RECLAMATION

Managing Water in the West

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Analysis of Selected Potential Water Conservation Technologies and Equipment

By Tom Gill

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

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MWD Agricultural Water Project

Analysis of Selected Non-Emitter-Uniformity
Water Conservation Measures

Background: The Water Conservation Field Services Program of Reclamation's Southern California Area Office (SCAO) is cooperating with Metropolitan Water District (MWD) in the implementation of an Irrigation Efficiency Incentive Program (Program). MWD has introduced the Program for agricultural water customers. SCAO has entered into agreement with Reclamation's Technical Service Center (TSC) in Denver, CO under which TSC staff will be providing technical assistance with program implementation.

The Program is structured to provide financial incentives for agricultural water users to purchase and install improved efficiency water application equipment. Most irrigation in the area is avocado groves along with a few vineyards, citrus trees and row crops. The existing irrigation systems are primarily drip systems with emitters near each plant/tree. Upgrading drip systems to achieve improved emitter uniformity resulting in reduced water application requirements has been identified by MWD staff as a type of system improvement that is being targeted in the Program.

In response to feedback from agricultural water users, MWD has requested that TSC perform an analysis of other selected technologies with respect to potential for these technologies to provide improved long-term irrigation efficiencies. The technologies specified for the analysis include catalytic water conditioners, hydraulically actuated valve systems, "smart" irrigation technologies, and micro sprinklers with a spinner on the emitter orifice.

Salt-less Water Conditioners: Dissolved minerals and salts in water can impact irrigation efficiency in multiple ways. Crust-like deposits from "hard" water agents like calcium and magnesium can accumulate on pipe walls and impact conveyance capacity or may clog nozzles or drip emitters. Dissolved salts may impact uptake of water by plant roots necessitating higher water application rates to meet plant evapotranspiration needs. Additional "leaching" flows are commonly required to transport salts down into the soil below the root zone.

Conventional or salt-type water "softeners" commonly used to eliminate spots left on dishware and to enhance the effectiveness of household soap and detergent products utilize an ion exchange resin system. Water to be softened is passed through a bed of resin pellets to which univalent ions (typically sodium (Na^+)) are initially attached. As water passes through the resin pellets, the univalent ions are replaced by bivalent calcium and magnesium (Ca^{2+} and Mg^{2+}) "hardness" ions.

To "rejuvenate" the ion exchange resin system, bivalent ions are periodically "flushed" from the resin pellets by passing a highly concentrated sodium chloride brine through the resin pellets in a process that replenishes the univalent sodium ions attached to the resin pellets. With this system, hardness agents are removed from the water at the cost of increasing salinity of treated water plus the cost of having generated "flush" flows containing high concentrations of the hardness bivalent ions that must be disposed of in some manner.

A number of "water conditioning" products are currently being marketed that do not utilize the ion displacement resin process. Two general categories of these "salt-less" systems for which manufacturer's purport benefits, including claims of improved irrigation performance, are magnetic water conditioners and catalytic water conditioners.

Magnetic Water Conditioners: Magnetic water conditioners provide a magnetic field through which water flows. The bullet list below is part of the promotional information downloaded from the website of Magna Clean Systems Inc., manufacturer of MCS Magnetic Fluid Conditioners:

The Effects on Water

*Imparts a charge to the water as it passes through the magnetic field
*Causes calcium to be retained in solution rather than plating on surfaces
*Reduces the odor and taste of sulfur in most cases
*Does not add anything to the water or take anything out
*Will enhance the operation and efficiency of water softeners
*Eliminates scale buildup
*Reduce the amount of chemicals needed in pools and spas
*WILL SAVE TIME, MONEY AND EFFORT IN MAINTAINING EQUIPMENT

Similar promotional claims may be found for the numerous other magnetic water conditioners. None of manufacturer-supplied information found in the literature provided any significant body of independently verified performance data from testing at either a university-based or a federal research facility.

