Instrumentation for Brine Flow Measurement

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ABSTRACT

Several types of flow meters are adaptable to brine flow measurements. Usually, differential pressure instruments are most suitable.

Inverted manometers give reliable measurements under steady flow conditions.

Mercury-type recorders are used, but the newer diaphragm-type recorders operate with less maintenance.

For the most difficult or critical applications, magnetic-type flow meters offer many advantages, and seem likely to gain wide acceptance in the future.

Before any choice can be made, the problems of corrosion, exposure to the weather, scaling, and gas must be considered. Selection of the most suitable meter also depends on many other factors, such as cost, location, personnel, accounting procedures, and accuracy expected.

INTRODUCTION

Every solution mining operation must inevitably be concerned with quantity of brine produced. While brine is not classified as an extremely difficult material to measure, there are numerous considerations which influence the selection of the meter type. Possibly there are brine handling operations where one kind of meter serves all purposes. But this has certainly not been the case at our Painesville Works. If we were to use but a single meter type, we would either be spending far more for instrumentation than necessary, or at the other extreme we would be gathering insufficient data.

Since the comments in this paper are based upon our experience at Painesville, a brief description of this facility will be helpful.

The brine for our soda ash and chlorine manufacturing is obtained from a 200-acre field situated about five miles from the plant. Approximately 3,000,000 gallons per day of saturated brine must be produced. Water from the plant is delivered to the field at 200 psig. After being boosted to 300 psig the water is pumped to four to six wells. The number varies with the requirements. The brine production returns through a vent tank, then is piped to the plant. To control the system adequately, it is necessary to measure water and brine flows at about 15 points.

The brine field is divided into three galleries. In each gallery there are several wells which are interconnected by fracturing. In order to develop and subsequently regulate the brine cavities, it is desirable to know the amount of water injected and the brine produced. This is done most conveniently by the use of orifice meters. Normally, manometers are used for flow rate indication. The conventional mercury manometer is widely used. But like all differential pressure type instruments it has a practical range limitation of at most five to one from maximum to minimum. This can be a serious limitation in some cases. Orifice plates can be changed, but frequently it is easier to change the manometer fluid from mercury to other fluids. For example, a heavy bromide compound, tetrabromoethane, with a specific gravity of 2.94, can increase the rangeability of a given orifice plate by a factor of 4.8. T.B.E. is corrosive to steel, but it can be used with brass, glass or stainless steel. Other fluids that are noncorrosive are also available.

Inverted Manometer

A less well-known, but very effective device is the inverted manometer. This arrangement is shown in Fig. 1. Since inverted manometers use the flowing fluid as the measuring fluid, there is no problem of losing mercury due to surges, gas, or valve manipulation. At Painesville, we have used such manometers for years with quite satisfactory accuracy. It is well adapted to freezing weather and exposed conditions, since it is very easy to keep the tube empty until a reading is desired. Then all that is necessary is to blow down the lines with the valves, shut off the blowdown and read the differential. These manometers are extremely simple and quite trouble-free.

By-Pass Rotameter

Another useful type of flow indicator is a by-pass rotameter. For the large volumes usually encountered in brine handling, rotameters are easily overlooked. But Fig. 2 shows the simple arrangement for measuring any flow rate with a by-pass rotameter. Actually, this is a differential pressure type of measurement. When a rotameter is connected to the pressure taps of an orifice plate, the pressure difference creates a flow through the rotameter. The rotameter has a small restricting orifice installed in the end fitting. The connecting pipes should be sized so that the pressure loss is insignificant. Thus, the differential pressure will be the same across both orifices, and the flows will be proportional to the areas. The rotameter measures the by-pass flow and is calibrated to show the total flow.

There are several advantages to by-pass rotameters. For one, the measurement is indicated on a linear scale rather than the usual square root scale. Secondly, there are no stagnant impulse lines which could freeze or could become plugged with insoluble solids. Maintenance is simple and requires no great amount of skill.

