WATER OPERATION AND MAINTENANCE

BULLETIN NO. 166

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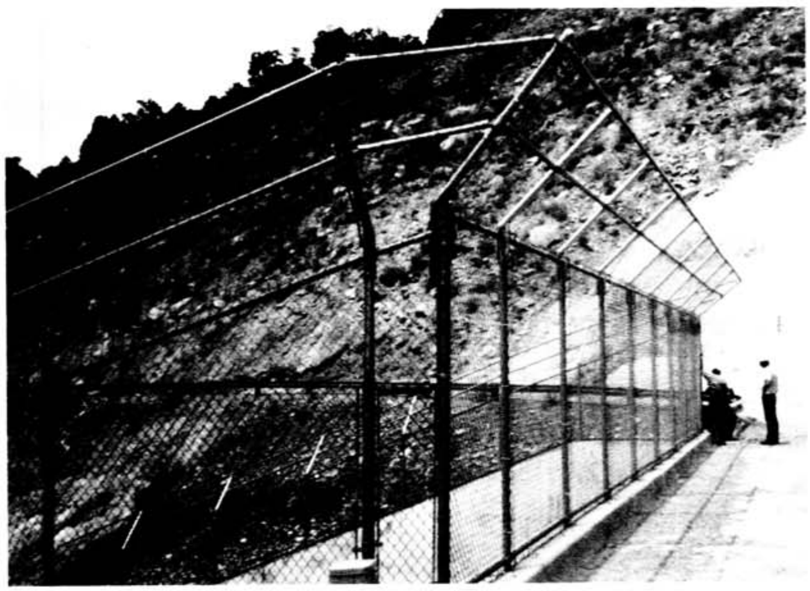

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

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Cover photograph:

Spillway fence extension, McPhee Dam, Colorado.

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FENCE EXTENSION MAY DETER ROCK TOSSERS

By Bill Bouley and Neil Gillis[1]

Most dam tenders get noticeably upset when they see a concrete spall in their hydraulic structures. They may wonder if more site visits, less sleep, etc., could have stopped the individuals from throwing damaging debris. Once the vandals are apprehended, the dam tender and local law enforcement could steer them into a better understanding of proper operation and maintenance practices.

Normally, safety fences around spillway and outlet work chutes and stilling basins consist of chain link fence fabric topped with strands of barbed wire. These fences are all that separate the rock throwers from their intended target.

On a recent inspection of McPhee Dam, Dolores Project, Colorado, Neil Gillis of the Operation and Maintenance Engineering Branch noticed an improvement to the safety fence around the spillway chute. An extension connected to the fence posts allows an inclined chain link fence fabric to be installed. This extension makes it exceptionally difficult for would-be rock throwers, out-of-work shot putters, disgusted bowlers, and other pranksters to toss their concrete-damaging debris into the spillway chute.

Spillway fence extension to prevent rocks from being thrown onto the chute floor.

1 Bill Bouley is a Civil Engineer and Neil Gillis is a General Engineer, Bureau of Reclamation, Denver Office.

Spillway fence extension connectors.

TESTING CLOSE-COUPLED OUTLET WORKS GATES AND VALVES UNDER UNBALANCED HEAD CONDITIONS

By Ernie Bachman[1]

The Bureau (Bureau of Reclamation) has developed two primary programs for testing dam outlet works guard gates and valves upstream of the main regulating gates or valves. (*Also see "Penstock and Outlet Works Guard Gate and Valve Testing," Bulletin No. 163, p. 25*). The purpose of the tests is to determine if the primary function to shut off waterflow in the event of a downstream failure can be served. The oldest program is the Bureau-wide Power Penstock Guard Gate and Valve Test Program, and the newest is the Outlet Works Emergency/Guard Gate and Valve Test Program. The outlet works program is also divided into two sections: Group 1 comprising facilities with "close-coupled" guard and regulating gates and valves and Group 2 comprising facilities with "distant-coupled" guard and regulating gates and valves. "Close-coupled" means less than five pipe diameters between the two. Group 2 facilities, having a risk of pipe collapse downstream of the guard gate upon emergency closure of that gate, have been analyzed for air venting demand and retrofitted in most cases with upgraded air/vacuum valves before testing is carried out. Group 1 facilities have been considered for unbalanced testing as they stand, since the close-coupled arrangement allows for sufficient air displacement for testing.