A report was located from Lawrence Livermore National Laboratory (Krauter et.al. 1996) that documents testing done with a magnetic water conditioning marketed by Descal-A-Matic, a Norfolk, VA company. The following is the abstract from that report:

"A commercial device (Descal-A-Matic@, Norfolk, VA) designed to treat water by means of a magnetic field has been evaluated for its effect on the formation of calcite scale at LLNL Treatment Facility D. At this facility, volatile organic contaminants (VOCs) are removed by air stripping, which raises the water pH, causing the deposition of calcium carbonate as calcite scale downstream. To evaluate the magnetic treatment technique, the ground water was passed through the Descal-A-Matic@ device before treatment by the air stripping unit, and the resulting scale formation and other water characteristics were compared with those found during a test with no water treatment and a test with chemical treatment with a polyphosphate additive. No beneficial effect was found when using the magnetic device."

Catalytic Water Conditioners: As is the case with magnetic water conditioners, there are multiple devices being marketed as catalytic water conditioners. The promotional information supplied with the respective products suggests that targeted customers are primarily homeowners considering an alternative to ion exchange resin type water softeners. Some of the devices, including the EcoFlow (formerly also called Hydrochanger) marketed by Morril Industries LLC of Scottsdale AZ and the Australian-made Care-Free Water Conditioners, are purported to enhance suitability of water for irrigation.

Morril states the EcoFlow water conditioner "Improves soil percolation and eliminates standing water by breaking up hard-pan soil layers. Plants and grasses survive and thrive in soils that are mineralized and saltier than what could normally be tolerated." A similar claim from Care-Free states "The better 'wetting action' of conditioned water breaks up soil clods and improves soil texture . . . by surrounding individual soil particles with tiny droplets of conditioned water. Not only does your soil become more permeable but it is able to retain its moisture content for longer periods."

Tests conducted in 2008 and 2009 at the Center for Irrigation Technology (CIT) at California State University, Fresno were commissioned by Morril Industries to compare the unsaturated hydraulic conductivity in sandy loam soils of untreated water and water treated by an EcoFlow unit. A CIT report (Adhikari & Zoldoske, 2011) produced at the completion of the year-long 2009 testing states that at the outset of the testing, there was no statistical difference in measured infiltration rates for the treated and untreated plots at all tension rates, while at the end of the testing period, the treated plots showed a statistically significant increase in infiltration rates at tensions of 2 cm and at 6 cm however there was no statistical difference at the 0.5 cm tension rate.

During 2010 another study at CIT was commissioned by Morril Industries to evaluate the effect of EcoFlow treated water in regulated deficit irrigation on yield and sugar content of tomatoes grown in saline sodic soils. Tests were configured with field sections to be watered by either treated or untreated water. For the first 45 days, all sections were watered at the same rate. Beyond the initial 45 days, the treated plots received 15% less water than the untreated plots. A CIT report (Adhikari & Zoldolske, 2010) produced at the completion of this study stated that there was no statistically significant difference in either yield or sugar content, despite the 15% reduction of water after the first 45 days for the treated sections. Curiously, none of the untreated sections in this test were similarly subjected to the 15% reduction of water after the first 45 days to limit the comparison to a single variable (treated vs. untreated water).

A study conducted at Oklahoma State University's Turfgrass Research Center (Martin & Gazaway, 2003) funded by a grant from the United States Golf Association examined the effects of water treated through a Care-Free unit on Tifway hybrid Bermuda grass. Comparisons were made based on visual quality inspections, dry matter production of grass clippings and water use efficiency. The authors concluded that ". . . visual quality, clipping yield and water use efficiency was not affected by water conditioning with the [Care-Free water conditioning] unit."

Dr. Stephen Lower, a retired faculty member, Department of Chemistry, Simon Fraser University, Burnaby/Vancouver, Canada has established a web page (http://www.chem1.com/CQ/gallery.html) which is headlined "Gallery of water-related pseudoscience". Drawing on his career background in chemistry, Dr. Lower provides commentary/assessment on an array of devices and/or methodologies being marketed to improve suitability of non-pure water for various applications. Dr. Lower takes issue with most, if not all, manufacturer's claims for virtually all magnetic and catalytic water conditioners.

