IRRIGATION MANAGEMENT SERIES

IRRIGATION WATER MEASUREMENT AS A MANAGEMENT TOOL

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In the defined use categories of municipal, industrial, stockwater, recreational, domestic, and irrigation, irrigated agriculture is the largest single water user in the state of Kansas. The approximately 3 million acres of irrigated land typically require 3 to 5 million acre-feet of water per year.

Most irrigation water is supplied by groundwater wells. However, declining groundwater levels in many of the major irrigated areas raise concern over the long-term availability of water. In other areas where either shallow recharging aquifers exist, or alluvial aquifers are used, irrigation may not cause long-term decline. However, irrigation use and increasing demand from other types of water use may cause occasional shortfalls with major environmental or economic impacts.

In either situation, irrigation managers need to make certain water use is within the limits of the irrigation allocation, and that no more is applied than needed for the crop. Implementation of best irrigation management practices is much more difficult without some means of water measurement. Water measurement can provide the basis for evaluations to optimize irrigation application. Water measurement data can help determine overall irrigation system efficiency, monitor system performance, detect well problems, monitor pumping plant performance, and simplify completion of the annual water use report.

While several water measurement methods are available, the most common method used in Kansas is an in-line propeller meter.

PROPELLER METERS

Propeller-type water meters use a multi-blade propeller positioned in the interior of the pipe water flow area (Figure 1). The rotational speed of the propeller is determined by the velocity (feet per second) of water flow which is then converted to volumetric flow rate (gallons per minute or gpm); or cubic feet per second (cfs); and volume (gallons, gal), cubic feet (cu-ft); or acre-feet (ac-ft), based on the pipe's diameter.

While all of the meters register the total volume, most modern designs register both flow rate and volume. A number of companies manufacture this type of meter in a variety of sizes and styles.

SELECTION

When selecting a water meter, be sure to check installation requirements with the conditions of your irrigation system and pipe supply network. If your situation does not meet all of the requirements, the meter should be calibrated after it is installed. The installed meter is commonly checked for accuracy using a non-intrusive sonic flow meter. It is also important to have spare parts and maintenance service locally available. While local service is usually the best option, convenience and speed are important.

Water meters vary in size, quality and design. Meter size should be determined by the size of the main pipe, the range of flow rates to be measured, and the head loss characteristics. Meter manufacturers should provide this information in a manner similar to the chart as shown in Figure 2. The meter must accommodate the expected range of flows, and the lowest anticipated flow should fit within the normal accuracy of the meter. It is also desirable to select a size that will not create excessive head loss.

For example, an 8-inch meter needs a flow velocity of 1 ft/sec, or a flow rate of 150 gpm to reach its full level of accuracy. Furthermore, that same meter will have a friction head loss of 5 to 6 inches of water with a

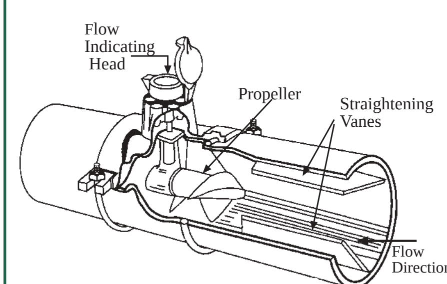
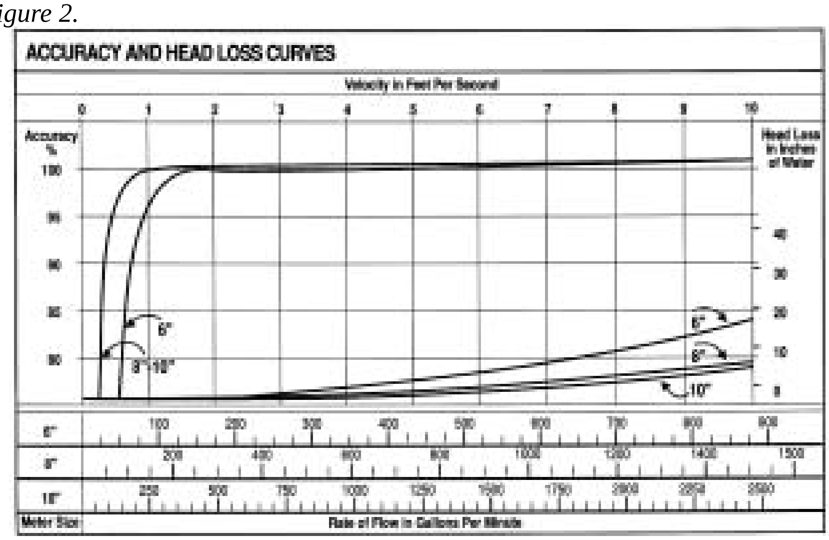


Figure 1.
Typical irrigation propeller meter. The large diameter propeller and straightening vanes are important for accurate measurement.