As a case of study for a close-coupled system, the unbalanced opening and closure test carried out during an RO&M (Review of Operation and Maintenance) examination at the Yellowtail Dam and Powerplant in May of 1992 will be described. Yellowtail Dam is a Bureau facility located in South-Central Montana on the Bighorn River. The outlet works consist of two 84-inch-diameter outlet pipes, the irrigation and evacuation conduits, which begin at the upstream face of the dam and extend through the dam to the ring-follower gates at the downstream side of the dam, and then to the hollow-jet valves immediately downstream of the ring-followers. The ring-follower gates serve as guard gates, which are normally operated in the fully open or fully closed position. The hollow-jet valves serve to regulate the flow and can be operated at any given setting. The maximum water surface elevation is 3660 feet (1116 meters) and the elevation of the ring-follower gates and hollow-jet valves approximately 3200 feet (976 meters) yielding a maximum pressure head on the gates and valves of 460 feet (140 meters).

A brief description of the ring-follower gates and hollow-jet-valves follows:

The ring-follower gates (fig. 1) are constructed of cast and welded steel and consist of a body, a leaf, and a hydraulic hoist. The leaf includes a follower ring having a circular opening equal to the inside pipe diameter, such that an unobstructed flow of water through the body is permitted in the open position. These ring-follower gates are designed to operate under maximum reservoir head, using a maximum oil pressure of 2,000 lb/in^2 (13.79 MPa) and have a total vertical travel of 7 feet 8 inches (2.3 meters). Normally, the gates are operated under balanced head with no flow through the outlet works, but they are designed for emergency closure with full flow under maximum reservoir head.

The hollow-jet valves (fig. 2) are constructed of cast and welded steel and consist of a circular body and a conical, moveable needle which forms an annular water passage and moves upstream to seal against the entrance throat. There is no downstream convergence of the water passage, resulting in a hollow jet with a column of air inside. Movement of the needle varies the cross-sectional area of the annular opening between the conical needle and the body and thus controls the amount of discharge.

[1] Ernie Bachman is a Mechanical Engineer, Bureau of Reclamation, Denver Office.

