WATER OPERATION AND MAINTENANCE BULLETIN

No. 189 September 1999

WATER OPERATION AND MAINTENANCE BULLETIN

The following Bulletins may be downloaded now. They are large files in ADOBE PDF format.
Need ADOBE ACROBAT READER?, you can get it here: GET ADOBE ACROBAT READER

June 1999 No. 188 -- March 1999 No. 187
December 1998 No. 186 -- September 1998 No. 185 -- June 1998 No. 184 -- March 1998 No. 183
December 1997 No. 182

BULLETIN SUBJECT INDEX
A--B--C--D--E--F--G--H--I--J--K--L--M--N--O--P--Q--R--S--T--U--V--W--X--Y--Z

Here is where you ORDER needed bulletins from index above: (Order by number following the topic.)

IN THIS ISSUE. . .

- Water Operation and Maintenance Bulletin Internet Publication and Address
- Accident Investigation
- Sticky Wickets, Solving a Problem—Drop by Drop
- Irrigation Flow Measurement - Instrumentation Development Part I
- Failure of Spillway Radial Gate Wire Ropes, Stewart Mountain Dam

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Reclamation personnel and water user groups in operating and maintaining project facilities.

Although every attempt is made to ensure high quality and accurate information, Reclamation cannot warrant nor be responsible for the use or misuse of information that is furnished in this bulletin.

For further information about the *Water Operation and Maintenance Bulletin* or to receive a copy of the index, contact:

Jerry Fischer, Managing Editor
Bureau of Reclamation
Inspections and Emergency Management Group,
Code D-8470
PO Box 25007, Denver CO 80225
Telephone: (303) 445-2748
FAX: (303) 445-6381
Email: jfischer@do.usbr.gov

***Cover photograph*:** Opening page of *Water Operation and Maintenance Bulletin* Internet site.

UNITED STATES DEPARTMENT OF THE INTERIOR Bureau of Reclamation

WATER OPERATION AND MAINTENANCE BULLETIN
No. 189—September 1999

CONTENTS

Page

Water Operation and Maintenance Bulletin Internet Publication and Address 1
Accident Investigation 3
Sticky Wickets, Solving a Problem—Drop by Drop 7
Irrigation Flow Measurement - Instrumentation Development Part I 11
Failure of Spillway Radial Gate Wire Ropes, Stewart Mountain Dam 17

