Irrigation Flow Measurement

Louisiana Irrigation

Measuring irrigation flow helps irrigators better manage and schedule irrigation. Measuring flow also is a tool for estimating irrigation water use. This publication will help irrigators learn to select, install and use propeller and ultrasonic flow meters as well as estimate flow without the aid of flow meters.

Propeller Flow Meters

Propeller flow meters are the most common devices used for measuring water flow rate (Figure 1). A propeller flow meter measures the velocity inside a pipe and shows the flow rate reading on a dial. Each of these meters are designed for a specific pipe size and work best within particular ranges of flow (Table 1). With adapters one flow meter can be used to measure several pipe sizes. Two main types of flow meters are saddle and flanged. Saddle are placed through a hole in an existing or specifically used pipe. Flanged flow meters are placed in between an existing flanged joint. When excessive trash will be in the water, a small propeller can be installed. Due to their reduced accuracy, these smaller propellers should not be used for all applications. When meters will be used on more than one site, irrigators have found it convenient to couple them to a designated section of aluminum or PVC pipe (Figure 2).

Figure 1. Propeller flow meter.

Figure 2. Designated pipe section for a propeller flow meter.

Table 1. Typical operating range of propeller flow meters.

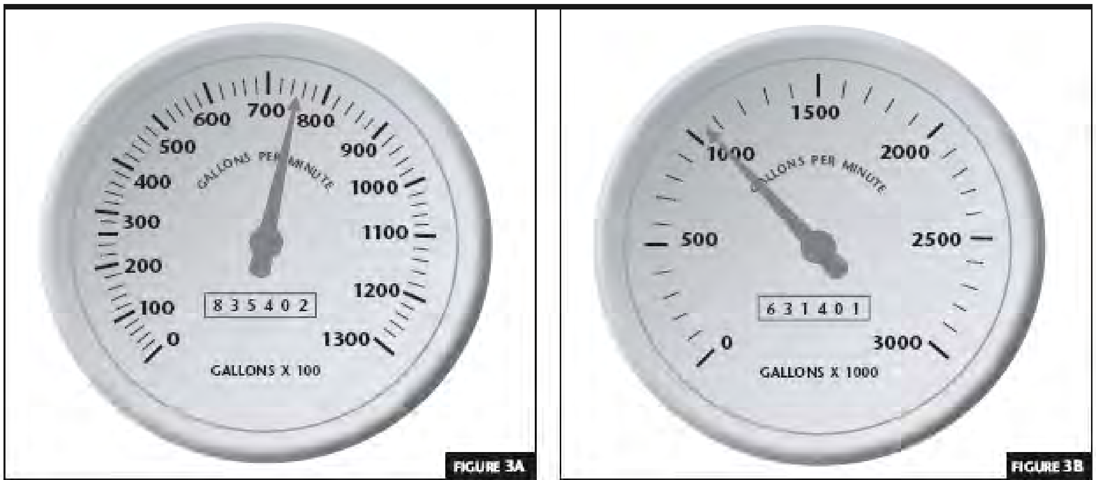
Meter/Pipe Size (in)	Minimum Flow (gpm)	Maximum Flow (gpm)	Head Loss (in)
3	35	250	29.5
4	50	600	23.0
6	90	1200	17.0
8	100	1500	6.75
10	125	1800	3.75
12	150	2500	2.75
14	250	3000	2.00
16	275	4000	1.75

Reading Propeller Flow Meters

Propeller meters are used to measure instant flow rate and the total volume over a period of time. The instant readings are in gallons per minute or cubic feet per second. The needle indicates the flow rate, and the box below the needle indicates the total volume of water. The total volume can be measured in acre-inches, gallons, cubic feet or cubic meters. Some irrigators prefer measurements in acre-inches because it relates to their traditional terminology. On the dial faces shown in Figures 3A and 3B, the flow rate is expressed in gallons per minute and the total volume in gallons. To obtain the volume, the reading is adjusted by a factor. In Figure 3A, the factor is 100; in Figure 3B, the factor is the three zeros to the right side of the dial. The readings for each flow meter are in the figure captions.