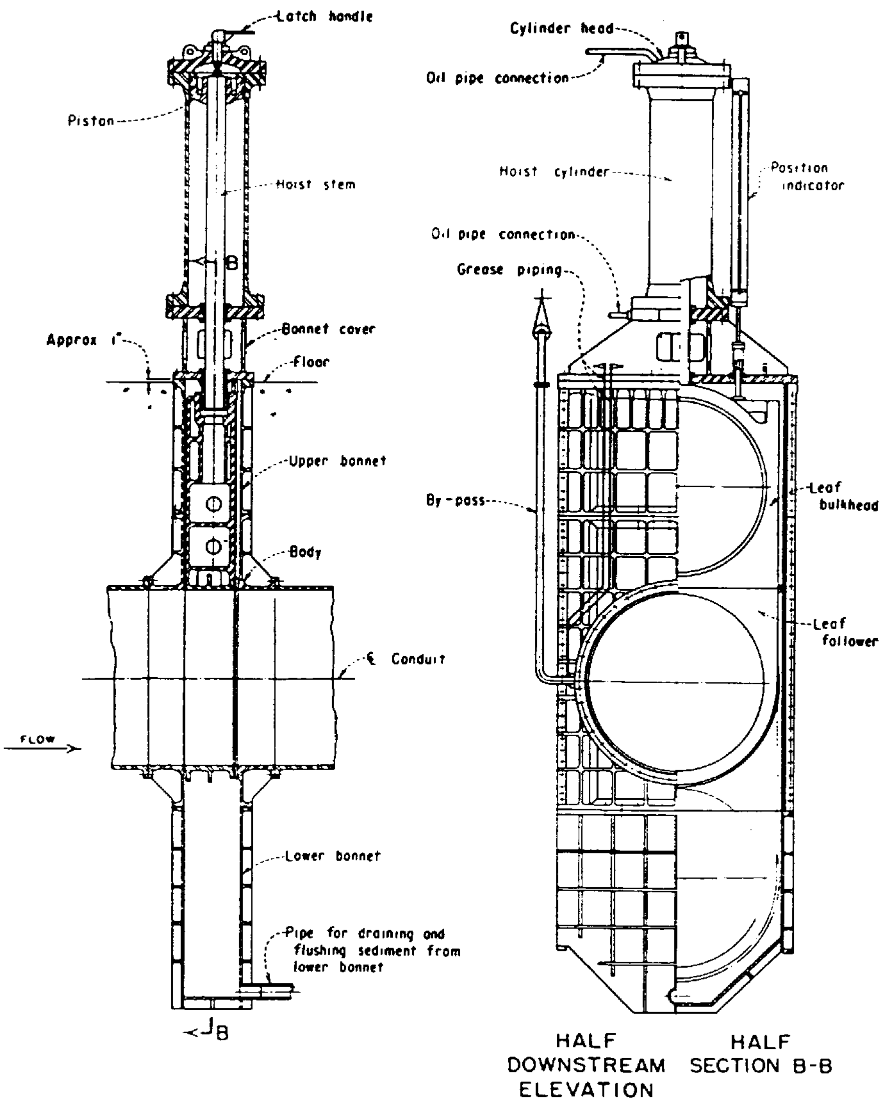

Figure 1. – Hydraulically operated ring-follower gate.

The hub or stationary body of the needle is supported by six radial members extending out to the valve body, splitting the jet into six sectors. The hollow-jet valves in the Yellowtail installation are hydraulically operated, using a hydraulic cylinder mounted inside the needle and effecting a total movement of 29-1/2 inches (74.9 cm) from the fully open to fully closed position. The valves are designed to regulate the discharge under any head up to 465 feet (141.7 meters); and at that maximum head, an oil pressure of 726 lb/in^2 (5.0 MPa) in the closing chamber of the cylinder is required to hold the valve in a closed position. Any intermediate position is maintained by confining oil in the opening and closing chambers of the cylinder. As a background for further discussion, note in figure 2 that the closing chamber has a much larger cross-sectional area than the opening cylinder, matching the normal operating demands of the valve.

A single hydraulic system (including two pumps, two 4-way valves, pressure relief valves, and limit switches) operates both the ring-follower gates and hollow-jet valves. Oil pressure for opening the hollow-jet valves is limited to 500 lb/in^2 (3.45 MPa) by relief valves. Closing pressure of 900 lb/in^2 (6.21 MPa) for the hollow-jet valves and operating pressure of 1,800 lb/in^2 (12.42 MPa) for the ring-follower gates are limited by pressure switches.

