WEED-RESISTANT PROPELLER-METER SYSTEM

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ABSTRACT

Seeking a flow measuring method that could exploit the usual farm delivery pipe placed under the canal roads common to irrigation canal systems, tolerate trash and weeds, and offer low maintenance and operating costs, we quickly discarded high-tech, high-cost meters in favor of modifying a reverse propeller meter system that had previously fouled in its original presentation. The modifications successfully handled weed and moss fouling while preserving the basic accuracy of the original meter system. The modified system uses specially configured trash-resistant appurtenances enabling operation in heavy moss and weeds environments, and flow profile conditioning accessories, that are also trash resistant, to condition flow jets from an upstream control gate and preserve meter accuracy. The system has operated in an active farm installation through several irrigation events since September 2011. It provides electronic output for data recording, transmission, or mechanized irrigation control. The system functioned successfully in adverse weed and moss conditions while maintaining its basic accuracy of +/-2% to 3%.

INTRODUCTION

The California Water Conservation Act (Senate Bill SBx7-7) was passed in 2009. The Farm Irrigation portion of the law requested Water Districts to supply to the State their long range plans to meter the volumetric flows into the Farm turnouts. The plans should provide to California documentation that they would implement suitable physical measures to record the annual volumes of water that they bill to the Farmers. Few reliable, accurate and economical commercial systems can easily accomplish the requirements of the law.

Our recommended metering criteria strive to be *(1)* accurate, *(2)* economical and *(3)* convenient.

As mentioned, the State requirements are to record the total annual delivery to each water user in the designated irrigation-delivery entities. However, discussions with several potential users prompted us to seek solutions that allow the recording of the basic annual deliveries plus an instantaneous flow rate reading observable to a gate operator for manually setting a flow rate, and to the farm operator for their irrigation management. Additional features could include upgrades to allow remote data transmission and storage, ability to add local constant flow-rate control to the delivery, or remote supervisory control to adjust the delivery rate, and the eventual ability to automate the entire system.

Therefore, any basic water measurement system should, at least, be battery powered, reliable (ability to turn on after a break in the irrigation cycle), economical, readily serviced by the water user, or delivery-authority personnel, and able to handle a variety of water-borne trash, weeds and grass.

GENERAL FLOW METERING OBJECTIVES

Flow Meters, a Brief Overview: Flow measuring systems consist of two main components. These are a *primary device* that interacts with the fluid in some way so that a *secondary device* can provide readout of some sort.

We considered these primary and secondary elements in our quest for metering systems to meet our selected criteria of being *(1)* accurate, *(2)* economical and *(3)* convenient. Of the many flow measuring systems examined, usually two of the three criteria could be readily obtained. However satisfying all three was more challenging.

Economics: Economics restricted many of the newer high-tech systems, such as those involving ultrasonic properties. Unfortunately high head loss is associated with orifice meters. Venturi meters, while able to pass debris and produce small head loss, share rather complex readout problems with the orifice meters. Both commonly use pressure differentials that usually require expensive equipment or special maintenance attention that may not be appropriate without the technical support of an industrial environment. These solutions are most commonly available in expensive set-ups marketed for high-pressure, industrial applications.

Convenience: The convenience of a flow measurement includes the maintenance as well as the ease of obtaining the desired result. Consideration of maintenance for some systems includes replacement parts and ease of repair and clogging-problem resolution. Some systems have the uncertainty of reading, such as the need to average many readings to achieve the promised accuracy. In addition, the effort needed to condition the reading for digital storage or transmission is an important consideration. For example, a vehicle driver while passing a meter station may readily observe a flume or weir scale attached to a canal sidewall, but totalizing a long-term delivery becomes more complicated.

SORTING AMONG ALTERNATIVES

We examined many commercially offered systems in terms of these criteria of *(a)* accuracy, *(a)* economics, and *(c)* convenience.

Ultrasonic and sonic types met the convenience and accuracy criteria, but current pricing seems prohibitive for farm turnouts required to report their deliveries.

Venturi meters, as previously mentioned, while trash tolerant; require readout systems that are questionably unreliable and inconvenient to maintain outside of an industrial plant or sewerage system facility. Orifice meters add to the Venturi meter problems by requiring significant head loss.

Flumes and weirs are sufficiently accurate and can usually be economical to construct and install. They are useful for occasional flow-rate readings. Continual site visits for visual readings or equipment for accumulating annual flows can become expensive.