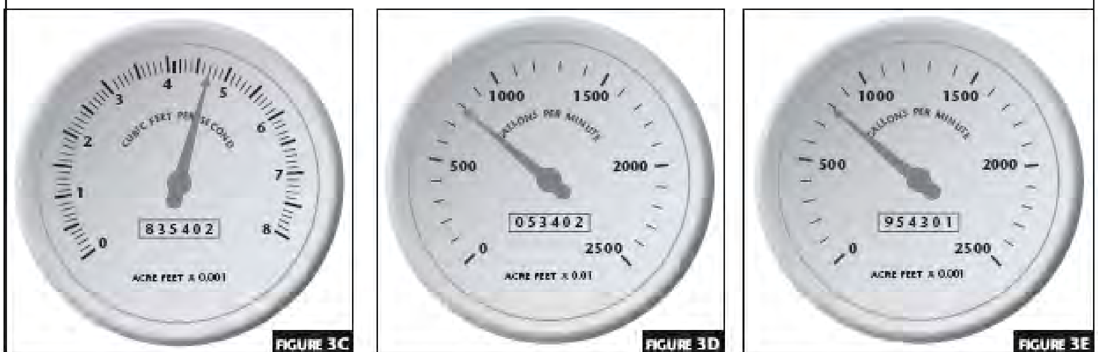
In Figure 3C, the flow rate is measured in cubic feet per second and the total volume in acre-feet when the reading is multiplied by the factor of 0.001 indicated on the dial face. In Figure 3D, the flow rate is measured in gallons per minute and the total volume in acre-feet when the reading is multiplied by a factor of 0.01. In Figure 3E, the flow rate is measured in gallons per minute, but the total volume is measured in acre-feet when the reading is multiplied by a factor of 0.001. The factors for adjusting the readings of each flow meter are shown on the meters.

Figure 3A-E. Reading propeller flow meters.



Standard 8-inch dial face with gallons totalizer. Add two zeros to the six-digit number.
Dial face reading = 83,540,200 gallons.

A 10-inch dial face with gallons totalizer. Add three zeros to the six-digit number.
Dial face reading = 631,401,000 gallons.



Dial with cubic feet per second indicator and acre-ft totalizer. Place a decimal point three places to the left.
Acre-ft = 835.402

Acre-ft totalizer. Place a decimal point two places to the left.
Acre-ft = 534.02

Acre-ft totalizer. Place a decimal point three places to the left.
Acre-ft = 954.301

Portable Ultrasonic Flow Meters

A relatively new alternative is the ultrasonic flow meter. The USFM is a non-invasive device that can be used to measure both flow rate and volume. Clamp-on transducers eliminate in-line installation, allowing one meter to be used at many locations (Figure 4). Exterior installation eliminates pressure losses and prevents leaking that can be associated with in-line meter installations. The popularity of ultrasonic flow meters is due in large part to their portability and ease of use; they can be installed almost anywhere. Due to their high cost (~$3,000 - $5,000), however, the use of USFMs will likely be limited to irrigation professionals, technical assistance providers or irrigators who manage several pumping units and/or farms.

The transmission, or transit-time, ultrasonic flow meter operates on the principle of phase shift. Two transducers act alternately as transmitter and receiver as two paths of

Figure 4. Ultrasonic flow meter.

sonic beams travel back and forth across the pipe (Figure 5). One beam travels downstream while the other moves upstream. The motion of the fluid causes a frequency shift in both waves. This shift is related to the velocity of the fluid. Research has shown that, when installed properly, USFM accuracy ranges from +/- 1 to +/- 5 percent of full scale.

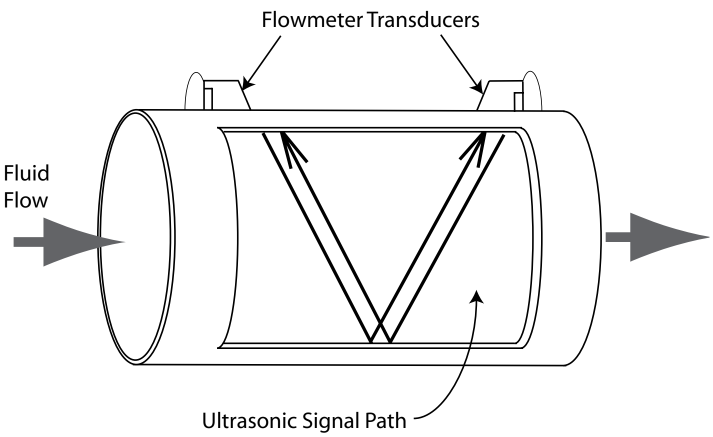


Figure 5. Ultrasonic flow meter measurement technique.