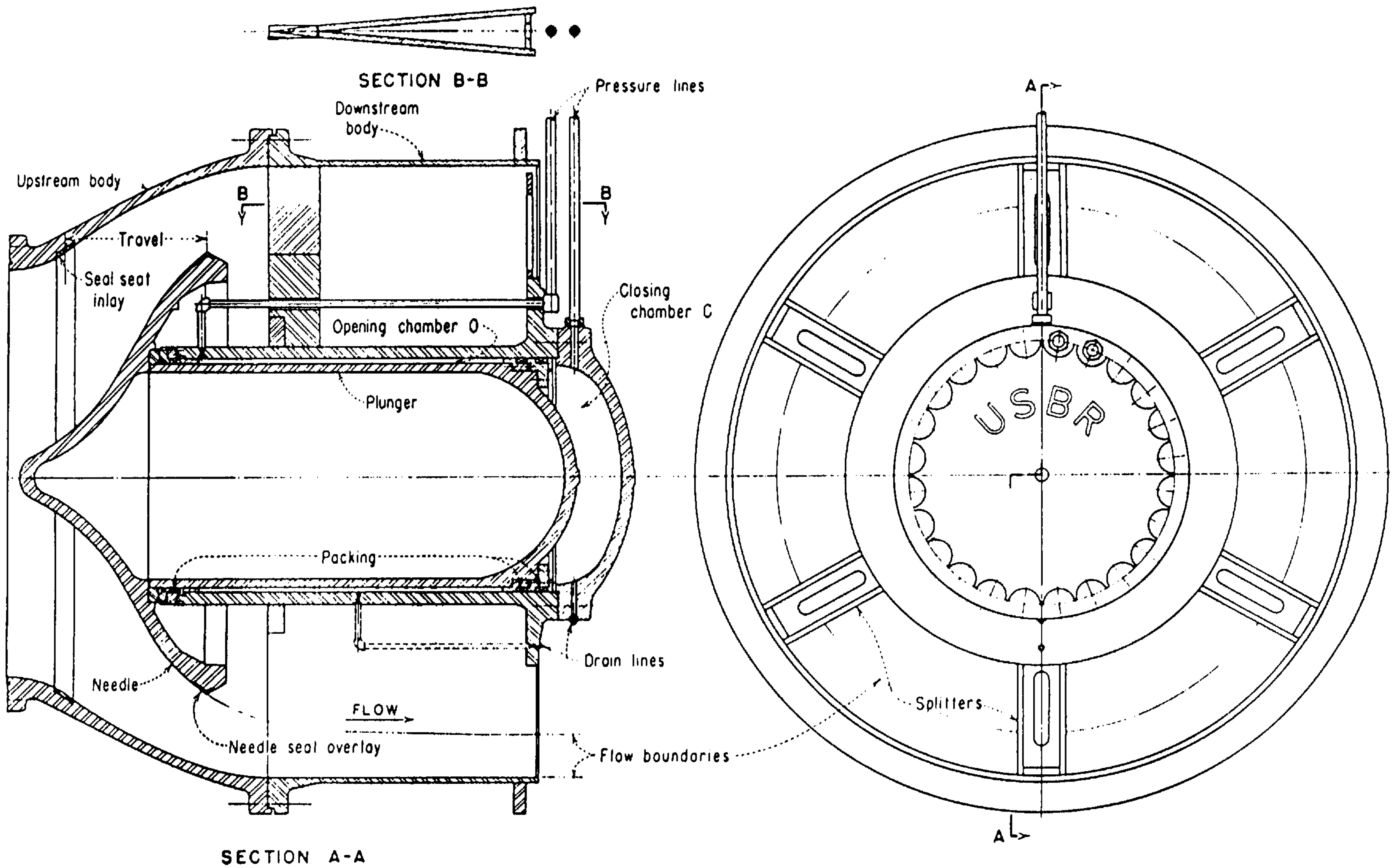

Figure 2. – Hydraulically operated hollow-jet valve.

The gate and valve test procedure was carried out for both outlet works. A summary of the test results for only the evacuation outlet works follows:

The manually operated air valve immediately downstream of the ring-follower gate, used for bleeding air during the filling of the discharge pipe between the ring-follower gate and hollow-jet valves, was examined and found to function satisfactorily. The ring-follower gate was first opened under balanced head with the hollow-jet valve closed, requiring a hydraulic pressure of 125 lb/in^2 (862 KPa), and an opening time of 6:41 (minutes and seconds).

The hollow-jet valve was opened and closed under unbalanced conditions through the maximum allowable opening of 18 percent, due to the riverflow conditions. This operation required an opening pressure of 625 lb/in^2 (4.31 MPa), an opening time of 1:24, a closing pressure of 700 lb/in^2 (4.83 MPa), and a closing time of 1:48. The ring-follower gate was then closed under balanced head requiring a closing hydraulic pressure of 170 lb/in^2 (1.17 MPa) and a closing time of 7:34.

The unbalanced guard gate test was then executed, first opening the hollow-jet valve with the ring-follower gate closed and then attempting to open the ring-follower gate to 10 percent of total opening height. The time required to open the hollow-jet valve with the ring-follower gate closed (under balanced conditions) should be noted. It required over 13 minutes to open the valve to 10 percent versus about 1-1/2 minutes to attain an 18 percent opening, under unbalanced head. Referring back to the hollow-jet valve description, note that normal operation under unbalanced conditions does not require much capability to open the valve because the movement is assisted by the waterflow and pressure. Under balanced head conditions, the valve is opened by hydraulic pressure alone, requiring a much longer time period to attain the required opening.

The above scenario presents an interesting problem. In preparing for the unbalanced test of the guard gate, some of the results of the close-coupling between the gate and the regulating valve were not expected. Operating the guard ring-follower gate under the unusual condition of unbalanced head requires operating the regulating hollow-jet valve under the unusual condition of balanced operation, with atmospheric pressure on either side of the valve, placing a limit on the conditions under which the ring-follower gate can be tested, unbalanced. The hollow-jet valve can only be opened 10 percent in a reasonable period of time, which could have some bearing on the performance of the guard ring-follower gate in the unbalanced test.