To briefly summarize findings from a literature review on magnetic and catalytic "salt-less" water conditioners, the small body of independently developed information for these technologies which has been located provides limited substantiation for beneficial claims put forth by the respective manufacturers. To the extent that there may be a strong interest on behalf of MWD's agricultural water customers in a more in-depth assessment of these technologies, setting up one or more field tests would not be difficult. Based on the information unearthed for this report, the beneficial aspects of using salt-less water conditioning technologies as a means of water conservation is not conclusive.

Hydraulically-operated diaphragm-actuated valves: Bermad, OCV, Singer Valve, Dorot, and Cla-Val, are among the brands of hydraulically-operated diaphragm-actuated valves that are commercially available. Diaphragm-actuated valves are opened or closed by differential forces acting on either side of a flexible diaphragm. The force on the side of the diaphragm in the direction of incoming flow is typically a function of the pressure in the flowing fluid. The force on the opposite side may be a exerted by a spring (in the case of a pressure regulating valve), a plunger (in the case of a mechanically- or solenoid-operated valve) or by fluid pressure or a combination of fluid pressure and spring force (in the case of a hydraulically-operated valve). Diaphragm-actuated valves may be utilized for binary (on/off) flow control, for pressure regulation, for pressure relief, and possibly other functions in a pipe network.

Hydraulically-operated diaphragm-actuated valves can utilize pressures in the fluid being handled to control diaphragm position. Hydraulically-operated valves typically have a pressure chamber behind the diaphragm as well as a spring. The force acting to open the valve is the resultant of pressure and momentum forces from the incoming direction acting on the diaphragm.

The force acting to close the valve would be a function of the combination of fluid pressure in the diaphragm chamber plus the spring force. The presence of the spring enables the valve to be closed with equal water pressure on each side of the diaphragm.

The hydraulically-operated, diaphragm-actuated valves are typically manufactured with removable plugs that allow control lines to be plumbed into the approaching flow section, into the diaphragm chamber, and also into the outflow section of the valve. Figure 1 is a schematic from the Bermad website showing an on/off manual control setup. A three-way valve is plumbed linking the upstream tap, the diaphragm chamber, and an atmospheric vent. To close the hydraulically operated valve, the manual three-way valve is adjusted to link the diaphragm chamber with the upstream pressure tap. To open the diaphragm valve, the manual three-way valve is turned to a position that links the diaphragm chamber with the atmospheric vent port.

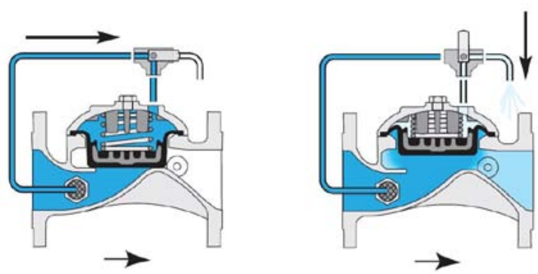

Figure 1. On/Off setup for Hydraulically-Operated Diaphragm-Actuated Valve

For an automated system the hand-operated three way valve shown in Figure 1 could be replaced with a three way solenoid valve. A hydraulically-operated, diaphragm-actuated valve could be expected to be a cost effective control valve for an automated system compared with a motorized valve or a pneumatically operated valve system in that the energy needed to adjust the valve is taken from the flow being controlled.