Figure 2.



flow rate of 1,200 gpm. Specific operating characteristics will vary with other meter designs.

Most meters use a magnetic drive between the propeller and the indicator head. This eliminates problems with sealing direct drive bearings, which sometimes bind because of sand or corrosion.

Propeller size usually ranges from 50 to 80 percent of pipe diameter. Small propellers are suitable when there is little variation in the flow. However, because larger propellers catch more of the total pipe flow, they provide more accuracy when wide fluctuations in flow occur within the pipeline.

The meter gear ratio must be selected to correspond with the inside diameter of the pipe in which the meter will be installed. All pipes with a certain listed "nominal" size do not necessarily have the same inside diameter. Because the inside diameter is used to determine flow rate from the propeller-indicated flow velocity, errors can occur with improper gear ratios. As an example, a meter geared for a 6-inch-diameter aluminum pipe, with a 5.884-inch inside diameter will be off by 6 percent if it is installed in a 6-inch-diameter seamless steel pipe with an inside diameter of 6.065 inches. Over the course of a season, a 6 percent measurement error can equate to 1.2 inches of water from a 20-inch application depth. This will influence records and your water management decisions.

INSTALLATION

The accuracy of the meter also depends on proper installation. Because different installation procedures are required for different meters, follow the guidelines provided by the manufacturer. Figure 3 shows correct and incorrect examples of water meter installation. Saddle meters are normally bolted onto the pipe, but some older styles were made to be welded in place. Meters mounted in straight pipe sections can be installed with dresser couplers or flanges, and some may be welded into the pipeline. Welding is not recommended unless there is a provision for removing the meter for service without having to cut the pipeline. For accuracy, the center line of the meter propeller must be positioned on the center line of the pipe. If the propeller is too high, off-center, or too low, improper flow velocity and flow rate readings will occur.

Propeller meters may be installed in any convenient position — vertical, horizontal or at an angle — but for accurate readings, the pipe must always be flowing full. If the pipe is not full, some arrangement — such as a restriction, bend or baffle plate — must be installed to ensure that full pipe flow occurs.

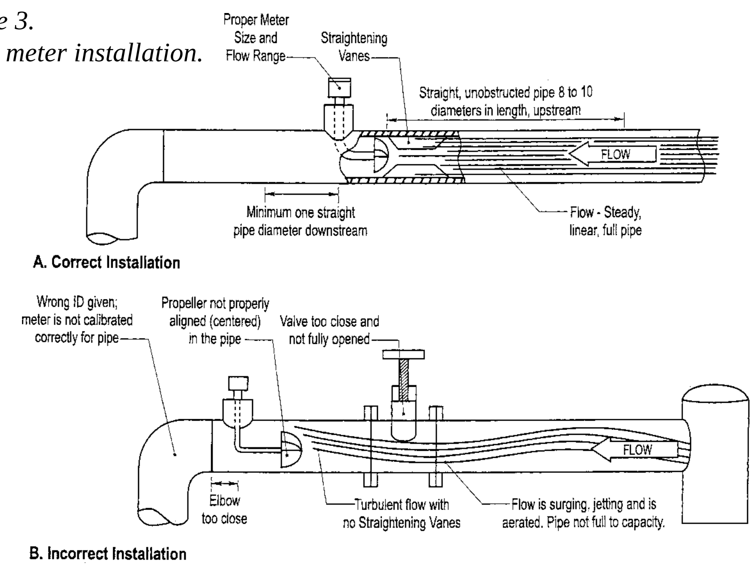
Spiraling flow or turbulence also affects meter accuracy. To minimize this problem, install the meter at least 10 pipe diameters downstream from any bend or obstruction, and at least five diameters upstream from such obstructions. However, follow the manufacturer's recommendations. For example, an 8-inch meter will need at least 80 inches of straight pipe between the meter propeller and the nearest upstream fitting or pump outlet.

If the minimum straight pipe cannot be provided, straightening vanes should be installed in the pipe ahead of the meter to reduce excessive turbulence. Many meters can be purchased as a flanged or vitalic (clamped) coupling pipe section that includes straightening vanes.