After opening the hollow-jet valve to 10 percent, an attempt was made to carry out the unbalanced opening of the guard ring-follower gate. The gate would open less than 1 percent, at which time the pressure limit switch shut down the hydraulic system at 1,900 lb/in^2 (13.1 MPa).

Similar results had also occurred for the testing of the irrigation outlet works, with the hollow-jet valve requiring 54 minutes to open 45 percent under balanced conditions, and the ring-follower gate failing to open beyond 1 percent before the hydraulic system shut down at 1,900 lb/in^2 (13.1 MPa). The tests were terminated without attempting to close either ring-follower gate under unbalanced head conditions.

As stated before, the unbalanced opening and closing of the ring-follower gate through 10 percent provides a maximum test of the hydraulic system without putting the outlet works at risk. The test assumes that if the gate can be opened 10 percent under unbalanced head, it can be closed under full-flow conditions, as required by the design criteria. One would expect this to be true since the friction and hydraulic down-pull forces are greatest over the 0 to 10 percent range, and since there is a greater available piston area for closing than for opening the gate. The ring-follower gates were designed to close under full flow, but the Designers' Operating Criteria do not mention opening under unbalanced head. The possibility that the need would ever arise to actually open the gate under unbalanced conditions is very remote, because of the multiple outlet works and power waterways that exist at Yellowtail.

In 1975 a similar test was carried out at Flaming Gorge Dam in Wyoming, another Bureau facility, which also has close-coupled ring-follower gates and hollow-jet valves. The test was done as a part of a study of the feasibility of automatically bypassing to the river a required minimum flow in the event of a shutdown of the Flaming Gorge Powerplant. The study was carried out to determine if one of the ring-follower gates could be operated unbalanced with the downstream hollow-jet valve preset to discharge 400 ft^3/s in the event of a plant shutdown.

The purpose of this procedure was to keep the hollow-jet valve unwatered and eliminate the possibility of freezing the valve during cold weather. The tests were completed, doing both unbalanced opening and closing of the ring-follower gate with a range of hollow-jet openings from 20 to 75 percent. The rate of gate closure varied with different valve settings due to the down-pull on the leaf, which over-ran the normal speed of the hydraulic system until frictional forces balanced the down-pull forces. In the process, a small amount of oil was spilled from the control system oil tank; some vibration was observed in the hollow-jet valve vicinity; and some minor paint damage occurred downstream of each ring-follower gate leaf. These minor damages occurred after doing five or six closures and openings and it was still concluded that it would be feasible to automatically bypass to the river a flow of 400 ft^3/s, operating the ring-follower gates unbalanced.

However, because of the minor damages that occurred at Flaming Gorge and the problems encountered at Yellowtail, the Bureau has deferred further unbalanced testing of guard ring-follower gates until further review can ensure that adequate control is maintained during the testing. There are several approaches to the problem. One approach is to acquire and analyze data from facilities with close-coupled ring-follower gates guarding power penstock wicket gates. Most of these facilities accomplish regularly scheduled full-flow closures of the guard with little or no damage occurring. Granted, the penstocks are designed for this, but there are enough similarities to warrant a comparison with outlet works. There are some data available from regularly scheduled tests eliminating the need to schedule special tests requiring the interruption of power production.

Another approach to unbalanced outlet works ring-follower gates testing is to work with laboratory models. A ring-follower gate is available in the Bureau's Hydraulics Laboratory, but funding would be needed to build an outlet works model, perform the testing, and analyze the data.

This past July and August, field prototype tests have been conducted at Anderson Ranch Dam and Navajo Dam outlet works by personnel from the Hydraulics Branch and the Operation and Maintenance Engineering Branch. Both facilities have ring-follower gates as intermediate guard gates, with fixed-wheel gates upstream acting as the primary emergency gates. The tests have been conducted, using additional instrumentation to document the performance of the ring-followers under unbalanced conditions.

Unbalanced operation was also attempted on the fixed-wheel gate at Navajo, which failed to open under unbalanced conditions. As a result of these tests on both ring-follower and fixed-wheel gates, the test procedures for these gates may be modified from the standard test developed for high-pressure slide gates.

Conclusion

During the outlet works guard gate testing, problems are being encountered which were unforeseen. Each facility has its own unique combination of guard and regulating gates and valves, and control systems.