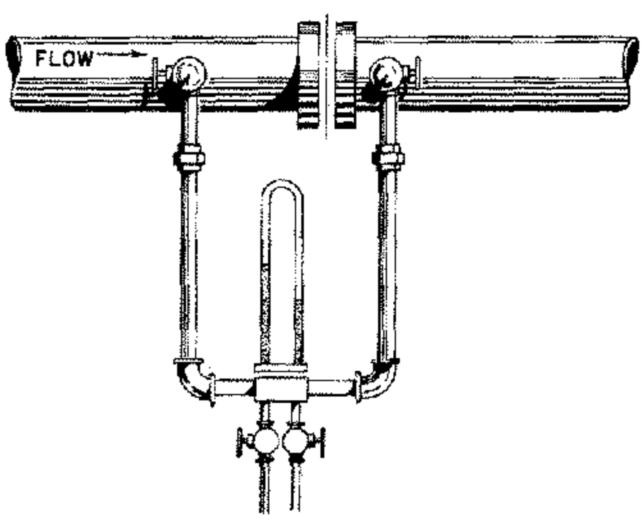

Figure 1. Inverted Manometer.

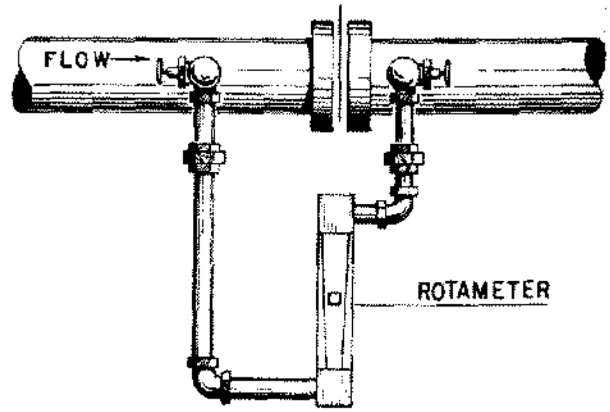

Figure 2. By-Pass Rotameter.

Recorder Installations

Up to this point, only indicators have been considered. For recording flow rates, the conventional mercury-type differential pressure meter has been most commonly used for many years. However, brine field measurements present some special problems. If natural gas is encountered in the brine, the readings can be quite erratic if the gas goes through the orifice in gulps. This problem can be easily corrected by installing an eccentric orifice located near the top of the pipe (in the case of a horizontal metering section). This prevents the gas from being trapped in front of the plate. Of course this does not eliminate the error resulting from the fact that the pipe is not full of brine. However, an eccentric orifice plate in this case would give a more readable chart, which in turn contributes to the accuracy of the measurement. Of course, the best solution is to eliminate the gas before the metering section.

If an eccentric orifice is used, the calculations will depend on the location of the taps around the periphery of the pipe. Coefficients are available for taps located 180° from the orifice, or 90° from the orifice. Using 180° taps would put them on the bottom, which is undesirable because of sediment. In the case of 90° taps it is possible that gas could enter the impulse lines, especially if the meter is located above the orifice. A compromise location of 135° from the top of the pipe, although not conventional, could avoid both the problem of gas and the problem of sediment. Of course, if the amount of sediment in the solution was significant, an orifice plate would not be a proper choice. Possibly a venturi tube would be a better choice. However, there might be many circumstances which could dictate the selection.

Another installation problem is exposure to the weather. If the meter is subject to freezing, the impulse lines and the meter must be protected. Electrical heating cables can be used, but sometimes they interfere with maintenance, such as cleaning the meter or poking out sediment from the taps and lines. Whenever possible, it is better to avoid tracing the lines by keeping the meter and orifice close together in a simple enclosure which is heated by a heating fan, strip heater, or some other device.

Among operational problems, the formation of scale on the orifice plate and pipe walls is the biggest obstacle to good flow measurements. There is no simple solution to this problem other than periodic cleaning of the orifice plate. Pipe wall scale has the effect of making the meter read low, whereas scale on the orifice tends to give a high reading. Our experience indicates that the combined effect results in progressively higher readings as the scale accumulates. However, the extent of the problem varies considerably with the characteristics of the solution. Some installations present no difficulties at all.

If the orifice taps have a tendency to scale up rapidly, it could be advantageous to install poke-out rods at the taps such as shown in Fig. 3. These devices make it possible to poke out the taps routinely in only a couple of minutes.