MAINTENANCE

Propeller meters, like all machines, require maintenance and care. Follow the manufacturer's recommendations for maintenance, including lubrication, periodic service, and frequent checks to make sure the meter is operating properly.

Figure 3.
Water meter installation.

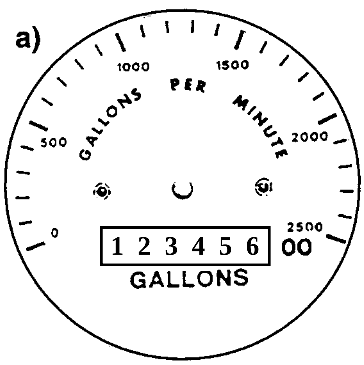


It is important that the propeller spins easily. If it seems to drag, check for the causes. Something may be caught on the shaft, or in the flow path to either bind the propeller or obstruct the pipe flow. Look for shaft wear and check bearings and gears.

Every meter should have a periodic calibration check. This may be done in place, or the meter may be sent to a calibration facility. Some irrigation systems will pump sand or other suspended debris, causing corrosion and wear that can increase friction between moving parts and affect meter calibration. Again, improper calibration will result in measurement errors that will affect water management decisions and records.

Figure 4.
Dial face configurations showing total readings.

a)



Standard 8" meter dial face with gallon totalizer. Note: Two fixed zeros at right to be included in the reading.
Gallons = 12,345,600

b) 1 2 3 4 5 6 000.

GALLONS

Standard 10" meter dial face with gallon totalizer. Note: Three fixed zeros at right to be included in the reading. Three zeros may also be found on some 8" meters.
Gallons = 123,456,000

c) 1 2 3 4 5 6

ACRE INCHES X . 01

Standard 8" meter dial face with acre inch totalizer. Note: The multiplier .01 places a decimal point two places to the left. The odometer wheels also change color at the decimal point.
Acre Inches = 1234.56

d) 1 2 3 4 5 6

ACRE FEET X.001

Standard 8" meter dial face with acre feet totalizer. Note: The multiplier .001 places a decimal point three places to the left. The odometer wheels also change color at the decimal point.
Acre Feet = 123.456

The pipe section containing the meter should be drained when not in use, especially over the winter when freezing conditions may cause damage. Meters that are removed during the off season should be drained and blocked to prevent the entry of dust, dirt, insects and rodents.

METER INDICATING HEAD OPTIONS

Water measurement can be done with a variety of meter styles and measurement units. As previously stated, rates are usually in gallons per minute, but totals may be shown in gallons (gal), acre-feet (ac-ft), acre-inches (ac-in), or cubic feet (cu-ft). Figure 4 shows an example of a water meter dial face and a description of the readings. The choice of units is largely a personal preference, although it should be one with a counter total that would not turn over more than once during an irrigation season.

Volume and flow rate units can be measured in one type of unit and then converted to different units. Table 1 lists equivalent water measurement units that are useful for irrigation management. For example, the volume of water applied and the acres covered must be known in order to calculate the depth of water applied.

Another option most meters have is indicators of flow rate. Flow rates are normally in gallons per minute (gpm) or cubic feet per second (cfs). Flow rate can be determined for any meter equipped with a sweep hand (Figure 5a), or a flow rate indicator (Figure 5b). A stop watch must be used in conjunction with the sweep hand to determine flow rate. Figure 5b depicts a meter featuring all options: totalizer, sweep hand, and flow rate indicator.

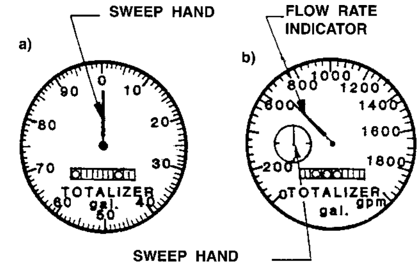


Figure 5.
Dial face configurations showing sweep hand and flow rate indicators.

Accurate water measurement figures allow the irrigator to adjust water applications to soil storage availability and crop requirement, thereby improving irrigation efficiency. Water measurement accuracy also allows the irrigator to monitor total applied water over the season, and to make adjustments to stay within water right the limits. Regular review of water measurement records can help identify system problems. For example, an irrigator could suspect an underground pipe failure if a higher than normal flow rate is detected. Water measurement for subsurface drip irrigation (SDI) can help identify if the emitters of the SDI system are plugging. This would be indicated by decreasing flow rates.