WATER OPERATION AND MAINTENANCE BULLETIN
INTERNET PUBLICATION AND ADDRESS

http://www.usbr.gov/infrastr/waterbull

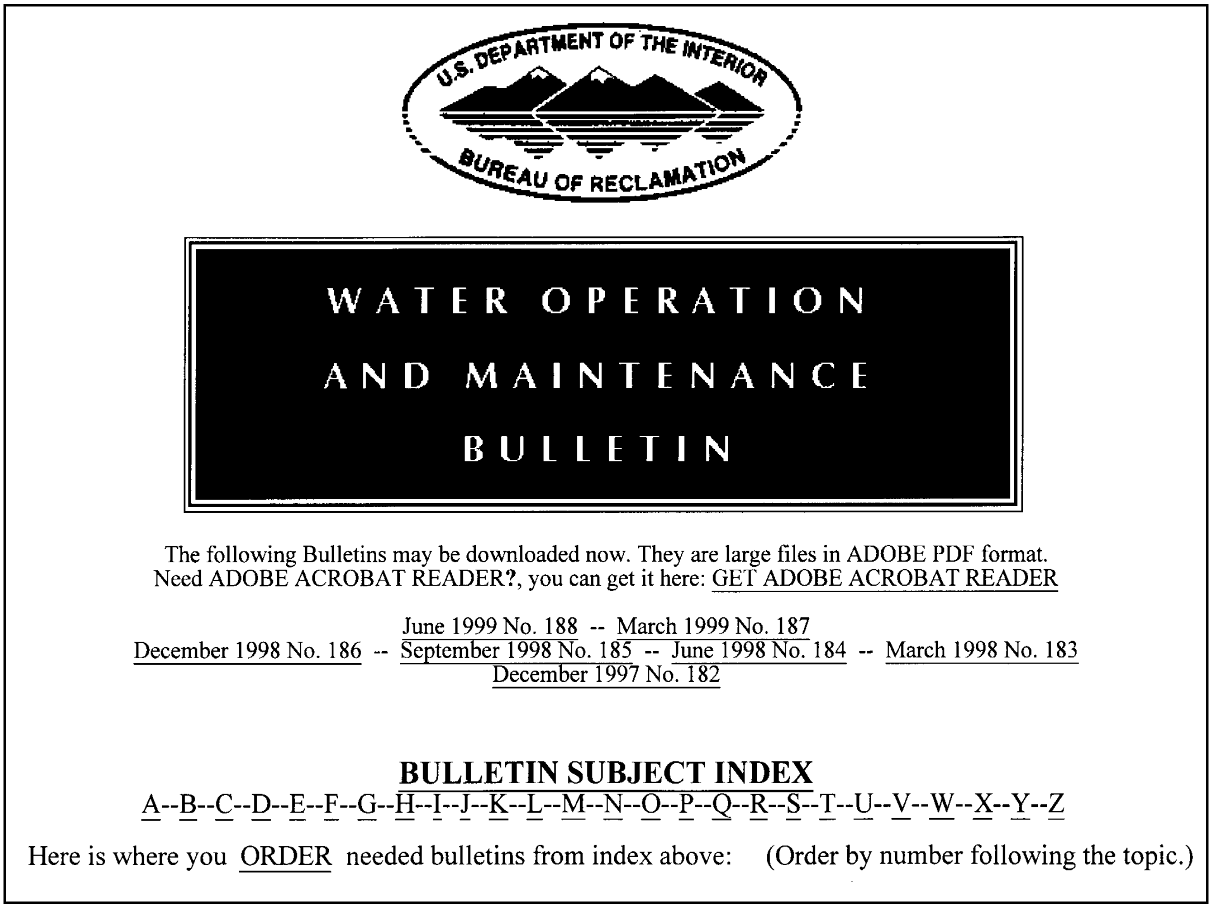

Figure 1.—Opening page of Water Operation and Maintenance Bulletin Internet site.

In order to more readily meet customer needs, reach a larger audience, and reduce printing and mailing costs, the Water Operation and Maintenance Bulletin has been posted on the Internet. All issues will be posted in Adobe PDF format where they can be viewed, downloaded, or printed. Figure 1 is an illustration of the opening page to the bulletin site. It retains the familiar front cover logo of the printed bulletin and the necessary links to get you around the site quickly. Following the logo is a link to GET ADOBE ACROBAT READER if you do not already have it—this reader is necessary for viewing the bulletins which are posted as PDF formatted files. Once you have Adobe Acrobat Reader, just click on the links for the O&M Bulletin issues that are posted and ready for immediate use. These will come up in the Acrobat reader that you have downloaded. You then may view the bulletin on screen, download it for future use, or send it to your printer for hard copy output. The issues are indexed by article, and thumbnail sketches make navigation easy. Navigational features of Acrobat reader will aid in finding the article of interest quickly and easily. Hitting the

"Back" button on the Acrobat Reader toolbar will return you to the opening page of the bulletin site (shown in figure 1). In the months ahead, more bulletins will be added to the posted list.

Topics of interest may be found in the BULLETIN SUBJECT INDEX, and if your topic is listed in an unposted bulletin, that bulletin may be ordered via e-mail by listing the bulletin number that follows each topic. Topics are listed in alphabetical order. Each letter is linked to its respective index. At the top and bottom of each index page you may return to the opening page of the bulletin site by clicking on RETURN TO INDEX. Unposted bulletins may be ordered by e-mail by clicking on ORDER at the bottom of the page. These bulletins will be sent to you in hard copy form as they are available or until they are posted on the site for immediate downloading. If ordering by e-mail, remember to give your full name and mailing address and the bulletin number(s) you are requesting. About 50 percent of correspondents do not tell us where to send requested items.

In the interest of best viewing and use, this site has been designed to work optimally with the latest versions of Netscape Navigator and/or Microsoft Internet Explorer and Adobe Acrobat Reader with screen resolutions set at 800 x 600 or higher.

http://www.usbr.gov/infrastr/waterbull

ACCIDENT INVESTIGATION

by Steven J. Melikean, RSC Safety and Health Program Manager

I made a career switch from Fire Suppression/Prevention to Occupational Safety and Health (OSH) in 1986. I soon found that I did not know a lot about accident investigation. This basic functional program element is required by OSHA Part 1960.29. However, 1960.29 does not say too much on how to investigate an accident, e.g., " . . . the extent of such investigation shall be reflective of the seriousness of the accident." What follows is some of what I have learned about accident investigation.

