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In This Issue . . .

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For further information about the
Water Operation and Maintenance Bulletin, contact:

Ben Claggett, Managing Editor
Bureau of Reclamation
Technical Service Center (86-68260)
PO Box 25007, Denver, CO 80225-0007
Email: bclaggett@usbr.gov

***Cover photograph*:** Mohave Valley Irrigation and Drainage District pipe-fitting Venturi meter demonstration site.

Water Operation and Maintenance Bulletin

No. 236 – June 2014

CONTENTS

Page

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VENTURI METERS CONSTRUCTED WITH PIPE FITTINGS: AN UNDER-APPRECIATED OPTION FOR MEASURING AGRICULTURAL WATER

by: Tom Gill,[1] Brian Wahlin,[2] and John Replogle[3]

Abstract

Increasing competition for limited water supplies, improved technology for managing water delivery systems, and a growing importance in being able to document use of water supplies are all factors driving interest in establishing the capability to measure flow at an expanded number of locations in agricultural water delivery systems. Pipe Venturi meters are widely recognized as a measurement technology in piped systems offering a high degree of accuracy while imposing comparatively small head loss. Researchers at the Agricultural Research Service have documented their efforts in using off-the-shelf polyvinyl chloride (PVC) fittings to produce "constructed Venturi meters" as a low-cost option for measuring water in agricultural systems. These devices can achieve an accuracy on the order of ±2% for a cost of about $180.

Despite many attractive attributes of this flow measurement concept, this technology has seen a limited degree of adoption. This paper examines field installations where constructed Venturi meters have been used to measure flows over a range of magnitudes and under a variety of data collection methodologies using a case study format. Guidelines for construction and installation are also presented.

Introduction

Replogle and Wahlin (1994) introduced the idea of creating low head loss Venturi meters constructed from plastic pipe fittings. True Venturi meters do not have stagnant zones, are more tolerant of upstream conditions, have lower head loss, avoid fouling problems, and are more accurate than most others meters. However, true Venturi meters are quite pricey and are typically beyond the means of most irrigation districts. The plastic pipe-fitting Venturi meters suggested by Replogle and Wahlin (1994) avoid the issue of high cost while maintaining the other benefits associated with Venturi meters. The original paper described

[1] Hydraulic Engineer, Bureau of Reclamation, Hydraulic Investigations and Laboratory Services Group, PO Box 25007, Denver, CO 80225, tgill@usbr.gov

[2] Senior Hydraulic Engineer, WEST Consultants, Inc., 8950 S. 52nd Street, Suite 210, Tempe, AZ 85284, bwahlin@westconsultants.com

[3] Retired.

experiments in which 15 Venturi-type meters were constructed using plastic pipe fittings that had symmetrical configurations (i.e., similar converging and diverging cones). By reversing flow through the meters, 30 configurations were available to assess the construction capability to make appropriate piezometer taps that responded the same to flow in either direction. With the 30 Venturi meters, an attempt was made to evaluate the statistical variability due to construction techniques and manufacturing differences in commercially available plastic pipe fittings. The results of the experiments indicated that the Venturi meters could be constructed for about $180 and could be constructed in about 2 hours. Using a standardized rating curve developed as part of the experiments, the accuracy of these meters is approximately ±2%, not including the errors associated with the readout method.

Theory

Venturi meters represent one of the oldest and most reliable of the differential head meters. These devices are well defined in the literature and little new information is available (see American Society of Mechanical Engineers [ASME] [1971] and Brater et al. [1996] for a more complete treatment). Certain angles of convergence and divergence must be observed for standard Venturi meter behavior. The conduit walls should converge at about 20° and diverge on the downstream side at about 5 to 7°. The approach piping requirements are similar to those for orifices; however, they can be relaxed somewhat with few detrimental effects. A frequently used Venturi meter is the Herschel-type Venturi tube. It has a converging cone of 21° ± 1° and a diverging cone of 7 to 8° (see figure 1). The throat length of these meters is equal to the throat diameter. This is considered by many users to be the "standard" or "classical" Venturi meter. The angle of the diverging cone does not influence the calibration coefficient, but it does have an effect on the overall head loss through the tube. Commercially produced Venturi meters claim a primary device accuracy of ±0.5% (ASME, 1971).

