ITRC

moving water in new directions

IRRIGATION TRAINING AND RESEARCH CENTER
BioResource and Agricultural Engr. Dept.
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Phone: (805) 756-2434
FAX: (805) 756-2433
www.itrc.org

Irrigation District Turnouts

Date: December 15, 2010

To: SBx7-7 ASC members

From: Charles M. Burt, Ph.D., P.E., D.WRE
Chairman, ITRC
Professor, BRAE Dept.
Office phone: 805-756-2379
Cell phone: 805-748-3863
cburt@calpoly.edu

Irrigation District Turnouts

This is meant to be a very quick, roughly written primer on irrigation district turnout selection. It by no means covers all of the details, but it might help out. ITRC offers flow measurement classes, with online registration at www.itrc.org. We have also done testing on quite a few designs over the years, but the work was almost all confidential in nature.

Definition

A "turnout" or "offtake" or "delivery gate" is the point at which the control of the water changes from the irrigation district to the customer(s).

Turnout Functions

At the turnout, several functions are typically found:

1. *On/off control of water flow*.
2. *Flow rate control*. That is, a turnout usually has a valve to adjust the flow rate somewhere between maximum and zero. However, in many cases the downstream conditions determine the flow rate, and the turnout on/off control valve remains completely open. An example would be a piped or gravity turnout with a pump immediately downstream.
3. *Flow rate measurement (instantaneous)*. A device may have a direct readout (digital or a needle or a height on a gauge). Or, a flow formula or table may be used with several measurements such as gate opening and difference in water level.
4. *Volumetric measurement*. A device may have an integral readout (totalizer wheels or digital), or there may be some way to integrate the flow rate over time (Volume = Flow rate × Time). "Integration" is done in several ways:
    a. The flow rate is measured periodically by an operator, and it is assumed that the average flow rate between readings is approximately correct.
    b. A datalogger automatically records key measurements frequently and sums up the volume of water per minute, or per 15 minute intervals, for example.

Maintenance of a Constant Flow Rate

In the "old days" of a few decades ago, it was thought that irrigation districts should deliver a constant flow rate. Therefore, a variety of control/measurement devices (such as the Neyrtec flow distributor baffle module) were developed to provide on/off, flow rate control, plus a constant flow rate (sort of). This is exactly the opposite of what is needed for more modern on-farm irrigation.

Figure 1. Baffle gates in Africa. Old, inappropriate technology for California.

What we need now is the ability for the district to not cause an unwanted flow change through a turnout. For example, over the course of a day the flow rate required by a drip system will constantly change. Every time the filters backflush, an additional 200 GPM or so might be needed for 10 or 20 minutes. As the water is moved between field blocks of varying sizes, the flow rate requirement changes. A center pivot sprinkler will turn end sprinklers on and off as it moves around a field. Therefore, farmers need the flexibility to change their flow rates easily, without constantly having to notify the district, and without needing to adjust their turnouts.

There are still various vendors of "modern" irrigation equipment that highlight the ability of their automated equipment to maintain a constant flow rate through the turnout. While this may be important for surface irrigation (such as in much of RD108 and Imperial Irrigation District), it is not what is needed for sprinklers and drip irrigation.

Figure 2. Example of an automated flow control turnout, with two adjacent manual turnouts

In the case of turnouts that need a constant flow rate versus time (such as with much of the surface, or flood, irrigation), irrigation districts attempt to maintain a constant pressure on the turnouts. This is done in canals with special canal dams called “check structures” that are designed to maintain very constant upstream water levels, regardless of the canal flow rate. These effective check structures can vary from very sophisticated PLC (programmable logic controller) controlled gates to very simple ITRC flap gates or long crested weirs.

Figure 3. Automated radial gates on Glenn Colusa ID main canal at IID. Radio tower and instrumental enclosure for a PLC are in the forefront.

Figure 4. Very long, but simple, long crested weir at San Luis Canal Company. California has many hundreds of these structures.

Figure 5. Three ITRC flap gates in parallel at San Luis Canal Company. These require no electricity, but must have a drop. There are hundreds of these throughout California.

Competing Demands

For irrigation district operation, it is convenient if farmers do not change their flow rates, and if they start and stop deliveries at prescribed, inflexible times. However, such inflexibility is contrary to the needs of modern on-farm irrigation. When districts provide more flexibility (to improve on-farm efficiency), they almost always suffer a loss in canal efficiency – that is, they have more spill at tail ends. There's a long explanation as to why this happens, but at this point just assume it's a challenging problem.