Accidents as Bad Luck

Like many people, I once thought accidents just happened. I bought into ideas of accident prone, bad luck, carelessness, fatigue, and acts of god. It took me awhile until I learned that an accident is an unplanned, but controlled, combination of events which causes damage to something or injury to someone. An incident is an undesired event (e.g., near miss) that may cause personal harm or other damage. I learned that there are approximately 600 incidents for every serious accident.

Fortunately, I was not assigned serious or complex accidents to investigate early in my OSH career. Back then, my main concern when investigating accidents was to complete the required paperwork and get it out of my in-basket." In short, I rarely looked beyond the accident's unsafe act or condition causal factor. It wasn't until my employer (another Federal agency) allowed me to attend two formal courses—Accident Investigation, Reporting and Analysis and Management Oversight Risk Tree Accident/Incident Analysis—that I found out I was taking the wrong approach toward accident investigation.

Domino Theory

Specifically, I discovered I had been unconsciously subscribing to the "**Domino**" theory of accident causation put forth by H.W. Heinrich, author of *Industrial Accident Prevention*, published in 1931. His theory states, "the occurrence of an injury invariably results from a completed sequence of factors, the last one of these being the injury itself. The accident which caused the injury is invariably caused directly by the unsafe act of a person and/or a mechanical or a physical hazard." He likened this sequence to a series of five dominoes standing on edge. These dominoes are labeled:

(1) Social environment
(2) Fault of a person
(3) Unsafe act or condition
(4) Accident
(5) Injury

When I found out about this theory in class, I mulled over my earlier actions of assigning blame to an individual or thing, and asked myself if I was addressing the **root cause** of the accident or just **symptoms**. The Domino theory seemed very logical—a practical and pragmatic approach. At least something constructive comes out of an accident, i.e., a very practical system for removing the things that are causing accidents. However, during class I found out my interpretation of the Domino theory had perhaps been too narrow. When I investigated accidents previously and I identified an act or condition which "caused" an accident, I wondered how many other causes I had left unidentified.

Multiple Causation Theory

I soon found out during class that behind every accident are many contributing factors, causes, and subcauses. This theory is known as **Multiple Causation**. The theory of Multiple Causation states that these factors combine together in random fashion, causing accidents. If this were true, then I thought my investigation of accidents ought to identify as many of these factors as possible, certainly more than one act or condition.

The Multiple Causation theory can be contrasted with the Domino theory with an accident example described by Dan Petersen, Safety Management Consultant and author of many OSH management textbooks. He relates an accident where an employee has fallen off a defective ladder. During the investigation, the supervisor has identified the unsafe condition as the defective ladder, the unsafe act as the employee climbing the ladder, and the corrective action as getting rid of the ladder. Mr. Petersen points out that this is a classic Domino theory approach to investigating an accident and attempting to prevent accident recurrence.

If the Multiple Causation theory were used by the supervisor to investigate this accident, then other possible investigation questions might have been asked, including:

(1) Why was the defective ladder not found during normal maintenance inspections?
(2) Why did the supervisor allow its use?
(3) Didn't the injured employee know it should not be used?
(4) Was the employee properly trained?
(5) Was the employee reminded not to use the ladder?
(6) Did the supervisor examine the job first?

The answer to these and other questions would have led the supervisor to the following kinds of corrective actions:

(1) An improved inspection procedure
(2) Improved training
(3) A better definition of responsibilities
(4) Prejob planning by the employee's supervisor

Near Miss Investigations

An accident that causes serious injury or deaths obviously should be thoroughly investigated. Early in my career, I did not recognize that the near miss that might have caused death or serious injury is equally important from the standpoint of safety and should be investigated. Similarly, any epidemic of minor injuries also demands study. The chief value of such investigations lies in uncovering contributing causes. Since my additional course work, I have been convinced of the necessity to investigate these types of incidents.