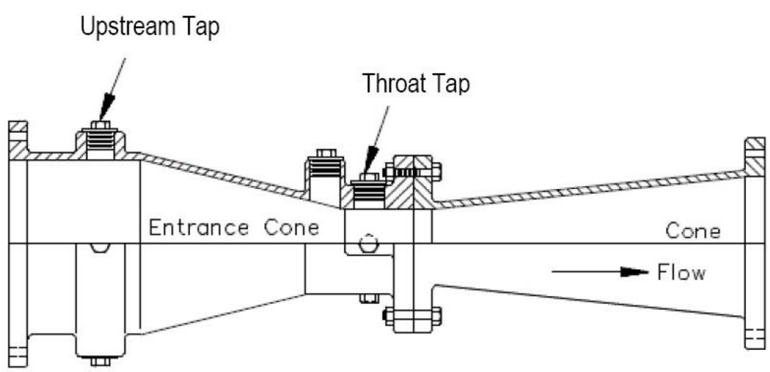

Figure 1.—Schematic diagram of a standard Venturi meter.

The basic expression for discharge, Q, is derived from the classical Bernoulli Equation and can be written in a form that is applicable to round pipes or other conduit shapes as:

$$Q = C_d \frac{A_p A_t}{\sqrt{A_p^2 - A_t^2}} \sqrt{\frac{2g}{\alpha} \left(h_p - h_t\right)}$$

where:

C_d	=	Discharge coefficient (typically between 0.96 and 0.99 for standard Venturi meters)
A_p	=	Area of approach piping
A_t	=	Area of contracted throat section
g	=	Gravitational constant
α	=	Velocity distribution coefficient (assumed to be 1.02)
h_p	=	Upstream pressure tap reading
h_t	=	Throat pressure tap reading

Experimental Setup

A schematic diagram of the plastic pipe Venturi meter is shown in figure 2. These devices were constructed using commercially available PVC pipe and fittings. The total construction cost is about $180 U.S. (2010) for the materials plus the cost of about 2 hours of labor. Once the meters were constructed, they were calibrated using a weigh-tank-and-timer system that is accurate to about ±0.1%. Initially, three Venturi meters were constructed with different throat lengths to determine the optimal throat length. In addition, there were two types of converging fittings that were tested: one with 15° contraction and one with a 25° contraction. The need for multiple pressure taps around the throat section was assessed by installing four pressure taps at 90° intervals around the center of the throat section. These taps were hydraulically connected for one series of tests in order to give an average pressure reading for the group. Next, they were grouped into two opposite pairs, and, finally, they were separated and read individually. Once the throat length and pressure tap locations were determined, 12 more meters were constructed and calibrated. All the meters then had the flow direction reversed and were calibrated again. Thus, the 30 unique calibrations obtained from the various Venturi meters were used to determine the scatter of calibration for these plastic devices.

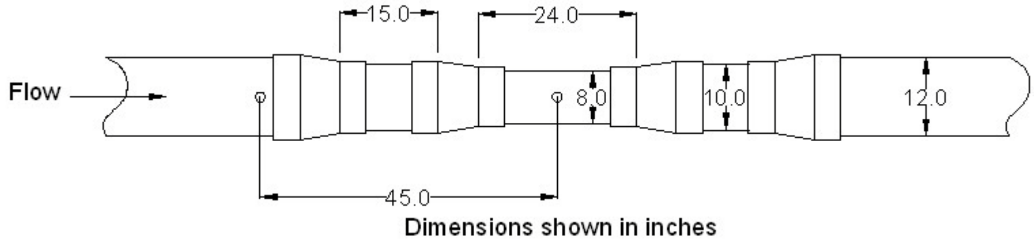

Figure 2.—Schematic diagram of plastic fitting Venturi meter.

