Selection and Use of Water Meters for Irrigation Water Measurement

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The demand for water by agriculture, industry, urban users, and recreation is increasing. Increasing demand makes proper management and conservation of our limited water supplies increasingly important. It is estimated that half of the water used in Florida is for irrigation, therefore efficient irrigation water management is necessary to conserve water.

Proper management of irrigation water use requires a determination of how much water the system uses. Water meters -- properly selected and maintained -- can be the most accurate and easiest method for measuring water flow.

Water meters may be used for the following purposes:

1. Improving irrigation water use efficiency by allowing accurate measurement of water applied.

2. Determining pumping plant efficiency to allow water to be supplied as inexpensively as possible.

3. Detecting potential well, pump or irrigation system problems.

Units of Water Measurement

A water meter can measure a given amount of water under stationary or mobile conditions. Units of volume are used to measure a given amount of water at rest. Water in motion is described in terms of flow rate, which is a unit of volume per a unit of time.

Volume

Volume units describe how much space an amount of water will occupy. Water tanks, ponds, and in-soil storage are examples of water at rest. Common units of volume are gallons, acre inches, acre feet and cubic feet.

- 1 Acre foot = the volume of water that would cover an acre one foot deep.
- 1 Cubic foot = the volume of water that would fill a container one foot wide by one foot long by one foot deep.
- 1 Acre inch = the volume of water that would cover an acre one inch deep.

Flow Rates

Flow rates tell how fast a given volume of water is moving past a fixed location. They can be used to describe the discharge of a pump, flow in a canal or river, and discharge of a sprinkler or trickle emitter. Flow units commonly used in irrigation are gallons per minute (gpm) and occasionally cubic feet per second (cfs).

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• 1 cfs = the rate of flow in an area of 1 square foot (e.g., a rectangular stream one foot wide and one foot deep), and moving at a velocity of one foot per second.

• 1 gpm = the rate of flow necessary to fill a gallon container in one minute.

If flow rates are known, the volume of water applied by an irrigation system during a period of time can be calculated using Table 1. For example, if a well produces 900 gpm, two inches of water can be applied to one acre in one hour (900 gpm/449 gpm per acre inch per hour per 2 acre inches). Table 2 can be used to determine the volume of water pumped for various time periods and pumping rates.

**Description of Meters**

There is more than one type of flow meter. To understand which meter will work best for a particular application, it is important to understand how the different types work, and to understand the advantages of each.

In the following discussion, two types of meters are described: 1) impeller meters, and 2) positive displacement flow meters.

**Impeller Meters**

Modern impeller meters operate continuously and have direct readouts. They are highly reliable, accurate (within 2%), easily installed, and economical. These characteristics make the impeller meter one of the most practical methods for measuring water flow.

The impeller meter uses a multi-bladed rubber, plastic, or metal impeller mounted inside the flow pipe (Figure 1). The flowing water causes the impeller to rotate, which in turn is connected to a totalizer through mechanical linkages (Figure 2). The volume of water which has passed the impeller is then indicated on the totalizer.

Impeller meters are manufactured by commercial companies in many sizes and styles. Most register total volume of flow only, but can be equipped with a rate meter to measure flow rates. A totalizing flow meter is adequate for most applications. If flow rates are frequently changing during irrigation, a rate indicator may be desirable in addition to a meter (Figure 3).

More often, however, flow rates will be determined by reading the totalizer before and after a measured period of time (i.e., total gallons recorded in a one minute period of time). Meters can be graduated in whatever units the buyer desires (i.e., for volume, acre inches, acre feet, gallons, or cubic feet; for flow rates, gallons per minute or cubic feet per second).

**Positive Displacement Flow Meters**

For domestic water systems and small irrigation systems, positive displacement flow meters (Figure 4) are used to determine the amount (volume) of water consumed by a household. Volume flow meters measure the amount of water that passes through a pipe over a given interval of time.
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Some residences have both a main water meter and an irrigation meter. The main water meter is installed by the utility company within the main water inlet pipe and is used to determine the total amount of water used by the household. The irrigation meter is installed within the pipe which branches off for the irrigation water supply; this meter only records the water consumed by the irrigation system.

Positive displacement flow meters are relatively inexpensive and accurate, operating on the oscillating pin principle. As water passes through the meter, a disk wobbles on a spheri-cal axis (Figure 5). Each complete wobble corresponds to a specific volume of water. The movement of the disk causes a pin attached to the central sphere to move in a complete circle. The tally of the circles completed by the pin corresponds to the volume of water that has entered the system.

Two typical dials used on positive displacement meters are shown in Figure 6. The meter is read from left to right; replacing the shaded zero with the number the arrow is most closely pointing (Figure 6a). For example this meter is reading 98,241 gallons. Figure 6b is also read from left to right where the final digit will be the number at the center of the dial to the extreme right. This meter reads 156,293 gallons.