Summary

By attending these two formal courses, I learned to recognize the reasons for investigating accidents beyond preventing recurrence of the singular accident event. I learned that accident analysis will determine other causal factors, provide interpretation of facts, help develop effective recommendations or countermeasures, satisfy employee and public concern, develop historical facts (incident frequency and severity rates), contain costs, and uncover other unrelated hazards to prevent additional accidents.

Years of cumulative experience and training have changed my personal attitude toward safety and allowed me to recognize that the human element emerges as the most important factor in reducing accidents.

STICKY WICKETS
SOLVING A PROBLEM—DROP BY DROP

by Gary McDermott[1]

Since its construction in 1968, the U.S. Bureau of Reclamation's 164-MW Morrow Point Dam has experienced seepage from drainage tunnels in its three galleries. Two sump pumps at the bottom of the dam keep the seepage under control. However, high amounts of calcium in the water caused deposits to form inside the pumps, threatening to make the pumps freeze. Routine, inconvenient maintenance of the pumps was required. The solution was the installation of a method to slowly drip water softener into the seepage water, causing the calcium to precipitate out and leaving calcium-free water to be pumped.

Morrow Point is the middle facility of three Reclamation hydropower stations in the Colorado River Storage Project on the Gunnison River about 25 miles east of Montrose, Colorado. Its double-curvature, thin-arch concrete dam is 468 feet tall and 724 feet long at the crest. Upstream is the 96-MW Blue Mesa project and downstream is the 28-MW Crystal project.

Preventing Calcium Buildup

A 25-horsepower vertical shaft pump in the foreground of this photograph is one of two pumps that clear seepage water from the bottom of the 164-MW Morrow Point Dam on the Gunnison River in Colorado. Rapidly building calcium deposits in the pumps, however, required inconvenient maintenance twice a year. The problem was solved by the white barrel in the background, which contains a water softener that is slowly dripped into the sump hole, preventing the calcium buildup.

During construction of Morrow Point, tunnels were excavated back into the abutments from each of the three galleries, and it was in those tunnels that drilling and grouting were done. Drainage holes were placed in the tunnels to monitor seepage.

Seepage from Morrow Point Reservoir passes from the abutments through the huge grout field and igneous rock, where it absorbs large amounts of calcium. The seepage flows into the galleries and through grates and pipes downward through the dam. The water has a final free fall of about 30 feet to the sump at the floor of the dam.

During the original construction, two 25-horse-power vertical shaft, multi-stage Gould centrifugal pumps were mounted side-by-side over grates on the floor just above the sump. The vertical shaft from each pump reaches down the 30 feet into the

[1] Supervisor II, power plant foreman, Morrow Point Dam, 1820 South Rio Grande, Montrose, CO 81401; (970) 249-5278; E-mail: gmcdermott@ibr4gw80.uc.usbr.gov.

sump. A probe in the sump automatically turns on one of the pumps when water is sufficiently deep. The pumps, working alternately, simply pump the water back into the Gunnison River.

The pumps are capable of pumping about 500 gallons of water an hour. As an estimate, the amount of seepage water pumped out of Morrow Point is about 1,000 gallons a day. Though that is not a large amount of water, it must be continuously removed or it builds up rapidly and can become deep at the bottom-most walkway.

The problems with the pumps began immediately after the dam became operational. The calcium in the seepage water rapidly built up deposits on the pumps' impeller, bulb, and casing. If uncorrected, the deposits would cause the pumps to freeze in six to ten months. If a pump had been allowed to seize, extensive internal damage would have been caused and the pump motor likely would have burned up.

For some years, a routine preventative maintenance program kept the pumps operating. The program, however, was time-consuming, and needed to be done twice a year. The remote location of the pumps at the back of the dam required that they be brought into a work space on wheelbarrows and dollies. Two days were required to take a pump apart, clean it, and put it back together. If a part needed to be replaced, the maintenance time was longer.

The preventative maintenance program was in place for some ten years before a better approach was found, probably during operations and maintenance review sessions. Though the origin of the idea is now lost, someone came up with the idea to drip water softener into the sump.