Experimental Results and Manufacturing Recommendations

Plastic pipe fittings of the kind usually used by the irrigation industry can be fashioned into suitable Venturi meters with an expected accuracy of ±2%, not including the errors of the readout method. The discharge coefficient for the plastic fitting Venturi meter is given by:

$$C_d = 0.964 - 0.0466e\left(\frac{-R_n}{254{,}000}\right)$$

where C_d is the discharge coefficient and R_n is the Reynolds Number based on pipe diameter. The experimental discharge coefficients for the plastic pipe Venturi meters ranged from about 0.92 to 0.96, slightly less than the discharge coefficients for true Venturi meters. Other conclusions from Replogle and Wahlin (1994) include:

- It is recommended that a throat length of three times the throat diameter be used for plastic Venturi meter construction. Shorter throat lengths appear to cause difficulties in pressure detection due to flow separation. Longer throat lengths produce excessive head loss.

- The rate of contraction of the reducer fittings (i.e., 15° versus 25°) caused no significant change in C_d and, thus, the meter calibration. However, the fittings with the 25° contraction rate exhibited a greater total head loss through the meter than those with the less severe 15° contraction rate.

- The most important construction factor is the fabrication of the pressure taps and the immediate connections. They should be drilled with appropriate backing blocks to reduce burrs and with a guide to assure that they are constructed perpendicular to the pipe wall. It is recommended that the pressure taps be installed on the sides of the meter to prevent air bubbles from entering the pressure lines. It is not necessary that the pressure taps be on the same horizontal line, and the meter can be mounted at any angle.

- Slow-setting PVC cement should be used to allow workers sufficient time to uniformly assemble and adjust large pipe parts.

- The cost of pipeline parts is within the economic range of most irrigation applications (costs are about $180 U.S. [2010] for the pipe and fittings, plus about 2 hours of labor, per meter).

Field Installation Case Studies

Three field installation case studies are presented that show the versatility of pipe-fitting Venturi systems for measuring flow either as stand-alone low-tech installations or as part of an automated data collection network. The first two case studies presented document field demonstration projects that were established to examine performance over time in terms of reliability and long-term cost effectiveness. The third case study included is a brief discussion of a temporary measurement installation where a pipe-fitting Venturi was utilized to measure flow as part of an irrigation research project.

Pioneer Irrigation District

The Pioneer Irrigation District (PID) diverts flow from the North Fork Republican River in Yuma County, Colorado, and has historically delivered irrigation water to farmlands in extreme eastern Yuma County and in western Dundy County, Nebraska. During the 2003 and 2004 irrigation seasons, the Water Conservation Field Services Program of the Bureau of Reclamation's (Reclamation) Nebraska-Kansas Area Office arranged for engineers from Reclamation's Hydraulic Investigation and Laboratory Services group (HILS) in Denver, Colorado, to provide technical assistance to the PID in establishing flow measurement capability at each operating farm turnout.

Site-specific constraining conditions dictated the use of multiple flow measurement technologies in the project. The pipe-fitting Venturi system developed by Replogle and Wahlin (1994) was proposed to PID as a cost-effective measurement option that may be applicable for some of the PID turnouts. PID agreed to work with HILS engineers to set up a demonstration site using a pipe-fitting Venturi.

The site selected for the demonstration project featured a 12-inch pipe turnout from the PID canal. A pipe-fitting Venturi was constructed using PVC bell reducer fittings in a configuration similar to that shown in figure 2 to reduce from 12 to 10 inches and then from 10 to an 8-inch-diameter Venturi throat. Downstream from the throat, the pipe was expanded through two steps back to a 12-inch diameter using a mirror image configuration of the fittings used for the contraction. Metering taps were installed in the 12-inch pipe just upstream of the initial reducing fitting and at mid-length of the throat section. For the demonstration site, a third tap was installed in the downstream section after the pipe diameter was expanded back to 12 inches as a means of showing the head loss through the meter. Figure 3 shows the installation of the Venturi meter at the PID demonstration site.

Figure 3.—PID ditch rider Dennis Waggoner (l) and ditch superintendent Dan Korf (r) assisting with the May 2003 pipe-fitting Venturi demonstration site installation.