As an alternate to using poke-out devices, it is sometimes more convenient to use purge water to back flush the impulse lines continuously. The purge rate is normally metered through purge rotameters at a rate of approximately 50 cc per minute. Otherwise, a false differential can be indicated due to the purge water flow. In remote locations where water is not available, we

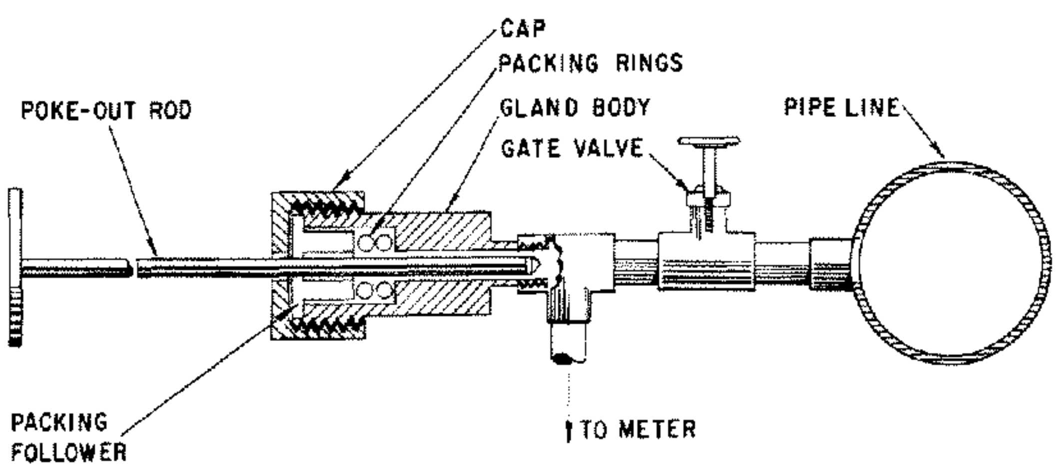

Figure 3. Poke-Out Rod Assembly.

have experimented with the use of brine as a purge medium. This is done by metering a very small flow from the high pressure connection through a small rotameter back into the low pressure connection. Though somewhat unconventional, this technique is effective under freezing conditions when the stagnant impulse lines might otherwise solidify. However, it must be remembered that in doing this, the purge rate must be kept low enough so as not to significantly affect the differential indicated by the recorder. This is easily verified by observing the recorder reading with and without purge flow.

Although mercury-type flow recorders have been widely used for many years, some installations can be troublesome. If the flow surges violently on occasion, mercury can be lost, which is not only expensive but also causes interruption in the flow record until repairs can be made. Inasmuch as solution mining operations are generally situated in remote locations, the problem of scheduling repairs can result in extensive delays. There is now available a mercury-less differential pressure instrument which eliminates this problem. This recorder is commonly called a diaphragm-type meter since it is composed of two stacks of metal diaphragms. Each stack receives the impulse from the lines connected to each of the two orifice taps. See Fig. 4. The diaphragms (or bellows) are filled with an oil so that even full line pressure on one side will not rupture the diaphragms. This feature, plus the fact that no mercury is used, makes for a very rugged and reliable recorder. The accuracy is equal to the mercury-type meter. Our experience with this type of meter has been very satisfactory, and we are now gradually replacing the mercury-type meters.