One of the ways we try to provide good on-farm irrigation flexibility while also minimizing spills is to use specially designed pipe systems to make up what is known as "downstream control" of canals, and regulating reservoirs. This is a whole topic in itself, and expensive.

Figure 6. Special entrance to a 200 AF regulating reservoir at Central California ID. The sluice gates in the center are automated to open if the water level gets too high. Pumps at the upper right hand side (not seen) empty the reservoir if the water level in the canal gets too low. The long walls are for emergency spill into the reservoir.

Flow Measurement at Turnouts

Every flow measurement device requires:

1. *Some type of "good" entrance condition*. In other words, most devices will ideally have a long, smooth entrance upstream of them so that the flow streamlines straighten out. Some pipeline measurement devices have special features that allow a short entrance section upstream of the device. But these are relatively new, and the exact sensitivity of a particular device depends in part on the manufacturer.

Figure 7. Example of poor entrance conditions into a field turnout. This is not in California.

2. *Some type of "good" discharge condition*. For a pipeline device, there is usually a short section of straight downstream pipe required. For flumes and weirs, it is typically desirable to not have too much "submergence" – that is, the downstream water level must be a certain depth lower than the upstream water level.
3. *Maintenance*. Gears wear out. Propellers collect trash. Algae grow on overshot gates and flumes. Dirt collects in pipes. Devices rust.

Figure 8. Several inches of algae and sediment on the crest of a flume. The water depth therefore gives an incorrect indication of flow rate.

4. *Proper installation*. Besides paying attention to proper upstream and downstream conditions, there may be other special considerations. Some devices are deployed in pipelines that must be completely full for accurate measurement. Other devices require measurement of water levels at very specific locations. Certainly, the access to water levels must therefore be properly sited.

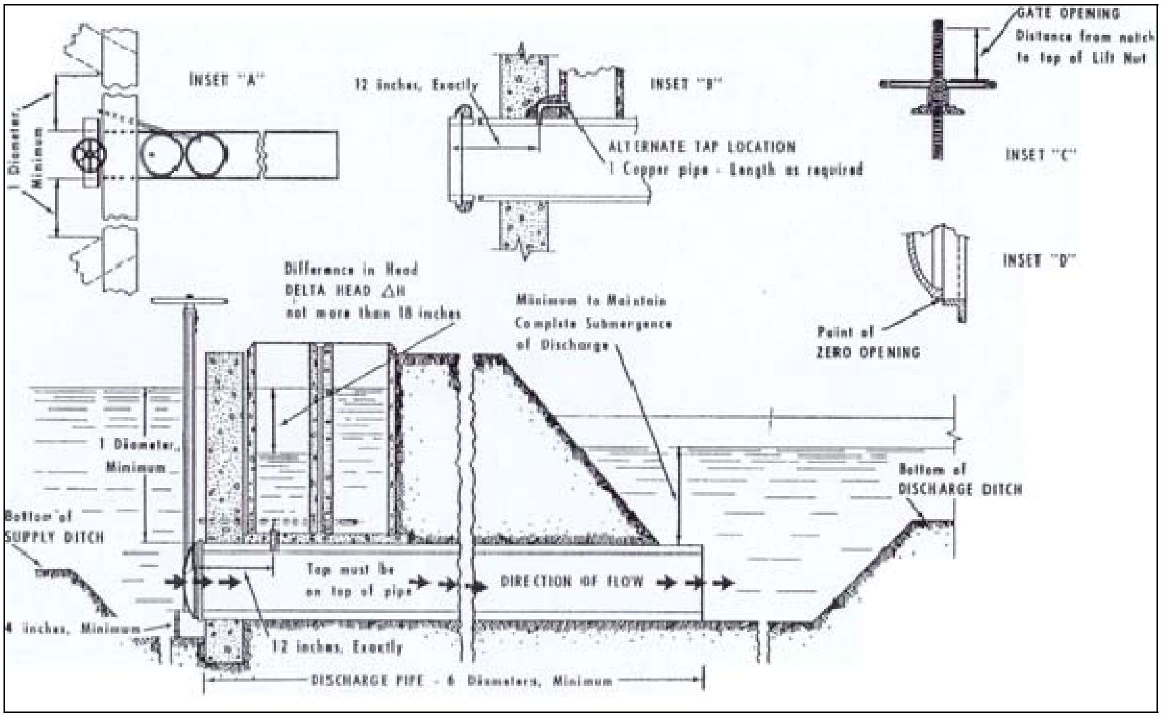

Figure 8. Photo courtesy of an old Armco flow measurement catalog. This depicts a common "metergate" with very specific dimensions that must be met if the rating tables are to be used.