A specialized manometer board was fabricated for the PID demonstration site that featured a sliding scale. The scale was marked to show head differentials in feet and also to show the flow rate in gallons per minute (gpm) (the flow rate measurement units historically utilized by PID). To determine the flow rate or head differential, the sliding scale would be raised until the zero line on the scale was even with the height of water in the low pressure manometer tube linked to the throat tap. The flow rate and head differential could then be read as the values from the respective scales that lined up with the water level manometer linked to the higher pressure upstream section tap. A manometer tube attached to the downstream tap was installed on the manometer board adjacent to the upstream manometer tube. A comparison of water levels in the upstream and downstream tubes provided visual evidence of head loss experienced by flow passing through the Venturi meter. Figure 4 shows the manometer board at the PID demonstration site.

Figure 4.—PID demonstration pipe-fitting Venturi and manometer.

Flow conditions being measured in figure 4 show an approximate 800-gpm flow rate with a meter head loss of approximately 0.35 foot. The throat tap plumbing may be seen near the bottom of figure 4. A tee fitting at the tap is oriented such that a valve is installed in the branch of the tee oriented normal to the Venturi throat while the manometer line leaves the tee in a direction parallel to the throat. With this configuration, the valve on the end of the tee may be opened to allow insertion of a thin rod or wire to clean debris that may clog the pressure tap from time to time with this canal-fed system.

HILS engineers and PID staff agreed that the pipe-fitting Venturi meter demonstration showed that the technology is cost competitive, can provide suitable flow measurement accuracy, and imposes comparatively modest head requirements. The landowner whom this turnout served, however, could not be convinced that the 12- to 8-inch pipe size reduction was not severely limiting his ability to receive water from the canal. A short time after the Venturi demonstration site was set up, the landowner removed it and installed a suppressed rectangular weir, which required a water surface level drop in the range of 1 foot for nonsubmerged operation.

At the request of PID staff, the PVC Venturi meter was later reinstalled in 2004 at a different turnout. The new location was higher in the PID delivery system within the Colorado delivery area. Figure 5 shows the reinstalled Venturi.

Figure 5.—PVC Venturi meter and manometer installed at the second PID site.

At the second installation site, the PID canal outflow pipe previously discharged into a concrete-lined field canal. The Venturi meter had to be installed on top of the canal lining. The “dog leg” configuration of two 45° pipe bends that served to raise discharge to a suitable discharge height for the initial demonstration site shown in figure 4 was also utilized at this site to ensure pipe-full flow through the Venturi. There is sufficient head available at this site to maintain the normal delivery flow rate. As may be seen in figure 5, the fall from the “dog leg” represents a significantly greater head loss than the measured ~ 0.35-foot head loss through the Venturi meter discussed above.

Flow measurement with the PVC Venturi meter at the second PID site was also fated to a limited time of operation. Ramifications from a U.S. Supreme Court case on water usage in the Republican Basin involving Colorado, Nebraska, and Kansas has led Colorado Republican Basin well users to seek augmentation water to offset streamflow injury resulting from well operations. Beginning in 2008, the

Colorado irrigators on the PID system entered into a long-term lease for use of their share of PID water to an upstream well users group and, for the present, have discontinued their PID irrigation operations. It is unclear whether this turnout will again be in service.

Mohave Valley Irrigation District

The Mohave Valley Irrigation and Drainage District (MVIDD) lies in Arizona along the east bank of the Colorado River a short distance downstream from the southern tip of Nevada. All water utilized by the district is pumped from the shallow groundwater aquifer fed by the river and is administered as diversion from the Colorado River. MVIDD had encountered problems with a range of previously tried flow meter technologies due in a large part to high concentrations of iron oxide present in the pumped flows.

In 2008, the Water Conservation Field Services Program of Reclamation's Yuma Area Office (YAO) requested technical assistance from HILS to identify cost-effective flow measurement methods that could function reliably over time given the water quality issues present along with other site-specific constraints at MVIDD. An automated data collection system was also a desired capability for the flow measurement system capability. YAO and MVIDD agreed to set up a demonstration site configured with a pipe-fitting Venturi as a preliminary step in the design of a flow measurement system. Figure 6 shows the MVIDD demonstration site.

Figure 6.—MVIDD pipe-fitting Venturi meter demonstration site.