Installing Flow Meters

When measuring fluid in a pipeline, proper flow meter installation is one of the most important requirements for accurate flow measurement. This is true for any type of meter discussed here – propeller or ultrasonic. Water should be clean, but if it contains sediment, the meter should be located so that settling sediment will not obstruct the flow. As water passes through valves, pumps, reducers, tees and elbows, it is agitated and sometimes sent into a swirling motion. It is difficult to accurately measure water that is agitated and swirling. To ensure that fluid flowing past the measuring location is "well-conditioned" (undisturbed), meters should be installed with a sufficiently long section of straight, unobstructed pipe upstream from the meter location. Unobstructed upstream distances often are measured in terms of pipe diameters, D (Figure 6). For example, if one were measuring flow in an 8-inch pipe, 5 D (five pipe diameters) equals 40 inches.

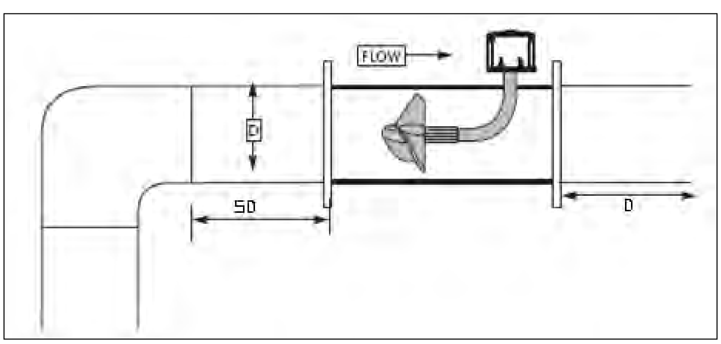


Figure 6. Proper placement of flowmeter on an irrigation system.

Most common meter location recommendations call for a minimum of 5 to 10 straight D free of obstructions upstream from the meter and at least 1 D free of obstructions downstream from the meter. If these requirements cannot be met, the piping conditions are "non-ideal" for flow measurement. A common problem found in irrigation-well meter installations is that the upstream unobstructed, straight pipe length recommendation cannot be met and metering often is done in a non-ideal piping configuration. If there is not enough length either upstream or downstream, meters should have straightening vanes. Adding vanes will reduce the undisturbed length requirement to about 1½ pipe diameters upstream and ½ pipe diameter downstream.

Plumb Bob Method

To measure the flow from a pipe using a plumb bob, the pipe must be running full. The discharge end of the pipe should be smooth, and the length should be more than 8 pipe diameters, or long enough to reduce turbulence from the pump. Accuracy of the plumb bob method is approximately 5 percent of the actual flow for level pipes and 10 percent for inclined pipes, depending on the accuracy with which the technique is applied.

Equipment needed

A yardstick, a piece of cord and a plumb bob will be needed. A straight 1- x 2-inch stick of wood 36 to 48 inches long is better than a common yardstick (Figure 7). The stick should be marked off in inches and subdivided into either eighths or tenths. A piece of steel or nylon tape may be fastened to one side of the stick instead of marking the graduations on the wood. The cord must be fastened to the end of the stick and the plumb bob fastened to the cord so that the bottom of the plumb bob hangs 8 inches below the lower edge of the stick or piece of wood. Technically, the plumb bob should hang 8 inches plus the wall thickness of the pipe being measured below the yardstick.

Measurement Technique

Place the stick on top of the pump discharge pipe being careful to center it far enough out of the pipe so that the plumb bob hangs free beyond the water. Next, slide the stick back along the pipe until the bottom tip of the plumb bob just touches the stream of water, and read