The system was ingenious for its simplicity and economy. A 55-gallon barrel of Calgon, purchased from the Nu-Calgon Company of St. Louis, Missouri, was laid on its side beside the pumps. A tube such as those used in a hospital to provide intravenous (IV) feeding was attached to the outlet of the barrel and dropped down into the sump. A drip control on the IV tubing allowed a drop of chemical into the sump every few minutes.

The chemical causes the calcium, as calcium carbonate, to precipitate out in the bottom of the large sump, leaving calcium-free water to be pumped. The specific chemical used is No. 340 Liquid Scale Inhibitor. The barrel of chemical lasts about a year.

Since the water softener has been dripping into the sump, both pumps—which are original equipment to the dam—have never caused another maintenance problem. Every five to seven years, Morrow Point maintenance staff replaces the bearing on the vertical shaft of each pump.

In the years since the original system was installed, the IV tubing has been replaced with a more durable and efficient needle valve that delivers about ten drops of chemical per hour.

Reprinted from *Hydro Review*, April 1999, HCI Publications, Kansas City, Missouri 64111, E-mail: hci@aol.com; Web: www.hcipub.com. Used with permission.

IRRIGATION FLOW MEASUREMENT - INSTRUMENTATION DEVELOPMENT PART I

by Blair L. Stringam[1] and Kathleen H. Frizell[2]

Background

The Water Resources Research Laboratory (WRRL), in cooperation with the Bureau of Reclamation's (Reclamation) Research and Policy Offices and the Montana Area Office, is currently developing and testing devices which would help farmers better measure their diverted water. The low-cost devices being tested are an open channel flow recorder, pipe flow meters, and a water level sensor.

Irrigation enhancements, environmental concerns, and urban growth continue to fuel the need for improved operation of water delivery systems. In many river systems, more water is required in natural streams to preserve fish, wildlife, and the surrounding habitat. As a result, water users are under pressure to improve management of diverted water. A direct benefit of better water management is usually a decrease in pumping costs and proper billing for the amount of water diverted. Despite a willingness on the part of many farmers to install flow measurement devices, the cost of appropriate water measurement devices is often prohibitive.

Objective

The objective of this study is to work with instrument manufacturers and Reclamation engineers to develop and test new and existing low-cost devices which can be used by irrigation districts and farmers to manage diverted water. Sensors and recorders which are used on irrigation systems must endure heat, humidity, debris, vegetation, dust, lightning, and vandalism and still maintain reliability and accuracy.

Generally, the more expensive devices are the most accurate, but maintenance and reliability in the operating environment often become the most important features when selecting the proper device. Each measurement device has strengths and weaknesses which must be evaluated for each application.

---

[1] Hydraulic Engineer, Water Resources Research Laboratory, Denver Technical Center, P.O. Box 25007, Denver, Colorado 80225.

[2] Research Hydraulic Engineer, Water Resources Research Laboratory, Denver Technical Center, P.O. Box 25007, Denver, Colorado 80225.

Devices for three specific applications are being tested—a newly developed device to measure and record water flowing over a flume in an open channel, existing flow meters for pressurized pipe flow, and encased pressure transducers to measure water level.

Laboratory Test Facility

Today's WRRL Group provides technical services and pursues applied research to provide solutions and new water resource management tools to Reclamation engineers and managers. An important facility in the laboratory is a model canal facility. The model canal facility is 300 feet long and made from clear acrylic plexiglas and aluminum. The model canal has motorized control gates, turnouts, a long-throated flow measurement flume, and an inverted siphon. The model canal has many of the control and flow measurement features currently being used on irrigation canals.

The model canal is continually used to test water measurement devices and instrumentation being considered for application by irrigation districts. For this study, the off-the-shelf instruments were set up and operated before being taken to the field. The newly developed open channel flow recorder was set up, debugged, and then compared to other meters before field installation.

Field Test Site

Presently, field testing of the sensors is being conducted at East Bench Irrigation District in Dillon, Montana. The East Bench Irrigation District diverts water from the Beaverhead River into their canal system. The majority of the canal has a buried membrane lining, and water is diverted from the canal into lateral canals or pumped directly into sprinkler systems. Silt and water vegetation are mixed in the water, typical of many canal systems in the west.

The irrigation season is only the summer months, but it is likely that the irrigators will not want to remove the instruments during the winter. Temperatures range from -30 degrees Fahrenheit (°F) in the winter to about 100 °F in the summer. The plan is to keep the sensors installed throughout the winter to see how well they perform in the next irrigation season after enduring the winter.