Standard propeller meter-installations work reliably in most ground-water pumping applications, but quickly foul in most canal flows because weeds, moss, and grass build up on the propeller. Sometimes portable units are inserted for a spot reading and withdrawn after a short period to clear or avoid fouling problems. They are not convenient to use and cannot readily provide total-volume delivery.

Summarizing, the challenge was to find an existing commercial offering, or develop a new system that could provide a convenient, accurate and economical method of obtaining a signal. This signal would then be used to accumulate the annual volume, simultaneously indicate instantaneous flow rate, and offer gate-opening control for constant delivery, or even be capable of upgrading to transmit data to a headquarters environment for discharge-rate control or automation.

After sorting through most of the previously mentioned flow measuring methodology, and failing to find a suitable offering, we sought to modify existing methodology to satisfy the requirements. We desired an electronic output to manipulate for data storage, readout, and possible flow control. This new system should be able to accommodate a variety of delivery-flow rates.

THE SELECTION TO BE DEVELOPED OR MODIFIED

Proposed System Selection: We first reviewed the basic systems described above to determine which would best fit all three criteria: flows through an orifice, flows over a weir or flume, flows measured using ultrasonics or Doppler technology or flows through a pipe. We determined that the most accurate, economical and convenient system to develop would be one using a propeller flow meter in an inexpensive plastic pipe. This system would be installed in the District's farm delivery pipe running through the canal bank, or connected to the delivery pipe and laid in the farm ditch or farm field.

We investigated a promising, but old, commercial system, used in Texas and Nebraska for many years, manufactured by the former Great Plaines Meters Company. The promising selection was a so-called "reverse" propeller meter. The Company had introduced the reverse-propeller meter to agricultural-water delivery systems that were primarily limited to wells, and some open canal systems. The product is currently owned and manufactured by McCrometer, Inc.[a] This system suspends the propeller from the front, or nose, by a sloping pipe intended to encourage floating weeds and grass to slide down and pass below the propeller blades. This is usually successful with grass and weeds that are less than about half meter long. The original reverse propeller meters used a flexible cable from the propeller that snaked through the propeller suspension pipe to display flow rate and record total volume delivery in the meter head. While this version is still available, a more recent configuration uses an electronic pick-up of the rotating propeller. This system allows more flexibility in usable pipe sizes that can be fitted with the meter.

[a] McCrometer Inc, 3255 WEST Stetson Avenue, Hemet Ca 92545

This newer version can be equipped to totalize flow and to transmit, or store, various data functions. It can operate from a standard AC power source or configured to operate using a 5-year life lithium battery.

This meter, if it could work in severe environments would fulfill our desire to provide a relatively economical electronic output that could be manipulated for instantaneous and accumulative flow records as well as fit many pipe sizes. The signal could be transmitted to headquarters for supervisory control or automation. Thus, this meter, as the heart of this pipe system could offer basic compliance and economical upgrades to an originally installed system.

SYSTEM DESCRIPTION

Flow Conditioning and Weed shedding: The conventional wisdom was that propeller meters are severely challenged by the vegetative growth that occurs in open channel flow canal systems similar to that of the Imperial Irrigation District (IID). In fact, most, if not all of the canal water engineers we interviewed suspected that even the reverse propeller system would not function and would be fouled, although we did not find those with first-hand experience of such.

Many of the farm irrigation water-delivery systems in the California irrigation districts deliver water through the canal banks, and frequently under a canal service road, in a pipe. The pipes are usually 6m (20-feet) to 12m (40-feet) long. The opening and closing of a pipe entry head gate, or sluice gate, usually controls the water delivery rate. This partly open sluice gate produces a strong jet at the pipe bottom that greatly affects most efforts to sense an average velocity in the available length of pipe.

Another difficulty to consider in obtaining an accurate flow measurement with propeller meters involves flow spin in the delivery pipe, which can cause over-spin or under-spin of the propeller for a given throughput of water. Thus, we must prevent *a)* velocity-profile distortion, *b)* flow-spin, and *c)* weed clogging, for a propeller meter to operate properly.

We first directed our initial attention to conditioning the flow, beginning with the jet, to form a uniform velocity profile across the pipe suitable for the propeller meter to function. We introduced special flow conditioning measures between the entrance gate and the propeller meter that controlled both the swirling and the jet, to produce the desired uniform-flow profile for the propeller, or for most any sensor, to detect velocity. This system could be installed in most locations where the farm deliveries were through a pipe under the canal road or through the canal bank. The ability to use the existing control gate at the delivery site is a low-cost measure and does not require changing the basic system to add any additional measuring elements.