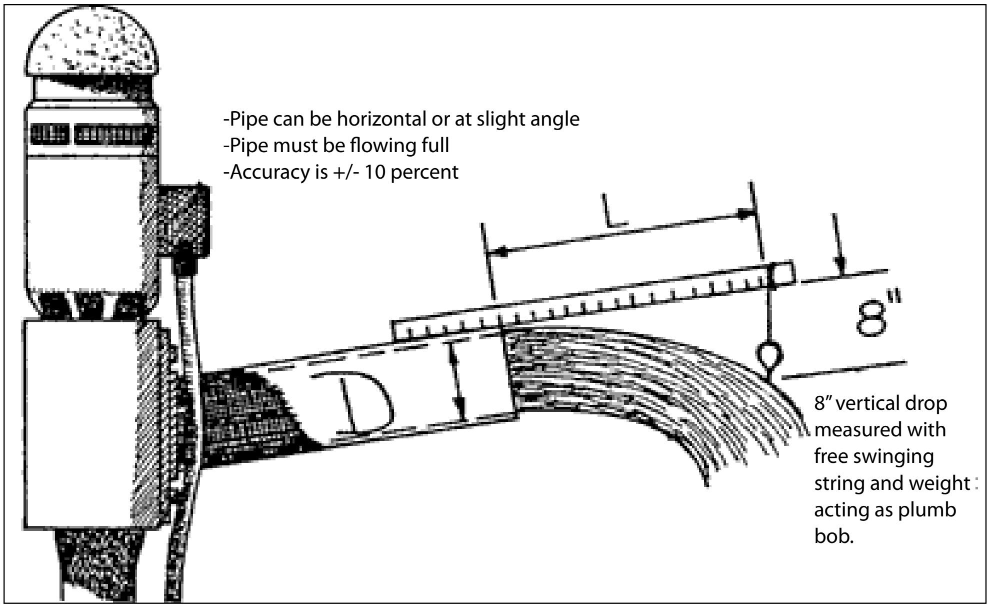


Figure 7. Measuring a pump flow using a Plumb-Bob.

the distance "L" the plumb line is out from the end of the pipe. When measuring a "bell" end of a pipe, measure the distance from the beginning of the bell flange, not the end of the pipe. Lastly, calculate the discharge "D (gpm)" by squaring the inside diameter of the pipe "D" and multiplying it by the distance "L."

Formula: Discharge (gpm) = the inside pipe diameter squared x the length in inches.

gpm = D x D x L

Example: For a pump with a 10-inch diameter (D) discharge, and the water discharge distance (L) was 14 inches, the flow rate is calculated by:

gpm = 10 x 10 x 14
gpm = 1,400

Measuring Partially Full Level Pipes

Flow from partially full level pipes is obviously less that the flow from full pipes. Refer to Figure 8, and note the measurements "D" and "Y." "D" is the inside diameter of the pipe. "Y" is the empty space, or air space, between the inside wall and the water surface. The ratio, Y/D, is used in Table 2 along with the pipe diameter, D, to determine the approximate discharge rate.

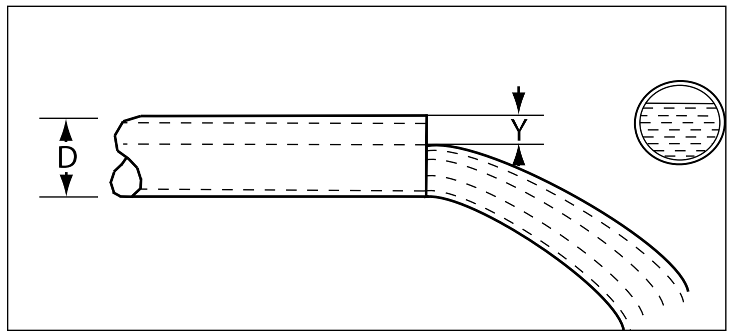


Figure 8. Measuring flow using a Plumb-Bob on partially full pipes.

Table 2. Discharge from partially full level pipes.

Y/D	Inside Pipe Diameter – "D" (in) 4	6	8	10	12
	Discharge (gpm)				
0.1	142	334	579	912	1310
0.2	128	302	524	825	1185
0.3	112	264	457	720	1034
0.4	94	222	384	605	868
0.5	75	176	305	480	689
0.6	55	130	226	355	510
0.7	37	88	152	240	345
0.8	21	49	85	134	194
0.9	8	17	30	52	84
1.0	0	0	0	0	0

Vertical Pipes or Casings

The approximate flow from vertical pipes or casing can be determined by measuring the maximum height (H) to which the water rises above the pipe, and the inside diameter of the pipe. Table 3 gives the discharge in gallons per minute for various pipe diameters and heights of water (Figure 9).