Interest in the pipe-fitting Venturi meter concept was based on comparatively low installation costs, lack of moving parts, and relatively low head requirements. Keeping pressure tap orifices unobstructed would be a concern given the water quality conditions at MVIDD. As a means of keeping tap orifices cleared, a prototype sensing system utilizing a bubbler sensor linked to a solenoid valve bank was configured. The operation of the bubbler and solenoid valves was controlled by a programmable remote terminal unit (RTU) that has onsite data logging capability along with a radio communications link to a base unit at the MVIDD office. The RTU, bubbler, and solenoid valve equipment may be seen in the electrical enclosure in the foreground of figure 6.

The MVIDD demonstration site differed from the Replogle-Wahlin design sketch shown in figure 2 in two key respects. First, the existing 12-inch pump discharge pipe was reduced by only one pipe size to 10 inches (as opposed to the double reduction to 8-inch pipe as shown in figure 2 and as employed with the PID Venturi meter). The demonstration site well motor is always operated at the same speed and produces a comparatively high discharge for the pipe size (~ 9 cubic feet per second). For the near-constant discharge at this site, a suitable pressure differential may be observed for appropriate measurement resolution with the single drop in pipe size.

The second design deviation was the absence of an expansion section back to the original 12-inch pipe size downstream from the Venturi meter. A downstream expansion can be a means of converting much of the increased dynamic (velocity) head seen in the reduced diameter pipe of the Venturi throat back to static (pressure) head. The lack of an expansion and associated increased discharge velocity results in an increased energy loss, but does not impact flow measurement. For limited-term operation as a field test, an expansion section was not initially installed at this site.

Measured discharge rate at the MVIDD demonstration site was compared against a flow measurement obtained using a stream gage technique with a Price type AA current meter in the downstream canal. Agreement between the Venturi measured flow and the stream gage measured flow were found to be within the accuracy limits of the stream gage measurement.

The MVIDD demonstration site has now been in operation for approximately 30 months. Over this period of operation, the bubbler-sensed Venturi has experienced no maintenance issues or interruptions in service. This technology appears to be suitable for maintaining flow measurement capability with the water quality problems present, which have proven problematic for multiple previously tested meter technologies at MVIDD. Following the initial 6 months of “field test” operations, a pipe expansion section was added to the Venturi meter at this site.

Palo Verde Irrigation District Deficit Irrigation Study

During 2008, a University of California Cooperative Extension Service field study to examine the impacts of deficit irrigation on alfalfa under the direction of Dr. Khaled Bali was being conducted at Palo Verde Irrigation District. As part of this study, a cost-effective means of measuring field runoff of irrigation water was needed. Dr. Bali contacted Mark Niblack, the Water Conservation Field Services Program Coordinator at Reclamation's Yuma Area Office, for assistance in measuring the field runoff flows.

Runoff from the test field is conveyed under a field road through a pipe culvert that discharges into a drain canal on the opposite side of the road. This culvert pipe entrance is several inches below the grade of the alfalfa field. An elevation survey of the culvert pipe revealed a slight upward slope of the pipe that would ensure pipe-full flow at the inlet any time water is being discharged into the drain. With pipe-full flow assured, a Venturi constructed of pipe fittings installed on the drain culvert inlet was suggested for measuring the irrigation runoff at this site.

Figures 7 and 8 show the pipe-fitting Venturi and solar-powered data logging system being installed to measure and record field runoff. A small solar charging system was set up to power a differential pressure transducer linked to a data logger at the site.

Figure 7.—Runoff measurement Venturi at Palo Verde Irrigation District.

Figure 8.—Installation of logging system at Palo Verde Irrigation District runoff Venturi.

Summary

Venturi meters constructed of pipe fittings can be a practical means of measuring flow with reliable accuracy for a range of applications. As presented in the field demonstration sites cited above, the technology can be configured as low-tech, stand-alone measurement sites based on reading water column elevations, or they may be readily incorporated into an automated data collection or supervisory control and data acquisition (SCADA) system. While the pipe-fitting Venturi meters are by definition a closed conduit measurement instrument, it may be feasible to install one in an intermediate closed conduit link in what is essentially an open channel conveyance system. For all applications, pipe-full flow must be ensured as flow passes through the Venturi section.