Figure 2 is a schematic from the Bermad website that shows how the same type of valve may be operated to regulate downstream pressure. In this operational configuration, a small spring-operated diaphragm actuated four way valve is plumbed to the approaching flow section, the diaphragm chamber, and the outflow section of the larger valve. In the schematic at left in Figure 2 low outflow pressure causes the small four way valve plunger to adjust to a position that links the diaphragm chamber with the vent port to allow the large valve to open. In the center image, excessive outflow pressure causes the small four way valve plunger to adjust to a position that links the inflow pressure with the diaphragm chamber which causes the large valve to close down. In the image at right, the force exerted in the small four way valve by the outflow pressure of the large valve is at equilibrium with the spring force in the four way valve under which condition the plunger in the four way valve stops flow from entering or leaving the diaphragm chamber of the large valve.

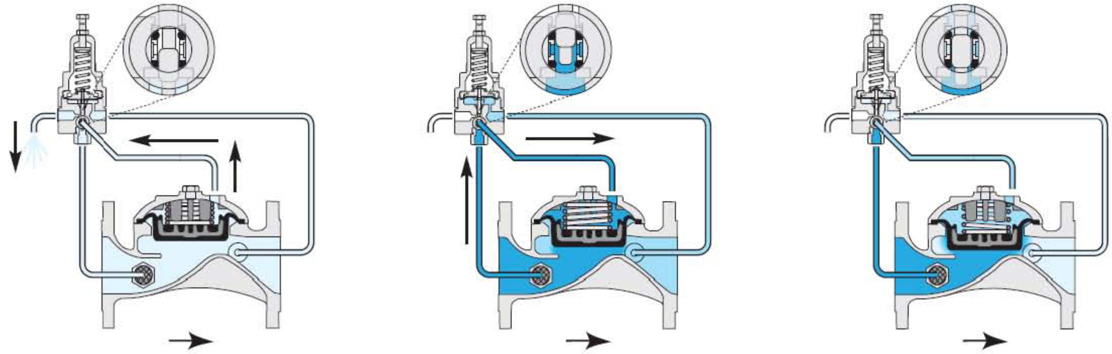

Figure 2. Pressure Regulating Setup for a Hydraulically-Operated Diaphragm-Actuated Valve

Hydraulically-operated diaphragm-actuated valves would likely be a cost-effective component offering versatile functionality for any piped irrigation delivery system. They could be readily and economically incorporated into an automated or remotely operated irrigation system. The potential water savings that may be associated with this valve technology would depend on the irrigation control system to which these valves might be incorporated, (i.e. “Smart” irrigation technologies discussed below).

“Smart” Irrigation Technologies: “Smart” irrigation control systems automatically adjust the timing and/or water application rate based on weather conditions, inputs from geographic information systems (GIS) and/or from soil moisture sensors. Field testing with prototype smart irrigation systems was recently performed with avocado production at the Mission Resource Conservation District (MRCD). A similar field test is on-going at the Rancho California Water District (RCWD).

The MRCD agricultural site was set in a 1.6 acre grove of mature Hass Avocados in production at Fallbrook, CA. A field test configuration was laid out by Dr. Gary Bender of the University of California Extension Service’s county of San Diego office. The grove was divided into six blocks. In three of the blocks, irrigation was controlled by weather-based electronic controllers which determined an irrigation schedule based on real-time weather information.

In the other three blocks, irrigations were managed by electronic controllers linked to tensiometers to monitor soil moisture content. In each of the three blocks an electronic controller was attached to two tensiometers installed near the root ball of an avocado tree, one at a depth of 12 inches and a second at a depth of 24 inches. In these blocks, irrigations would be initiated when soil moisture dropped below a pre-determined low value and would be stopped when soil moisture reached a pre-determined high value.

A preliminary audit was performed to assess emitter uniformity (EU) of the drip irrigation system. To improve the EU of the irrigation system, additional pressure regulators were installed and new sprinkler heads were installed in conjunction with setting up for the "smart" irrigation technology field testing. These upgrades raised the drip system EU from 84% to 91%. The planted area was also measured to develop a baseline plant water requirement (PWR) value developed for comparison with the amount of water actually applied. The PWR is a weather-dependent reference that is a function of the daily reference evapotranspiration rate.