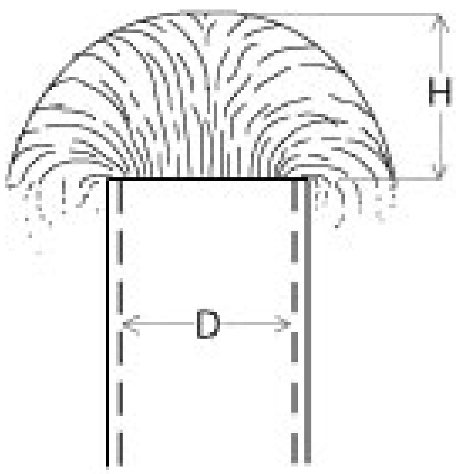


Figure 9. Flow from a vertical pipe or casing.

Time to Fill an Acre-Inch

The flow from a pump also can be estimated by recording the time it takes to fill a level field 1 acre-inch (Figure 10). This method is useful for rice and crawfish producers where a pool of standing water is desirable. This method will underestimate the flow because it does not account for pumped water lost through seepage. In the figure, a flooding time of 54 minutes to cover 1 acre-inch equals a flow of 500 gallons per minute.

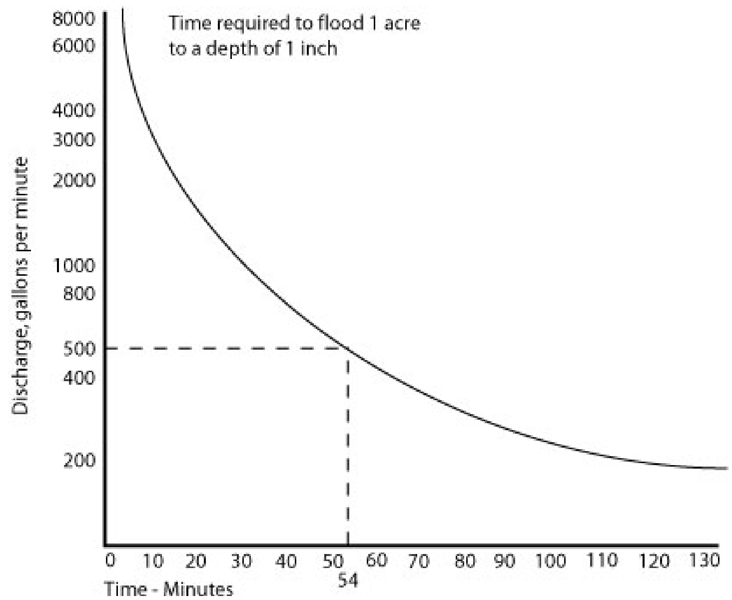


Figure 10. Flow determined by the time to fill one acre-inch.

Table 3. Flow from vertical pipes or casings.

Water Height (H) (in)	Diameter of Pipe (D) (in) 4	6	8	10	12	14	16
	gallons per minute (gpm)						
3	135	311	569	950	1394	1898	2479
4	161	369	687	1115	1612	2194	2866
6	202	469	872	1415	1975	2688	3511
8	236	548	1025	1640	2281	3104	4055
10	265	621	1155	1840	2547	3466	4528
12	294	685	1275	2010	2789	3796	4958
14	319	740	1380	2170	3014	4103	5359
16	342	796	1480	2370	3224	4388	5732

Summary

Knowing pump discharge is important information. It allows producers to check the efficiency of their power and pumping units as well as monitor the amount of amount of water delivered for the amount of fuel being used or purchased. Lastly, as freshwater supplies become more limited, either from saltwater intrusion or aquifer drawdown, monitoring irrigation flow rates will allow irrigator to better manage water resources.

Useful water volume and flow conversions and equivalents.

Volume	equals
1 gallon	8.33 pounds
1 cubic foot	7.48 gallons
1 acre-foot	325,851 gallons
1 acre-foot	43,560 cubic feet
1 acre-inch	27,154 gallons
1 acre-inch	3,630 cubic feet
Flow	equals
1 cfs	448.83 gpm
1 cfs	1 acre-inch per hour
1 gpm	0.00223 cfs
1 gpm	0.00221 acre-in per hour
1 liter/second	15.83 gpm
1 cubic meter/minute	264.2 gpm
1 cfs for 1 hour	1 acre-inch
449 gpm for 1 hour	1 acre-inch

cfs = cubic foot per second, gpm = gallons per minute

Developed from:

Benham, B.L. and D. E. Eisenhauer. 2001. Using ultrasonic flow meters in irrigation applications. University of Nebraska-Lincoln Extension. NebGuide G1426.

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