Increased head loss in the downstream expansion section may be measurably greater with a pipe-fitting Venturi than for an engineered Venturi. However, in comparison with numerous other commonly employed measurement structures in agricultural water systems, the pipe-fitting Venturi head losses are comparatively small. For water districts with in-house fabrication and installation capabilities, pipe-fitting Venturi meters can represent a cost-competitive measurement alternative in comparison to alternative flow measurement technologies, including commercially available Venturi products.

None of the demonstration site case studies presented covers a timespan that would approach a desired life expectancy for operation of a flow measurement system. Thus, assessment of long-term reliability and cost effectiveness would require some degree of extrapolation. Given the extremely basic functionality of Venturi meters, along with fact that the Venturi solution for measuring flow is an analytic (as opposed to a calibrated) relationship, expectations for an appealing life expectance should be quite high. Pipe-fitting Venturi meters are a technology that should be factored into the thinking of any water delivery entity seeking an economical means of expanding flow measurement capabilities.

Additional items of interest regarding use of Venturi meters that are not brought out in the case studies cited are worth noting: Venturi meters do not require horizontal installation. The static head components that may be measured as a water column at the respective upstream and throat cross sections represent a combination of pressure head and elevation head. For an installation where Venturi taps are not in the same horizontal plane, an increase (or decrease) in pressure heads (compared with a horizontal installation) is exactly offset by the differing elevation heads. Thus, the measured water columns for either case will be the same.

When manometers are used to measure Venturi static heads, the manometers do not necessarily need to be vented to atmospheric pressure. A manometer system may be constructed with the tops of both the upstream and Venturi throat manometer tubes plumbed together in a manner that allows an increase in air pressure or a vacuum pressure to be present above the water column surfaces. Adjusting the air pressure above the water surfaces with this manometer configuration allows the water columns to be read at a more convenient level than would be the case for manometers vented to the atmosphere.

Actual head loss through a Venturi meter is commonly quite small compared with opportunities for head recovery that might exist at a pipe exit. As an example, for the site shown in figure 6, the addition of pipe fittings to create an underwater discharge would enable a recovery of static head currently being lost that could easily represent an amount several times the head requirement presented by the Venturi meter.

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Affordable Self-Cleaning Trashrack
Irrigation Districts Can Now Build Their Own Self-Cleaning, Solar-Powered Trashrack

by Tom Gill[1] in collaboration with Tetsel Ditch Company, Merino, Colorado

Problem

Removing debris from water flowing in canals is an operational issue for virtually any open-channel conveyance system. Materials such as tree leaves and branches, tumbleweeds, aquatic plant matter, dead fish and animals, along with human-created trash are typically carried along with water flowing in a canal. Stationary trashracks are commonly installed to serve as a debris collection point, but these must be cleaned to prevent excessive head loss and/or overtopping of the upstream canal banks as the debris mat accumulates on the rack.

The accumulated debris must be removed manually or mechanically, manually at most trashrack sites. Under adverse conditions (i.e., windy weather or rapid growth of aquatic plants) a trashrack may require cleaning every few hours—or in extreme situations—multiple times per hour. Keeping a trashrack cleaned can tie up an irrigation district's staff time resources as they travel to, and spend time on, a site. Existing automated trashrack cleaning systems typically have significant power requirements and represent a level of investment that has only been feasible for high volume sites on large water delivery systems. Automated cleaning systems have not been an economically viable alternative for most irrigation water delivery systems.

Solution

Bureau of Reclamation (Reclamation) researchers have developed a trashrack system in which the rack bars themselves function as the cleaning mechanism. A self-cleaning prototype was constructed and tested in a laboratory flume. The prototype rack bars were constructed of ½-inch-wide by 3-inch-deep steel bars spaced 3 inches apart on center. The bars are oriented at a 3:1 (horizontal:vertical) slope with the canal invert sloping upward in the direction of flow. The upper edges of the bars were cut in a saw-toothed shape. Each bar is able to travel back and forth in the direction of the rack slope at a distance of approximately 1 foot.

[1] Principal investigator, hydraulic engineer, Hydraulic Investigations and Laboratory Services Group, Technical Service Center, 303-445-2201, tgill@usbr.gov

The bars are mechanically linked to synchronize the motion of every third bar. Three 12-volt DC gear motors power the motion of the bars. Each motor is linked to a shaft that passes under the upper end of the rack perpendicular to the bars. Sprockets mounted on the respective shafts are in line with every third bar and engage in sections of roller chain welded to the underside of the bars.