Instrumentation Under Investigation

Open Channel Flow Recorder

The flume flow measurement device was developed recently by WRRL staff. The device consists of a small central processing unit chip (CPU), an ultrasonic water level sensor, and a solar power supply (figures 1 and 2). This flow recorder is a simplified version of many

Figure 1.—The open channel flow recorder installed upstream from an 8-foot Parshall flume. The solar panel is mounted on top of the post with the battery below.

Figure 2.—View looking down on top of the flow recorder showing the readout in cubic feet per second and total flow in acre-feet.

acoustic flow metering devices that are currently on the market. The device was developed because there were no low-cost combined water metering and recording devices for flume applications available. The device was designed for installation on the upstream side of a flume where it measures the water depth. The CPU then computes the flow rate using a power equation. The device can be easily adapted for weirs or other flow measurement structures provided a rating equation is available for the structure. A totalizing feature has also been incorporated into the program so that total volume of water diverted can be computed. The flow rate in cubic feet per second and total diverted water in acre-feet is displayed on an LCD screen for easy viewing (figure 2). A reset feature is also designed into this meter which allows the water user to push a button and reset the totalized flow for a new irrigation period.

Figures 1 and 2 show the instrumentation box, which contains the sensor and CPU, at the installation on a Parshall flume near Dillon, Montana. Because the measurement system is incorporated into a small enclosure, the entire system can be installed in a short period of time and with little difficulty. The system shown in figure 1 was installed in about 2 hours and has been functioning with no reported problems.

The cost for this device, including the CPU, sensor, solar panel, voltage regulator, and battery, is slightly less than $1,000. We believe that a manufacturer could fabricate this sensor for around $1,000.

Pipe Flow Meters

Four low-cost flow meters are also being tested to determine their compatibility with irrigation water piping systems. There are a number of pipe flow meters available, but the majority of them are unacceptable for irrigation use due to high cost, incompatibility with untreated irrigation water, or high energy losses. The flow meters that are presently being tested are two paddle-wheel-type sensors (figures 3, 4, 5, and 6), a unique propeller-type meter that is presently in the development and testing stages by the manufacturer (figure 7), and a vortex shedding meter (figure 8). These meters have digital readouts that display flow rate and accumulated flow.

Figure 3.—The paddle wheel flow meter with display installed on an 8-inch pipe in Montana. (The white can is placed over the sensor to shade it from the sun).

Figure 4.—The paddle wheel flow meter display for the installation in figure 3. The flow rate is displayed in gallons per minute and total gallons.

Figure 5.—Another paddle wheel flow rate sensor which is also installed on an 8-inch pipeline.

Figure 6.—The display for the paddle wheel sensor in figure 5. The top number displays gallons per minute, and the bottom number displays total water in cubic feet.

Figure 7.—Propeller flow meter and display installed on a 10-inch pipeline.

Figure 8.—Vortex shedding meter and flow display which is also on a 10-inch pipeline.

All of these meters have been installed on irrigation pipelines in Dillon, Montana. The field installation sites have algae, water weeds, and silt in the water; some of the sensors have had problems with algae and debris. All of these meters are mounted on the pipeline via a saddle. The installation is easy and can be accomplished in a short period of time.

A problem in the study has been finding a sufficient length of straight pipe for proper flow measurement. Some testing has been done to determine discharge factors which can be used to adjust the measured flow rate in case there is an elbow or some other geometry interfering with measurement flow conditions. Presently, we are addressing accuracy and durability in the irrigation environment, and we hope to address other issues in the future. The cost for the meters, including a power supply, ranges from $800 to $1,200.

Water Level Sensor

In many cases, a water level is required to compute flow through a flume or to maintain a canal at a desired level. Unfortunately, there are no sensors available to measure the level for less than $300. With a little ingenuity, a water level sensor can be developed consisting of a nonsubmersible pressure transducer and a polyvinyl chloride (PVC) pipe. The transducer is installed inside the pipe to keep the nonsubmersible portion of the sensor away from the water. To construct this device, a cap is drilled and threaded with pipe threads that fit the sensor threads. The transducer is screwed into the cap from the inside. The cap is then fastened to the end of a 2-inch standard size PVC pipe (figure 9). The pipe can then be fastened to a structure wall so that the pressure port is under water (figure 10).

