touch the meter housing during normal operation. Since the isolator doesn’t touch the meter housing, the seal must be made by the fluid. This fluid seal is called a “capillary seal”. The integrity of this seal is a function of the fluid viscosity. This means that the less viscous the fluid the greater the rate of slippage. And, conversely the more viscous the liquid the less the slippage through the meter. This means, if a meter is used for measuring different products, a meter factor for each of the products must be established and used only for that product. This problem becomes even greater as factory tolerances increase. The greater the tolerances in the meter become, the greater the meter factor shift with changes viscosity.

The second thing that will affect the amount of slippage across the isolating member is flow rate. As the flow rate increases, the pressure drop across the meter also increases. With the greater pressure differential, more fluid will slip through the capillary seal. This means that the meter factor is only accurate when the flow rate remains relatively constant. Most companies have a policy to reprove the meter if the flow rate changes by more than 10%.

Since we are dealing with a pressure differential across the meter during proving, we have to ensure that the pressure at every point in the entire proving system is greater than the vapor pressure of the fluid being metered. If the pressure drops below the flash point of the fluid at any point, the fluid will vaporize and the volume will be overstated. A good rule of thumb is to maintain a minimum of 20 PSIG on the system for non-volatile fluids. Of course, as the flash point of the fluid increases, the amount of back pressure on the proving system must be increased proportionally.

Some older metering installations have a “stack” of mechanical components going from the measuring device up to the meter counter. These stacks have a gear train that can cause mechanical friction to the meters output, if not properly maintained. As gears wear and friction sporadically increases, the meter may show poor repeatability. Additionally, some of them have mechanical type temperature compensator. These devices can cause the meter’s output to be inaccurate, if they fail. Some failures results in the meter under registering while other result in meter over registering up to 11%. Cyclic type calibrators will often cause poor repeatability.

Turbine Type Meters

The turbine type meter directly measures the stream's velocity and from that measurement, the flow rate is inferred. For that reason turbines are called "Inferential Type Meters". Basically, they work like a windmill. As the velocity of the stream increases, the speed of the turbine rotor increases proportionally. This allows us to calculate flow by knowing the speed of the rotor. Of course, this is only true as long as everything remains constant. For instance, if the cross-sectional area of the meter bore is decreased by something like a paraffin buildup on the walls of the meter, the fluid velocity will have to increase, even though the flow rate doesn't change. This will cause the meter to over register the volume being metered.

Since the meter is getting its rotational energy from the flowing stream, the force on each blade of the turbine must be the same. This means that the entire stream's energy must be exerted on the front edge of each of the blades. To accomplish this, the stream going through the turbine bore must be straight with no turbulence or swirl. This can only be accomplished if the meter is properly installed in accordance with API recommendations. In general, this installation calls for 10 diameters of straight pipe preceding the meter, equipped with a straightening section. Some of these straightening sections, also called "flow conditioners" are held in the pipe with a set screw. They sometimes come loose and travel downstream ending up at the meter inlet. This causes turbulence and problems with the meter's performance.

Changes in viscosity and density will also cause changes in the meter's performance. As viscosity increases, the drag on the turbine rotor will increase causing the meter to under register. For this reason conventional turbine meters are not recommended for viscous products. Flow rate changes on a turbine meter will also cause changes in meter performance. This is especially true at lower flow rates and in operations where the viscosity is at the meters upper limit. A good rule of thumb is to reprove the meter if the flow rate changes by more than 10%.

The only possible exception to the statement about viscosity is the "Helical Rotor type". This design utilizes an auger rather than a windmill to measure the stream velocity. The auger design allows the helical turbine to be used in a lot of areas that were traditionally reserved only for displacement type meters. A helical rotor meter, because it only generally produces 2 pulses per revolution of the rotor, must be proved using "Pulse Interpolation" techniques to produce enough discrimination to develop a meter factor to 1 part in 10,000. This requires special equipment.

Another thing that will cause the turbine meters performance to be erratic is pulsation. A turbine meter is designed so that the rotor turns without touching the upstream stabilizer or the downstream stabilizer. This can only occur if there is no pulsation on the meter. There was a case of a turbine meter registering flow when the meter inlet valve was closed. The problem was determined to be a positive displacement pump pumping into the connected pipeline over a mile away. The action of that pump caused the rotor to rock back and forth. This rocking of the rotor caused 1 blade, located directly under the pick-up coil, to generate pulses to the counter. Remember a pulse is a pulse to a flow computer. It doesn't add a pulse to the counter in one direction and subtract it in the other.

Coriolis Mass Flow Meters

Coriolis meters, like turbine meters, are Inferential Type Meters. Using the Coriolis affect, the meter measures mass. But, you say our industry doesn't typically measure mass, we use volume. That is true, but the Coriolis meter also measures density. Now we are getting somewhere because mass divided by density equals volume.

Because of the way the meter works it doesn't directly produce a pulse, as a turbine type meter does. Therefore it must take several measurements from different sensors and do some number crunching in order to produce a pulse. This process results in a "Manufactured Pulse". We will deal with this subject later.

These meter's internals vibrate as some known rate. Therefore once a Coriolis meter is properly installed and put into operation, nothing can be allowed to affect its rate of vibration. There is a story of an operator in a control room experiencing a meter alarm with a Coriolis meter at the same time every day. The alarms just happened to occur around lunch time. After a lengthy investigation, it was determined that a contract laborer was using the housing of the meter as a table to hold his lunch pail while he was eating his lunch. After all, the meter was in the shade. Just the weight of his lunch pail was enough to change the meters vibration and cause the alarm.

Another thing that can cause an error in meter performance, especially at low rates, is anything that will change the meters “Zero”. For this reason, the meter should be proved, re-zeroed and then re-proved periodically.

Mulitpath Ultrasonic Meters

Like the Coriolis meter, the multipath ultrasonic meter is an inferential type meter. And since it has multiple sonic paths measuring time of flight or other parameters, it too has to crunch some numbers to produce a manufactured pulse. It should also be re-zeroed periodically.

Manufactured Pulses

Manufactured pulses tend to cause problems with conventional repeatability requirements. This is caused by the fact that the switches on a prover are actuated by the displacer. This happens at a discrete time in history. This being the case, the time required for a Coriolis or Multipath Ultrasonic meter to crunch the numbers and produce a pulse, means that the reporting of the pulse is sometime after the measurement. As this happens when the switch is made, a pulse is reported after the actual measurement. And on the other end a pulse may be measured but not reported until after the second switch is made. Understanding this fact the API, in the MPMS Chapter 4.8, has a table showing acceptable repeatability levels with different numbers of proving runs. As the number of runs increase, the acceptable spread is increased resulting in the same level of uncertainty. These guidelines should be used when proving a meter producing a manufactured pulse.

Conclusion

Troubleshooting a metering and proving system can be a challenging proposition. There are a myriad of things that can and will make the job more difficult. Years of experience, a good understanding of the system coupled with a good knowledge and application of Syllogistic Logic will make the job much easier.
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