Figure 1 shows the flow-conditioning parts of the system. Starting from the pipe entrance behind the sluice inlet gate, there is a weir blade on the pipe bottom. It is about ¼-pipe diameter high and about two diameters downstream from the inlet gate. It acts as a “jet spoiler” and tends to distribute the jet velocities randomly across the pipe diameter before it reaches the first of two 90%-open-area orifices that directs wall jets to mix with the center flows. The first orifice is about another two diameters from the weir blade. A second similar orifice is located about 6-diameters farther downstream, with three or more anti-spin vanes that have 3:1 slopes for weed shedding accompanying this orifice. They resemble "shark fins" with a downstream rectangular extension, and a total length depending on the number of fins used. The fins extend about ¼-pipe diameter into the flow. The propeller meter is located about seven diameters downstream from this last orifice and fin system. The required weir blade and the orifice spacing were estimated, as was the distance to the propeller.

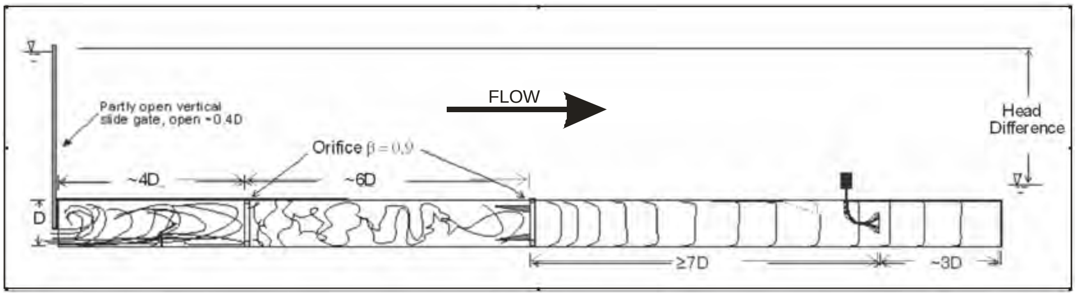

Figure 1. General Layout of initial system..

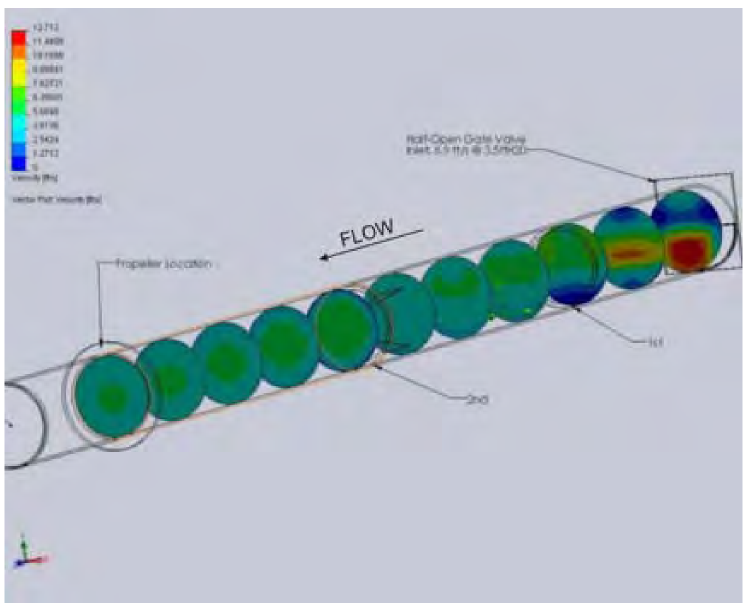

Figure 2. Results of Computational Fluid Dynamics Study.

Micrometer, Inc.[a] commissioned a Computer Fluid Dynamics (CFD) study to evaluate these flow conditioning offerings. The results of the study are shown in Figure 2.

Our mutual conclusion was that the system should function as hoped, but did not provide information on optimal sizes and locations of elements.

FIELD TEST OF INITIAL SYSTEM

History of Problems. We installed the above described reverse propeller metering system, into an available steel pipe 610 mm (24-inch) inside diameter (rather than the recommended plastic pipe), at a location in the Imperial Irrigation District, California.

To field calibrate this system we used a portable long-throated flume installed in the farm canal which matched the set flow rate to within about 2% at a flow of about 0.3 m^3/s (11 cfs). This flow rate is about 50% of full scale for this meter, but near the top of the range for this location that was limited by the head difference between delivery canal and field ditch.