Initially, one of the sensors and its pipe housing was broken away from its mount because of turbulent water, and the sensor was ruined and had to be replaced. Presently, two of these devices are in place in the field and are functioning well. Initial tests indicate that this method gives consistent and reasonably accurate measurements.

Figure 9.—Pressure transducer threaded into a pipe cap prior to attaching the cap to the end of PVC tubing.

Figure 10.—The transducer is pipe mounted to a concrete structure upstream from a weir wall.

The total cost for the transducer and materials is about $250. This is less than half the cost of submersible transducers. A power supply and recording device or data logger, which can range in cost from $500 to $2,500, will need to be added.

Conclusions

Testing is ongoing for all these devices at the field site. Initial tests indicate that all the devices are functioning and will continue through this irrigation season. A followup article will be written for a future *Water Operations and Maintenance Bulletin*.

FAILURE OF SPILLWAY RADIAL GATE WIRE ROPES STEWART MOUNTAIN DAM

by Connie Berte[1]

On April 13, 1999, the radial gates and hoists on the Stewart Mountain Dam Auxiliary Spillway were tested. This test occurred during a mechanical features examination for the comprehensive facility review (CFR) of Stewart Mountain Dam, Central Arizona Project, Lower Colorado Region - Arizona. Examination participants included representatives from the Technical Service Center, Lower Colorado Regional Office, Phoenix Area Office, and the Salt River Project.

The reservoir water surface elevation is 1523.79 feet. The total reservoir head on the auxiliary spillway gates is about 29 feet. The normal operational water surface elevation is 1529.00. Maximum water surface elevation is 1530.78.

The auxiliary spillway is located on the right abutment of the dam. The mechanical features consist of four 30-foot-wide by 34.78-foot-high radial gates (figure 1), each controlled by two wire rope hoists. The gates are numbered 10 through 13 when viewed from left to right looking downstream.

The Bureau of Reclamation spillway radial gate exercising guidelines require a differential head test every 5 years while the gate is subjected to maximum head for the operating season. All spillway gates are to be tested annually to confirm that the gates will open and close satisfactorily.

Figure 1.—Downstream side of the auxiliary spillway radial gates (Stewart Mountain Dam).

The intent of the Stewart Mountain Dam spillway gate testing was to raise each gate approximately 1 foot. Applying power to the hoist of gate No. 10 caused the wire ropes to fail without the gate even lifting off the sill. The same thing happened when gate No. 11 was tested.

[1] Mechanical Engineer, Mechanical Equipment Group, Reclamation Service Center, Bureau of Reclamation, P.O. Box 25007, Denver, Colorado 80225.

The wire ropes are connected at both ends to the drum dropping down at its center to pass through an equalizing sheave on the gate on the upstream side of the skin plate. The covers from both drums on gate No. 10 were not removed to examine the ropes. The wire ropes were severely corroded just below the water level and failed slightly below the normal high water mark. Figure 2 shows the approximate points of failure.

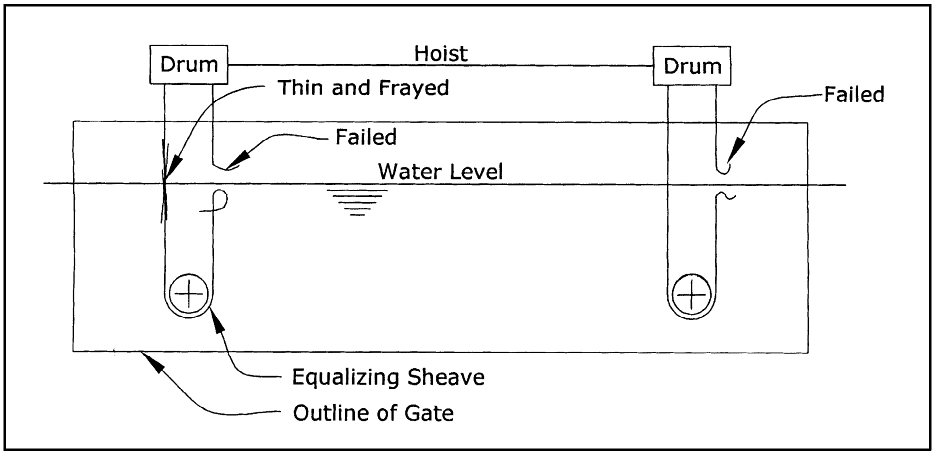

Figure 2.—Approximate points of wire rope failure.