Selection

When buying a meter, it is necessary to have it graduated and calibrated for its specific application. It is also important to have replacement parts and maintenance service available from the manufacturer’s representative, should they be required.

Water meters vary in size, quality and design. Thus, selection should be based on these considerations. The meter size should be determined by the size of pipe, the range of flow to be measured, and the head loss due to flow through the meter. The manufacturer should provide this information in a manner similar to Figure 7.

The range of flow to be measured should be given highest consideration when selecting a meter. At lower flow rates, the accuracy of the meter will decline rapidly, while at higher flow rates, accuracies decrease slowly as head losses increase. These are illustrated in Figure 7. A meter should be selected so that the lowest anticipated flow will be measured at or near 100% accuracy. Also, the meter should

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Figure 4. Positive displacement flow meters.

Figure 5. Mechanism of a positive displacement flow meter.

Figure 6. Typical dials used on positive displacement flow meters.

Figure 7. A chart such as this should accompany a flow meter to allow proper selection.
operate near the mid-range of its capability for greatest accuracy.

Table 3 and Table 4 list the common flow ranges suggested by manufacturers for various sized impeller and positive displacement meters respectively. Because of rapid decreases in accuracy at low flow rates the accuracy of the meter should be checked at the lowest flow that will be measured.

Better quality meters now use a magnetic drive between the impeller and the indicator head. This is desirable because it eliminates problems with sealing direct drive bearings which sometimes bind because of sand or corrosion.

The size of the impeller usually ranges from 50% to 80% of the pipe diameter. Smaller impellers are designed for usage where a nearly constant flow rate is being measured. Larger impellers are more accurate when a wide fluctuation in flow rates is experienced, because the larger impeller is driven by more of the total flow in the pipe.

When choosing a meter it is very important that it be applicable to the exact inside diameter (I.D.) of the pipe in which the meter will be installed. Otherwise, measurement errors will occur. An error of 6% will occur if a meter geared for 6 inch diameter aluminum pipe (actual I.D. = 5.884 inches) is installed in a 6 inch diameter seamless steel pipe (actual I.D. = 6.065 inches). This problem can be eliminated by specifying meters which are factory-installed in a short section of properly sized tubing. The tubing will normally be equipped with fittings to simplify installation. Also, straightening vanes to help eliminate turbulence and assure accuracy can be added by the manufacturer (See Figure 1).

Proper installation of flow meters is one of the most important criteria for accurate flow measurement. Different installation procedures are required for different meters. Saddle meters (Figure 1) can be welded or bolted onto the pipe. Tube meters (which are factory-installed in straight tubes) can simply be welded into the pipeline or installed with flanges or couplers (Figure 1).

For accurate measurement, the impeller meter must be installed in the center of the pipe with the axis of rotation parallel to the direction of flow. Saddle meters are most subject to these installation problems as illustrated in Figure 8. Tube meters are factory designed to avoid these problems provided the tube is installed in-line with the properly sized pipe.

The impeller meters must be installed at least five pipe diameters downstream and at least one pipe diameter upstream from any bends or obstructions in the pipe. As an example, for an 8 inch meter, 40 inches of straight pipe would be required between the impeller and the obstruction. For better results, 8 to 10 diameters are preferred upstream and 5 downstream. Positive displacement meters must be installed 10 diameters upstream and at least 5 diameters downstream from any bends or obstructions. If the minimum required straight pipe section cannot be obtained, and for greater assurance of good accuracy in measurements, straightening vanes should be installed in the pipe ahead of the meter to prevent a spiraling flow. These vanes are typically limited to large pipes (i.e., 4 inch diameter and greater).

Impeller meters can be installed in any position that is convenient - vertical, horizontal or inclined. They can also be installed on either pump intake or discharge lines (Figure 9). The pipe must always be flowing full for accurate measurement. If the pipe is not flowing full, then either orifice plates to constrict flow or a U-shaped pipe arrangement can be used to create enough pressure to fill the pipe.

Positive displacement flow meters can be installed directly into the mainline, before the lateral tees. The indicator arrow on the meter casing should point in the direction of the water flow. The pipe must be clean and contain potable cold water with a working pressure generally to not exceed 150 psi. The pipeline should have no other obstruction within approximately ten diameter lengths of the inlet of the meter.
and at least five diameter lengths from the outlet of the meter. This is to ensure against superfluous turbulence in the flow through the meter to maintain accuracy in reading.

**Maintenance**

Flow meters are like any other piece of machinery. They require maintenance and care. It is necessary to follow the manufacturer's recommendations for maintenance including periodic servicing and frequent checks to assure that the meter is operating properly.

It is necessary that the impeller spins easily because drag causes inaccurate measurement. If it drags, obstructions might be binding the impeller or shaft or a bearing or gear may be worn. Each meter should be calibrated in place periodically because corrosion and wear may increase friction in the moving parts and affect the calibration.