To give a quick test of the installed reverse meter, we tried to pass some plastic grocery bags through the system. The propeller immediately slowed down and we had to stop the irrigation and remove the bags from the meter blades. After the grocery-bag problem, the meter operated for several hours then began to drop reading even though the farm ditch appeared to flow unchanged. We suspected that the meter was fouling with moss and weeds. We confirmed this when the meter was removed at the end of the irrigation event, Figure 3. This fouling continued with another irrigation, Figure 4, strongly confirming the general local warnings that even the reverse meter would likely clog with the native moss and weeds. When the meter was pulled out of the pipe, it had vegetative material wound tightly around the meter shaft.

Figure 3. Moss and weed vegetation that fouled the unmodified reverse propeller metering system.

Development of Trash Protection. We subsequently developed a successful weed handling methodology to improve the reliability of the reverse propeller meter, which we describe below along with field-operation results. We installed this system on September 2, 2011, and used it for the irrigations in September and October, 2011.

Figure 4. Confirming that the unmodified reverse propeller metering system again clogged.

Weed-Shedding Features. Even though the flow conditioning vanes and orifices, themselves, can readily pass most grass, moss, and weeds, the propeller required further protection from particularly long vegetative filaments, Figure 4.

At this point, we installed the methods of diverting the long vegetative filaments past the propeller blades similar to that shown in Figure 5. The diverting system consisted of another vane system, not to be confused with the flow-conditioning vanes previously described in Figure 1. This system consisted of a "shark fin" suspended from the pipe top, sloping at three units horizontal to one vertical, in the downstream direction. The vane needed to be longer than most or all of the vegetative strings, and be able to slide the strings below the propeller. For the IID installation, which used a pipe diameter of about *D*= 0.61 m (24-inches), the length of this large vane should be greater than 1.5 times the pipe diameter (*D*) and hang from the pipe top with a dimension of half the pipe diameter plus half the propeller blade diameter, *d*, in this vertical direction. The propeller diameter for this site is *d*=250 mm (10 inches). Figure 5 illustrates the relationship of the various flow conditioning and weed vane appurtenances.

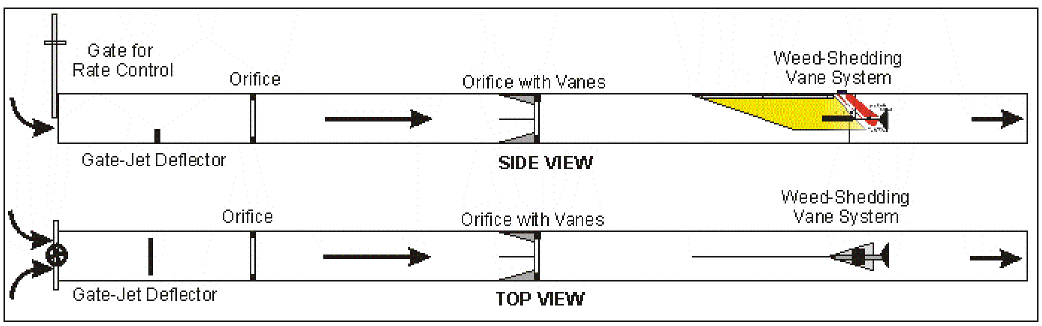

Figure 5. Flow conditioning vanes and weed vanes.

We designed the system considering several flow and weed situations. Imagine a vegetative string partly straddling and sliding down this vertical slide. As it descends, its downstream end can encounter the propeller. The resulting entanglement can stop the propeller. We handled this scenario by attaching two more side vanes on the large vane that align with the propeller axis. A sliding filament will then encounter the side vanes and be forced to the side, thwarting the opportunity to entangle with the propeller. There still is the unlikely chance of a long, straight string gliding near the vane and parallel to the vane and just above or below the side vanes, without encountering either. This strand would arrive at the propeller but would likely be rejected by the reverse propeller blades because of the straightness of the strand that allowed it to get there in the first place.

These vanes should further align the flow and reduce flow rotation that would affect the propeller readout. We offer a caution on the design of the side vanes. They are half the propeller diameter (*d*) in the side direction for the described situation, and with a 3:1 slope, would be 3/2*d* long. These smaller side vanes are attached to the large-vane near the propeller end of the vane. In no case should the upstream end of the side vanes coincide with the sloping edge of the large vane. If the side vanes did coincide here, this would create a "wedging" configuration that could trap the vegetative strings.