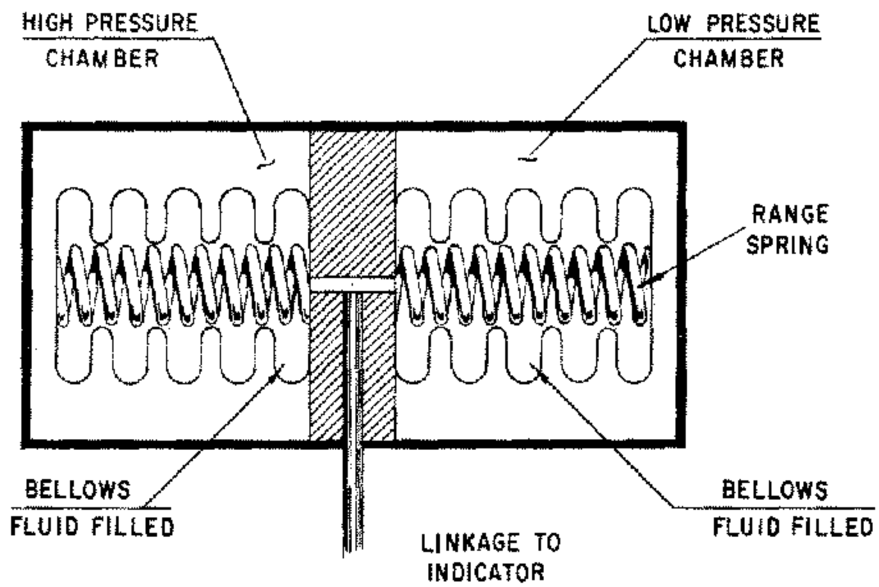

Figure 4. Bellows-Type Differential Pressure Mechanism.

Magnetic Flow Meter

In the last few years, a new instrument called a Magnetic Flow Meter has gained wide acceptance. The meter is not a differential pressure type. It is basically a velocity meter. It consists of a nonmagnetic tube in which two small electrodes flush with the wall of the pipe are in contact with the flowing stream. Around the pipe are two large electrical coils which develop an electric field. Any conducting fluid such as brine (or even water) flowing through the field will induce a voltage which is proportional to velocity. The electrodes measure the voltage and since the area of the tube is known, the volume of flow can be precisely measured. Magnetic flow meters have some very significant advantages over other measuring devices. First of all, the tube is fully open with no obstruction. Secondly, the recorder can be remotely located, being connected to the measuring tube by wires. The flow is recorded on a linear chart with a rangeability of at least 10:1. Magnetic flow meters are unaffected by conductivity (above a low minimum value), specific gravity, or viscosity. No long straight sections of pipe are required as for orifice-type meters. Pulsating flows can also be measured accurately. Moderate amounts of gas present in the solution do not interfere with the measurement.

The principal disadvantage of a Magnetic Flow Meter is cost. Depending on size, an orifice-type recorder might cost roughly \$600 to \$800 installed, whereas a similar Magnetic Flow Meter could be \$2,000 to \$4,000 installed. In spite of this substantially higher cost, the advantages of Magnetic Flow Meters can frequently justify the added cost.

On one important brine measurement, we experienced some difficulty with a differential type recorder as a result of scale formation on the orifice and the impulse taps. Frequent calibrations were made due to the concern about the meter accuracy. Over a period of time poke-out rods were installed, purge water was introduced into the impulse lines, and an indicating manometer was provided for quick checking. Obviously, all this attention to one measurement was costly. Despite this, the apparent error had increased to almost 5% in a period of six months.

Finally, this installation was replaced by a Magnetic Flow Meter. The results were very gratifying. This meter has proved to be consistently accurate and has operated without any significant adjustments, or attention.

The problem of actually verifying the accuracy of a large meter can be quite difficult, however. In this case, for example, the normal flow was about 1,800 gpm. There was no easy way to verify the flow by means of volumetric measurements. It was decided to check the accuracy by a chemical addition technique. This procedure involved the addition of a precisely weighed rate of Na_2S solution of known concentration for a period of approximately 20 minutes to the suction of the brine pump. The pump provided good mixing so that samples taken downstream would be truly homogeneous. By analyzing for Na_2S concentration downstream, it was then possible to calculate the brine flow rate equivalent to the observed dilution. Average values for this test were 19.8# / minute of sulfide solution with a concentration of 77 gms/liter (as H_2S). The downstream samples showed an analysis of 0.080 gms/liter. Using this technique, it was determined that the accuracy of the Magnetic Flow Meter was in the order of ±1%.

Another type of velocity meter utilizes a propeller which is driven by the flowing stream. Connecting gears drive an indicating dial or register similar to the familiar domestic water meter integrator. Where only totalized flow is required, this type of meter can be used on brine quite satisfactorily. We did experience some difficulty when our back flushing procedure caused loose scale to tear up the polyethylene propeller. But by changing to a bronze propeller, this difficulty was eliminated.

Generally speaking, many factors must be considered before selecting a particular type of instrument. Each instrument has certain advantages and disadvantages. Cost, simplicity, location, environment, accuracy, and accounting procedures must be considered. But whatever the need may be, there are many good instruments available to do the job.