5. *Proper size*. Flow meters can be too big or too small to be accurate for a flow rate. This is especially problematic for areas with rice fields, where at the beginning of the season there are high flows, and low flows are used in the summer.

<u>Permanent Turnouts from Pressurized Pipelines</u>

The best flow rate measurement is typically found on newer, pipelined irrigation districts. Those districts are often laid out with large, rectangular fields, and have pressurized pipe. Furthermore, the flow rates per turnout are often relatively small, and the water is filtered via centralized filtration screens at the head of the large lateral pipelines.

<u>Propeller meters</u>. Most of those districts were designed with propeller meters for measuring instantaneous flow rate, plus totalizing volume. Of course, maintenance is still needed on a systematic basis. But these are the easiest measurement situations – clean water, relatively small flow rates, pipelined, and easy access.

The old standby, depicted below, is the propeller meter. With correct installation and maintenance, it is generally understood to be within about 2-3% accurate over the rated range of flows and volume.

Figure 9. Typical propeller meter in a prefabricated, flanged section. Photo courtesy of McCrometer.

Mag meters. Many of the problems experienced with propeller meters (trash plugging, wearing of bearings, and the requirement of a long, straight inlet and outlet section) are eliminated with some of the newer magnetic meters (called "mag meters") of a spool design, as seen below. Some of these are battery operated. There is a large difference in quality among manufacturers. Also, there are limited models available in sizes greater than 6"or 8". ITRC testing has shown very accurate results from some mag meters, and less-to-horrible results from others.

Figure 10. Two different models of mag meters. Photo courtesy of Seametrics.

Transit-time meters. There is a class of meter that uses a different technology called "transit time" in which an acoustic signal travels from one side of a pipe to the other. The travel time varies, depending upon the velocity of the water. These tend to be expensive for turnout pipes, with variable results reported. They have not yet become well-accepted, permanent flow measurement devices for turnouts.

Venturis. Venturis are found in large pipe installations, such as for lateral turnouts from the Friant-Kern Canal or the Tehama-Colusa Canal. They have a restricted cross section, and two pressures are measured – one upstream of the restriction, and one at the restriction. Because of the large pressure loss across these devices, their high cost, inability to accurately measure at low flows, and sensitivity of instrumentation, they are almost never found on field turnouts.

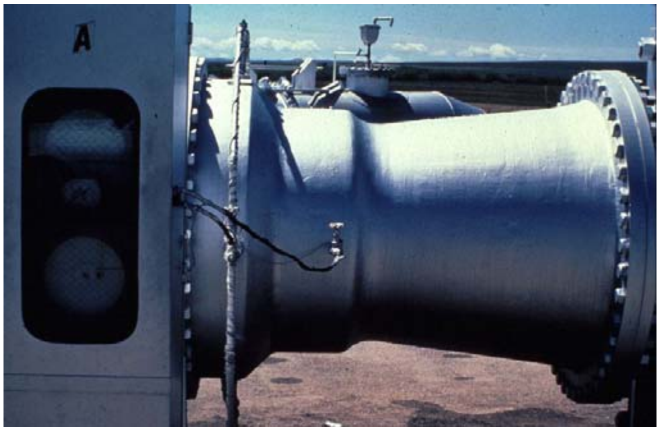

Figure 11. Large, old venturi and instrumentation at Berrenda Mesa WD pumping plant

Insert meters of any type. There are many types of "insert meters" – including small paddle wheels and mag meters. They are relatively inexpensive because they can be inserted into a tapped hole on a pipeline. But, because of their small sample area, they are extremely sensitive to poor entrance/exit conditions. Furthermore, they tend to accumulate trash (because they stick into the flow) or sometimes have cheap bearings that seize up and stop rotating. Many have been tried in irrigation districts; I am not aware of any large successful, sustained usage of them on turnouts.

Figure 12. Three models of paddle wheel flow meters. Courtesy Seametrics.

Flow Measurement – Canal to Open Ditch or to a Pipeline

This is where the biggest challenge lies in California. I won't try to cover every condition, as there are numerous special cases. Instead, I will focus on the main solutions that are available.

Physical configurations. There are several points to consider:

1. Many, but not all, canal turnouts have a pipeline under an access road between the canal and the field. If the pipeline can be kept full (and not fill up with trash and silt) during deliveries, a special type of propeller meter can be used.