As a cleaning cycle is initiated, all bars are moved in unison toward the upper end of the rack. After this advance travel stroke, two thirds of the bars remain stationary while one third of the bars retract to the original position. Once the first group of bars has been retracted, a second group of bars retracts, and then the third group retracts. During each phase of the retraction, two of every three bars remain stationary. The saw-toothed shape of the bars tends to grip against the debris mat as it is being advanced, and the debris mat is held in place by stationary bars during the retraction. The saw-toothed shape also allows the retracting bars to slip back under the debris mat with minimal grip. Photograph 1 shows the prototype rack in the laboratory flume. Photograph 2 shows the shaft/sprocket drive mechanisms.

Photograph 1.—Saw-toothed edge rack bars.

Photograph 2.—Shaft/sprocket drive system.

Automation components include a programmable logic controller along with a water level sensing system capable of monitoring water levels upstream of, and downstream from, the trashrack. The system is programmed to perform a cleaning cycle once the level differential across the trashrack exceeds a target value.

Application

During 2012, the self-cleaning trashrack was tested in the laboratory. The first test used synthetic aquatic plants, followed by tests with sago pondweed, and then filamentous algae materials collected from field sites. Following laboratory testing, the prototype unit was installed at a site on the Tetsel Ditch delivery system in northeastern Colorado. Photograph 3 shows a mat of debris that has been transported off the upper end of the rack and deposited onto a holding deck at the Tetsel Ditch site.

Photograph 3.—Prototype trashrack installation and operation at the Tetsel Ditch site in northeastern Colorado.

The prototype unit was operated continuously in automated mode beginning in mid-June and continuing through the end of the 2013 irrigation season. For this small-scale site, accumulated debris is deposited on a holding deck. The ditch rider manually clears the deck on his daily rounds. The unit operates entirely on solar-charged 12-volt DC power.

Future Plans

The Reclamation research project teams are in discussions with the Angostura Irrigation District (Angostura) in southwestern South Dakota, along with the Dakota Area Office Water Conservation Field Services Program, to explore the possibility of installing a similar unit at Angostura's Cheyenne River inverted siphon entrance. Historical debris accumulation problems at this site are a key issue that led to development of the self-cleaning trashrack concept. With the solar-charged power configuration, this system can be suitable for sites where debris accumulation is a problem at almost any open channel location. The team estimates that total costs (including concrete placement) for a structure similar to the prototype unit (~3-foot-wide channel) will range from $20,000 to $30,000.

Bottom Line

This research project developed a self-cleaning, low-head, low-energy trashrack system that effectively removes debris from irrigation canal systems.

Better, Faster, Cheaper

This system can reduce time, labor, and money invested in canal maintenance. Head loss across the self-cleaning trashrack is reduced from the head loss associated with self-cleaning screen mechanisms. As this system is solar-powered, it can be installed in remote locations.

Quote:

"After seeing this device installed, I wondered how it worked. Now that I have seen it operate during a cleaning cycle, it is really a simple system that works well."

Herman Neiman
Ditchrider for the Tetsel Ditch Company

More information:
www.usbr.gov/research/projects/detail.cfm?id=3107

PROTECTING AN EXPOSED CONDUIT FROM ROCKFALL

by Jim Foster[5] and David E. Nelson[6]

Helena Valley Irrigation District near Helena, Montana, has an aboveground steel conduit that extends 475 feet from Canyon Ferry Dam to Helena Valley Pumping Plant. The 10-foot-diameter penstock with about ½-inch wall thickness is exposed to rockfall from an adjacent cliff of sedimentary rock (photos 1 and 2). The penstock and pumping plant were completed in 1958. The pumping plant was provided with rockfall protection during construction, but the penstock protection was not installed until 1961, in response to rockfall problems that were being experienced. Over the years, it is believed that the lumber penstock protection has absorbed hundreds of rock impacts.