System Experience: We used the new system on several irrigation events starting on September 8, 2011. Figure 6 is the delivery recorded by the propeller meter. The canal operator (Zanjero) had set an estimated flow rate of 10.9 cfs (309 L/s) based on the gate opening and the upstream and downstream water levels through the sluice gate that was upstream of the meter. The uncertainty associated with this determination is unknown. The propeller meter reading was 10.5 cfs (297 L/s). Because of the small elevation difference between the delivery canal and the farm ditch, the flow rate is sensitive to both canal-level changes and farm-operator influences, such as changing field delivery points causing the farm-ditch level change. Some of the several flow-rate changes are due to these farm ditch changes and to head-gate adjustments by the Zanjero during the delivery. This also illustrates the value of using a totalizing record and the hazards of only "spot checking" during a delivery event.

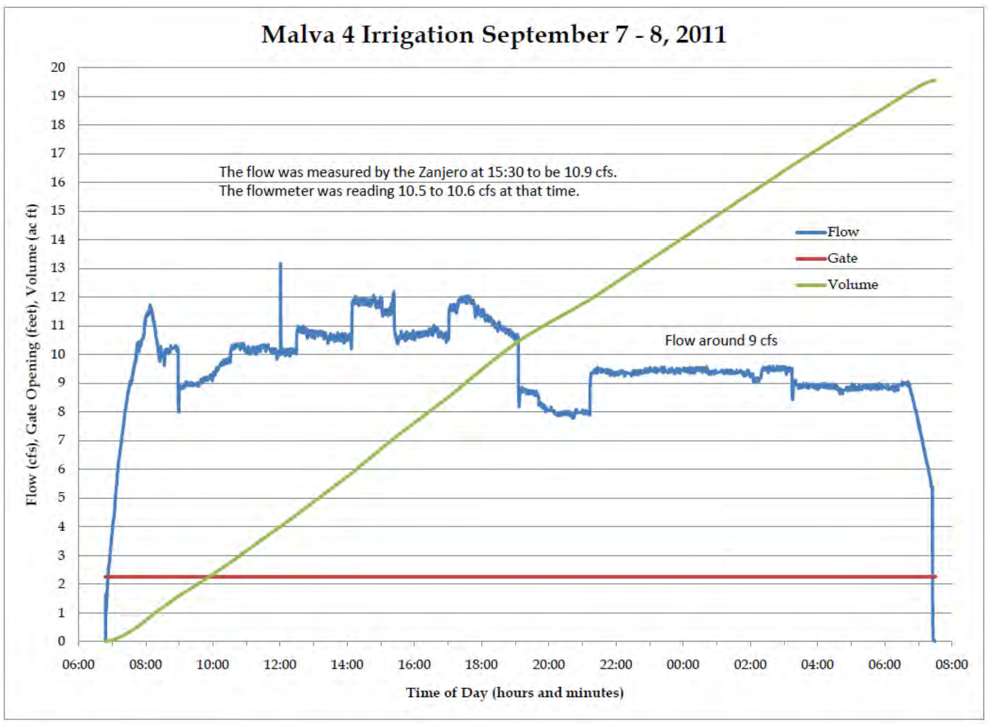

Figure 6. Record of irrigation delivery, September 7-8, 2011.

When the meter was removed (Figure 7,) some vegetation came out with the meter. It was draped over the propeller blades and was not wound about the propeller shaft. It was most probably suspended in the pipe flow when the flow halted, and not involved with the meter performance during the irrigation. The small blade attached to this meter in Figure 7and 8 was left over from a failed previous test and is not required with the current recommended long-vane system.

After another irrigation delivery on September 26-27, 2011 the meter was clean, Figure 8.

Figure 7. Vegetation is not wound onto meter shaft, so likely was suspended in pipe at shut-off and caught at meter removal. (September 8, 2011).

The next irrigation on September 26-27 also competed a 24-hour delivery without clogging, Figure 8.

For the October 8-9, and the October 25-26, 2011 irrigation deliveries, the weed protection system again worked well, Figures 9 and 10.

Figure 8. Propeller meter shows no weed fouling after a 24-hour run, using the propeller protection system, September 26-27, 2011.

During one of the last four irrigations, we again introduced several plastic grocery bags of the type that had crippled the original installation and the system handled them without incident.

Figure 9. No weed fouling after a 24 hour run, October 8-9, 2011.

Figure 10. No weed fouling after a 24 hour run, October 25-26, 2011.

CONCLUSIONS

We examined many commercially offered systems in terms of accuracy, economics, and convenience. A measurement system using a commercially available, reverse-propeller meter equipped with several of our developed appurtenances provided many features satisfying these criteria for accuracy, convenience and economics.

The developed metering system was tested successfully using four 24-hour long deliveries in the late summer and fall of 2011 in the weedy situation of the Imperial Valley Irrigation District, California.

ACKNOWLEDGEMENTS

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