Based on the project description and project data as presented in the Final Report (Bender, 2009) the demonstration project was not configured with classic "treated" and "control" areas that might provide a comparatively sharp comparison of the impacts of the respective irrigation technologies. Water application rates for both the tensiometer-based irrigation and for the weather-based irrigation systems are compared with the derived theoretical PWR value.

For the 2008 crop year, the PWR was determined to be 60.6" of water. During this time 48.5" of water was applied on sections of the grove irrigated by the weather-based controller while 28.8" of water were applied on sections irrigated by the tensiometer-based controller. On a per-tree basis, approximately 12,000 gallons were applied per tree to the tensiometer-based sections while approximately 18,000 gallons were applied to the weather-based sections.

2008 crop yield on a per-tree basis were approximately 110 lbs on the tensiometer-based sections and approximately 170 lbs on the weather-based sections. The county average yield, estimated at 7,000 lbs/acre would project at approximately 65 lbs per tree. In terms of production from a "unit of crop produced per unit of water applied" perspective, for both the tensiometer-based and the weather based irrigation systems, production was approximately 0.009 lbs of avocados produced per gallon of water applied. Since no information was available regarding the county average water application, a comparison with the county average production per unit of water applied cannot readily be determined from information presented on the project Final Report.

The available information from the MRCD "smart" irrigation technologies demonstration project suggests that currently available technologies such as the systems used in this project can provide enhanced water use efficiency for agricultural applications. The limited scope of this study leaves uncertainties as to repeatability of the observed results over multiple seasons and does not include information to determine how cost-effective these systems might be. A similar on-going study at the Rancho California District may enhance the understanding of how "smart" irrigation technologies could fit into the future of irrigated agriculture.

"Micro-Spinner" Sprinklers: A factor in the level of efficiency of an irrigation system for trees and shrubs can be how well the water application pattern matches the extent of the plant's root zone. A range of nozzle styles are available for “drip” or “low volume” irrigation systems. The water pattern from a spray-type nozzle will be a function of the nozzle geometry. A spinner-type nozzle features a rotating head. The centripetal force exerted on water droplets by the rotating head creates a larger wetting radius for operation under a given pressure than spray-type nozzles will provide.

Nozzles with rotating “spinner” heads can provide a more uniform application pattern with a larger application radius for a given operating pressure than other nozzle types are capable of. Micro spinner nozzles can provide a good wetting pattern for watering trees. In comparison with “mist” type spray nozzles, the more uniform droplet size from spinner nozzles can be less prone to evaporation losses or wind drift.

Conclusions: This essay represents a survey-scale review of available literature documenting water savings potential of technologies of interest specified by the MWD personnel associated with Irrigation Efficiency Incentive Program including “saltless” water conditioners, hydraulically operated valves, “smart” irrigation technologies, and “microspinner” irrigation nozzles. The topics examined in this study represent technologies which have been brought to the attention of the MWD Program staff by ag water user customers. This study should not be viewed as a comprehensive review of available technologies with potential to enhance irrigation water application efficiency**.**

There is a good deal of conflict in the literature regarding “salt-less” water conditioning technologies. There appears to be more skepticism than endorsement from academic sources. It is curious that there is such a limited body of independently-produced performance data available for these technologies, yet there is a fairly broad range of commercially available products, suggesting a significant market niche exists. As noted above, the information in this topic area that has been reviewed for this paper is inconclusive.

Hydraulically actuated valves have been shown to be highly versatile and cost effective for performing multiple types of functions as part of a remotely operated or an automated irrigation system. To that extent, there is strong potential for hydraulically operated valves to be utilized as components of improved efficiency irrigation systems.

Smart irrigation technologies may represent the greatest potential for approaching an “optimal” level of irrigation efficiency. The MRCD field tests show that at present these systems are technically viable. It is likely that as more work is done with these systems and as refinements and compatible components are identified, smart irrigation technologies will become increasingly cost effective as implementation of the technology expands.

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