In October 2005, the old lumber was removed, the penstock was cleaned and re-coated with an epoxy-type primer and paint, and new lumber and cables were installed. About a 50-foot length was covered with 11 rows of rough-cut 3-inch by 12-inch fir lumber treated with chromated copper arsenate. The lumber is held in place with ⅜-inch stainless steel cables, turnbuckles, and 3-inch by 2½-inch galvanized steel angle iron retainers welded onto the pipe. The lumber rests directly on the pipe coating. Because of inaccessibility, the lumber had to be winched into place. The crew cabled themselves off with safety belts while carrying and placing the lumber onto the penstock.

[5] Manager, Helena Valley Irrigation District, Helena, Montana.
[6] Engineer, regional office, Bureau of Reclamation, Billings, Montana [retired].

Photo 1.—Helena Valley penstock and the downstream face of Canyon Ferry Dam. The arrow shows the location of the timber penstock covering.

Photo 2.—Helena Valley penstock and adjacent cliff of sedimentary rock.

Photo 3.—Helena Valley penstock, showing the timber covering, cables, and supports.

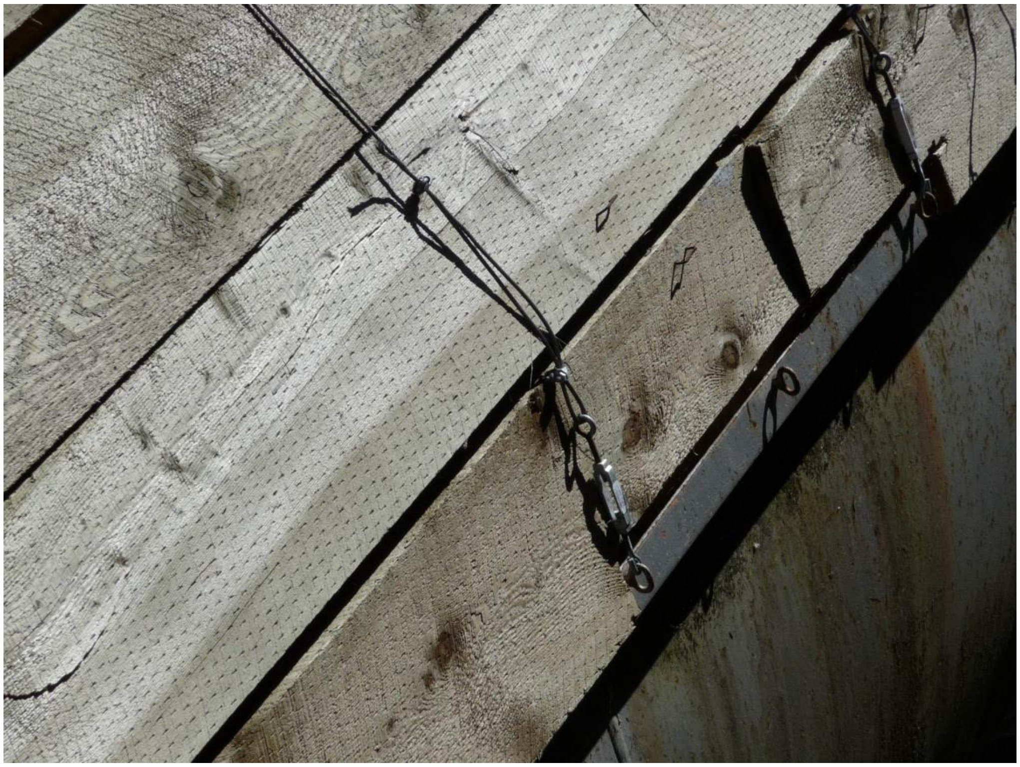

Photo 4.—Helena Valley penstock – closeup of a support. The planks are supported at each end.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Regional Bureau of Reclamation contacts are listed below:

Scott Boelman, Great Plains Region, email: sboelman@usbr.gov

Paul Caruso, Mid-Pacific Region, email: pcaruso@usbr.gov

James Dean, Pacific Northwest Region, email: jdean@usbr.gov

Scott Foster, Lower Colorado Region, email: sfoster@usbr.gov

Darrel Krause, Technical Service Center, email: dkrause@usbr.gov

Rick Scott, Upper Colorado Region, email: rscott@usbr.gov