Positive displacement flow meters are relatively low maintenance. However, when repairs are needed, the measuring chamber may be removed while the body can remain inline. Measuring chambers may also be entirely replaced with manufacturer pre-tested assemblies. Some types of flow meter require complete replacement of both measuring chamber and casing, as they do not separate.

Meters should not be stored in a full pipe of water during the off-season. Meters that are installed in short portable pipe sections are best stored standing on end and covered.

**Economics of Metering**

Prices of water meters vary widely. This is due to differences in quality, options selected on the indicator head, type of meter section or method of fastening the meter to the pipeline, and the ranges of flow the meter is designed to measure. Meter costs can be expected to be in the range of $400-$800 for meters with fittings and flow ranges applicable to irrigation pipes from 4-12 inches in diameter.

On an annual basis metering water is relatively inexpensive. Based on an initial meter cost of $500, and an application of 12 inches of water to 90 acres per year, the annual costs are:

**Fixed costs:**

\$500 \times 0.1241 \text{ (capital recovery factor @ 9%, 15 years)} = \text{ \$62.05}

**Repair and Maintenance:**

12 inches x 90 acres = 90 acre feet per year
90 acre feet \times \$0.15/acre-feet = \$13.50

Total costs:

**Estimated Annual Cost = \$75.55**

Annual cost is 84 cents per acre per year for this example. Only a small water savings would be required to pay for the cost of metering. If water is being applied by a traveling gun irrigation system powered by a diesel engine, only approximately 1/5 of an inch of water per acre would need to be saved to pay for the meter. This is based on diesel fuel cost of $3.0/gal and a total pumping head of 300 feet (operating pressure + lift). Greater savings will be realized as fuel becomes more expensive.

**Summary**

Measuring water pumped for irrigation is useful for evaluating present management practices, determining pumping plant efficiency, detecting well pump and irrigation system problems and regulating water usage. Knowledge of the units of measuring both flow rate and volume are necessary when evaluating irrigation practices. Impeller meters are an accurate and convenient tool for measuring both flow rate and volume when properly selected, installed, and maintained. Effective use of an impeller water meter requires:

1. Proper selection of the meter based on pipe size, range of flow and head loss characteristics.

2. Proper installation of the meter so the pipe is always flowing full, turbulence is not excessive and the meter is positioned correctly.

3. Provision of good maintenance so the meter remains accurate and has a long, useful service life.

**References**


### Table 1. Conversion Factors -- Volume Units

<table>
<thead>
<tr>
<th>Conversion Factor</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cubic foot</td>
<td>7.48 gallons</td>
</tr>
<tr>
<td>1 acre inch</td>
<td>3,630 cubic feet</td>
</tr>
<tr>
<td>1 acre inch</td>
<td>27,154 gallons</td>
</tr>
<tr>
<td>1 acre foot</td>
<td>43,560 cubic feet</td>
</tr>
<tr>
<td>1 acre foot</td>
<td>325,850 gallons</td>
</tr>
</tbody>
</table>

### Flow Rate Units

- 1 cfs = 449 gpm
- 1 cfs for 1 hour 1 acre inch
- 449 gpm for 1 hour 1 acre inch

### Table 2. Volume of Water Applied for Various Flow Rates and Time Periods

<table>
<thead>
<tr>
<th>Flow Rate (gpm)</th>
<th>Volume (Acre Inches) Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 hr</td>
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<tr>
<td>25</td>
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<td>50</td>
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<td>500</td>
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<tr>
<td>1000</td>
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<tr>
<td>1500</td>
<td>3.32</td>
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<tr>
<td>2000</td>
<td>4.42</td>
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</table>

### Table 3. Recommended Flow Ranges for Impeller Meters

<table>
<thead>
<tr>
<th>Meter Size (inches)</th>
<th>Minimum Flow Rate (gpm)</th>
<th>Maximum Flow Rate (gpm)</th>
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</thead>
<tbody>
<tr>
<td>4</td>
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<td>400</td>
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<tr>
<td>6</td>
<td>90</td>
<td>900</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>1,200</td>
</tr>
<tr>
<td>10</td>
<td>125</td>
<td>1,500</td>
</tr>
<tr>
<td>12</td>
<td>150</td>
<td>2,000</td>
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</tbody>
</table>

### Table 4. Recommended Flow Ranges for Positive Displacement Meters

<table>
<thead>
<tr>
<th>Meter Size (inches)</th>
<th>Minimum Flow Rate (gpm)*</th>
<th>Maximum Flow Rate (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8” x ½”</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>5/8” x 3/4”</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3/4” x 3/4”</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>3/4” x 1”</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>1”</td>
<td>3/4</td>
<td>50</td>
</tr>
<tr>
<td>1 ½”</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>2”</td>
<td>8</td>
<td>160</td>
</tr>
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</table>

* (with 98.5-101.5% accuracy)