Figure 13. Propeller meter in a typical installation, facing upstream into a full pipe

2. In general, constructing something on the field side of the pipeline is problematic. It gets in the way of tractors. The districts do not have authority to do any construction on farm property.
3. Anything constructed on the canal side must not interfere with canal maintenance operations (which can be somewhat brutal on equipment).
4. New equipment should not stick up too high, or it will be knocked off by vehicles traveling down the access road.

Calibrated slide gates. The simplest version is found in districts such as Imperial Irrigation District, which uses a rectangular gate for on/off, flow regulation, and measurement. It is open on both sides. The gate position and water level drop across the gate are measured, and then a formula or table is used to compute the flow rate. There are challenges with maintaining either continuous back pressure, or no back pressure, on the downstream side of the gate. A different formula must be used in those two hydraulic conditions, and it can be confusing for operators at some turnouts.

Figure 14. Imperial Irrigation District turnout. The gate opening and difference in head are measured for a known size of gate. The blue slip of paper in the hole near the top is left behind by the zanjero (operator) to let the farmer know the measurements and flow rate.

Metergate. The metergate was depicted earlier in a drawing from an old Armco gate measurement book. These are very popular in California, on perhaps 30% of the turnouts in one form or another. They function the same as the IID gate, except for three differences:

1. They must always have a submerged downstream condition.
2. They are placed directly against a pipeline on the downstream side, so the water level measurement must be taken at a specific distance downstream, using a stilling well that is tapped into the top of the pipe.
3. The gates themselves are circular.

Figure 15. A classic metergate installation. The two round holes are stilling wells to measure the water level in the canal, and downstream of the gate. The gate is in the closed position in this photo (the stem is down).

Constant Head Orifice (CHO). This is another variation of the IID-style turnout. To avoid having the hydraulic condition change from submerged to free-flow on the downstream side of a fixed orifice, a second gate is installed. The second gate is used to turn on/off, and to adjust the flow while also keeping the downstream side of the first orifice flooded. The first orifice is usually adjusted once to make sure that everything works out as intended. Alta ID has a variation of this type of device.

Figure 16. CHO at Alta ID. The orifice (on the canal, upstream side) is a standardized rectangle with an adjustable, bolt-secured opening. The downstream gate with the round handle is used to adjust the flow rate to the target.

Weirs and flumes. Some districts have attempted to use weirs or flumes downstream of the on/off and flow adjusting gate. These can work very well if there is a large elevation drop between the field and the canal. But the remaining challenging installations are usually found in flat topography, and in general flumes and weirs are not recommended because they become flooded (they are highly dependent on downstream hydraulic conditions) in flat ground. These were very popular in the inter-mountain West on old USBR projects because there was often a lot of elevation gain.

Figure 17. On-farm flume with maintenance issues, installed in a slip-form canal

Weirs and flumes, of course, are not suitable for sprinklers and drip where the flow rates continually change and, by definition, the water must always back up to the source to provide flexibility. Installing weirs and flumes may meet temporary needs, but will be inadequate if the on-farm irrigation system is modernized. This pertains to fixed or adjustable weirs and flumes.

Vane meters. These were an interesting concept. The idea was that a pivoted shank, having a special triangular-type shape, was stuck into the water and the faster and deeper the flow, the more it would tilt. Therefore, by measuring the tilt one would know the flow. However, they only sampled a small section of the flow rate, were very sensitive to balance, and were susceptible to wind distortion. They are found in literature but not in the field. I saw one many years ago (abandoned) in Glenn Colusa ID. Several of us have looked at them over the years, but always discard the notion.

Bottom Line

Almost any standard device, whether a propeller meter, weir, flume, metergate, calibrated sluice gate, mag meter, etc. can provide volumetric measurement within 6% if it is:

- STANDARD,
- installed in conditions that match its calibration conditions,
- measured properly, and
- properly maintained

The specific device that is "best" for a situation will depend on numerous factors such as the size of the flow rate, the amounts and types of dirt in the water, the physical room available for installation, potential for theft (especially batteries and solar panels), susceptibility to being used as shooting targets, the ability to maintain a steady upstream pressure or canal water level, and obviously the initial and annual costs. Furthermore, some devices that are being promoted simply do not have a long track record of success, and are sometimes very complicated to understand and maintain. To complicate matters, spare parts may not be available. Therefore, districts are wise to be very deliberate about selecting the best option for their individual cases.