Accurate water measurements can also help in early detection of well and pump problems, or how water level changes from declining ground water are affecting pumping performance and efficiency. Pumping plant efficiency can be better estimated when accurate water measurements are available. These are just a few examples of how accurate water measurements can help irrigators make sound irrigation management decisions.

EXAMPLE CALCULATIONS

Example 1: *A totalizer unit similar to Figure 4a indicates an ending reading of 12,345,600 gallons, and the beginning reading was 98,785,300 gallons. What was the total volume applied?*

Solution: In general, all that is required is subtracting the beginning meter reading from the ending. However, in this case that would result in a negative number. This means the totalizer unit has passed its maximum reading of 100,000,000 gallons and started over. So, add the maximum reading (100,000,000 gallons) to the ending reading, then subtract the beginning reading.

Ending reading:	112,345,600 gal.
Beginning reading:	98,785,300 gal.
Volume applied:	13,560,300 gal.

Example 2: *How many acre-inches were applied in Example 1?*

Solution: From Table 1:
one ac-in = 27,154 gal.

$$\frac{13{,}560{,}300 \text{ gal.}}{27{,}154 \text{ gal/ac-in}} = 499 \text{ ac-in}$$
Total volume applied

Example 3: *The volume of water from Example 2 was applied in three irrigations to a field with a row length of 1,000 feet, and was planted in 1,045 rows, 30- inches wide. What was the total applied depth and average gross irrigation depth for each of the three irrigation events?*

Solution: The area covered is:

$$\frac{1{,}000 \text{ ft x } 30 \text{ in/row x } 1{,}045 \text{ rows}}{12 \text{ in/ft x } 43{,}560 \text{ ft}^2\text{/acre}}$$

Area covered = 60 acres

$$\frac{499 \text{ ac-in}}{60 \text{ acres}} = 8.32 \text{ in.}$$
Total applied depth

$$\frac{8.32 \text{ in.}}{3 \text{ irrigations}} = 2.77 \text{ in./irr.}$$
Average irrigation depth

The calculated and measured information can also be compared to other known data. For example, an hour-meter reading from the pumping plant could be compared to the calculated hours of pumping using the flow rate indicator. If these values are similar, the operator would know that both devices are functioning properly.

Example 4: *The flow rate indicator registers 500 gpm when the pump is operating. The hour-meter or the engine indicates 450 hours of operation. Are these instruments indicating similar results?*

Solution A: Example 1 showed 13,560,300 gallons were pumped.

$$\frac{13{,}560{,}300 \text{ gal.}}{450 \text{ hrs x } 60 \text{ min hr}} = 502 \text{ gpm}$$

This pumping rate compares favorably with rate indicator.

Solution B: Example 2 showed that the water volume was equal to 499 acre-inches. The well is producing 500 gpm.

$$\frac{500 \text{ gpm}}{450 \text{ gpm/ac-in}} = 1.11 \text{ ac-in/hr}$$

$$\frac{499 \text{ ac-in}}{1.11 \text{ ac-in/hour}} = 449 \text{ hours}$$

This compares favorably with the hour meter.

ABBREVIATIONS USED

gal. = gallons
ac-in. = acre-inch
in. = inch
hr. = hour
min. =minutes
sec. = second

OTHER RESOURCES

See the K-State Research and Extension Library at:
www.oznet.ksu.edu/library
Irrigation Web sites:
www.oznet.ksu.edu/mil
www.oznet.ksu.edu/irrigate
www.oznet.ksu.edu/sdi

Table 1.

EQUIVALENT MEASURES

Volume Units:
1 gal = 8.33 pounds
1 cubic foot = 7.48 gals
1 cubic foot = 0.02832 cubic meters
1 liter = 0.264 gallons
1 gal = 3.79 liters
1 cubic meter = 264.2 gals
1 ac-in = 3,630 cubic feet
1 ac-in= 27,154 gallons
1 ac-foot = 43,560 cubic feet
1 ac-foot = 325,381 gallons

Units of Flow:
1 cu ft per second = 449 gals per minute
1 cu ft per second for one hour =1 ac-in
1 cu ft per second = 0.02832 cu meter per sec
1 cu ft per second = 35.31 cu ft per second
1 ac-in/hr = 450 gpm
1 gal per minute = 0.00223 cu ft per sec
1 gal per minute = 0.00221 ac-inchs per hour
1 gal per minute = 0.06309 liters per sec
1 liter per second = 15.85 gal per minute

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