The wire rope installed under the Stewart Mountain Dam Safety Modification was extra improved plow steel (XIPS), 6 x 19, independent wire rope core, 1-inch diameter, right regular lay. The sample shows significant corrosion, especially at the failure location. The failure location is exposed to both air and water due to the daily lake level fluctuations. Shown below is the corroded wire rope (figures 3 and 4).

Figure 3.—Stewart Mountain Dam wire rope.

Figure 4.—Stewart Mountain Dam broken wire rope.

The grooves on the drum of the hoist limit the diameter size of the wire rope that can be installed on the hoist. Therefore, a larger diameter wire rope could not be used. The alternatives were to replace the rope with either galvanized wire rope, plow-type wire rope, or stainless steel wire rope. Considering a stainless steel rope, Type I general purpose, class 2, 6 x 19, and class 3, 6 x 37 single operation strand, corrosion resistant steel, IWRC with a federal breaking strength of 83,300 pounds, the safety factor can be determined as follows:

The wire rope hoist has two ropes with two-part reeving, giving **4 ropes** to provide the lifting capacity.

Each gate weighs **70,000 pounds**.

The safety factor for the stainless wire ropes would then be:

83,300 pounds x **4 wire ropes** = **70,000 pounds** x (safety factor)
(breaking strength) (gate load)

Safety factor = 4.76

Similar calculations gave the following safety factors for the other two ropes: galvanized wire rope—safety factor 5.9 and plow-type wire rope—safety factor 5.9.

Stainless steel ropes were chosen to replace the existing ropes instead of galvanized ropes or the existing plow-type wire rope. Even though the galvanized ropes would start with a higher safety factor, the safety factor would be reduced quickly by the corrosive water. If the same rope (improved plow steel) were to be used, it would corrode within the same 10-year time period (auxiliary spillway hoists at Stewart Mountain Dam were installed in 1989). Therefore, the improved plow steel would have a reduced safety factor of 4.76 after 2 years and would continue to deteriorate with time. Installing stainless steel wire ropes will result in a much slower rate of corrosion and will prevent failure before a 10-year operating period.

Investigations are being planned by the Technical Service Center to determine the chemistry of water at Stewart Mountain Dam and to analyze the use of different types of ropes for corrosion resistance—galvanized wire rope, plow-type wire rope, and stainless steel wire rope.

If the wire ropes had been inspected and the gates tested on an annual basis, the corrosion probably would have been evident at the first inspection, or at least the second. Then, the ropes could have been protected so that the failure incident would not have occurred. The aluminum stoplogs at the site could have been used so that the annual inspections could have been performed with minimal loss of water. A mobile crane capable of lifting 14,500 pounds would be needed to install the stoplogs.

This incident reinforces the need for gate exercising and periodic inspections to ascertain the condition of mechanical features at dams.

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.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Jerry Fischer, Technical Service Center, ATTN: D-8470, PO Box 25007, Denver, Colorado 80225-0007; (303) 445-2748, FAX (303) 445-6381; email: jfischer@do.usbr.gov

Vicki Hoffman, Pacific Northwest Region, ATTN: PN-3234, 1150 North Curtis Road, Boise, Idaho 83706-1234; (208) 378-5335, FAX (208) 378-5305

Dena Uding, Mid-Pacific Region, ATTN: MP-430, 2800 Cottage Way, Sacramento, California 95825-1898; (916) 978-5229, FAX (916) 978-5290

Albert Graves, Lower Colorado Region, ATTN: BCOO-4846, PO Box 61470, Boulder City, Nevada 89006-1470; (702) 293-8163, FAX (702) 293-8042

Don Wintch, Upper Colorado Region, ATTN: UC-258, PO Box 11568, Salt Lake City, Utah 84147-0568; (801) 524-3307, FAX (801) 524-5499

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, Montana 59107-6900; (406) 247-7630, FAX (406) 247-7898