The basic distinction of close versus distant coupling between guard and regulating gates reduces the number of problems, but the different types of gates and valves in each category must be examined closely to ensure a safe test procedure. The basic test procedure was designed primarily for high-pressure slide guard gates which are present in many facilities. Other types of guard gates, and the effects of close-coupling with the regulating gate or valve must be analyzed, and modifications of the test procedures may be needed.

SILICA FUME CONCRETE PLACEMENT
KENT DIVERSION STRUCTURE – NEBRASKA

by Kurt von Fay and Kurt Mitchell[1]

Silica fume concrete was placed as a 6-inch-thick inlay to protect the undersluice base of the Kent diversion structure from abrasion erosion caused by water-borne abrasive sediments. Silica fume concrete was selected because it is much more abrasion resistant than conventional concrete under the conditions that were present at the site. The inlay is sacrificial and was designed for easy replacement.

Silica fume concrete is a high-performance material, and its use is relatively new to Reclamation. As such, special attention to mixture proportioning, mixing procedures, placement procedures, and finishing and curing is required. Standard practices followed for mixing and placing conventional concrete may not work well for silica fume concrete.

The mixing procedure for mixing silica fume concrete ingredients does not usually follow mixing procedures used for conventional concrete. Because of differences in concrete materials and admixtures, mixing procedures should be developed on a case-by-case basis. The mixing procedure for Kent diversion structure was developed by the contractor's (W. R. Grace) technical specialist and entailed the following:

- Emptying 50-pound bags of silica fume admixture into the transit mixer.
- Placing one-third of the high-range water-reducing admixture (HRWRA) in the transit mixer with the mixing water, and start mixing.
- Adding the sand, coarse aggregate, and cement; and mixing for 3 minutes.
- Adding the rest of the HRWRA, and mixing for 3 minutes.
- Adding the water-reducing admixture (WRA), and mixing for 2 minutes.
- Adding the air-entraining admixture (AEA), and mixing for 1 minute.

This mixing procedure was adapted from earlier procedures to eliminate the formation of cement balls that occurred during the first placement (left river gate). All the admixtures, including the silica fume, were added by hand to the transit mixer.

At the suggestion of the contractor's technical representative, when admixtures were added to the batch, the mixing drum was reversed, and the concrete brought to the top of the drum. Admixtures were then poured directly onto the concrete and mixed in. Two batches were required for the placement, which totaled about 12 yd^3.

The silica fume concrete placement, finishing, and curing operations are very important for a successful application. Speed of placement and finishing are even more critical with silica fume concrete than with conventional concrete. Specific plans need to be developed to ensure that the silica fume concrete is placed, finished, and cured as quickly as possible.

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[1] Kurt von Fay is a Civil Engineer and Kurt Mitchell is a Civil Engineering Technician employed by the Bureau of Reclamation, Denver Office.

Placement and finishing operations were basically divided into three stages, corresponding to the level bottom area, the sloped middle area, and the level top area of the sluiceway. Two types of screeds were used - an H-beam with an attached vibrator and a vibrating screed. First the H-beam was hand winched, using winches attached to each end of the beam, over freshly placed silica fume concrete to spread and level it. Hand-held vibrators were used in front of the H-beam screed to assist with consolidation. After the bottom area of the placement was screeded with the H-beam, the beam was detached from the winching cables. The winching cables were then attached to winches at each end of the vibrating screed. The vibrating screed was hand winched over the previously screeded concrete to provide a smoother finish. After screeding, a bull float and hand troweling were used for final finishing. Placing and finishing of the sloped area and top level area were done similarly.

The sloped portion of the undersluice proved the most difficult to place and finish. Hand-held vibrators were used sparingly on the sloped portion since the vibration caused the silica fume concrete to flow downslope. Also, pulling the screeds up the slope seemed more difficult, particularly at the transition from the level bottom to the sloped middle section. The transition area was largely hand consolidated and finished. Concrete discharged from the bucket sat on the sloped portion for about 30 minutes before screeding.

In the Kent diversion structure application, liberal amounts of evaporation retarder were used throughout the placement to reduce water loss from the concrete and to ease finishing. The long-term impact of the use of large amounts of evaporation retarder is unknown. After finishing, a curing compound was applied with hand-held sprayers. Burlap was then placed over the concrete, with soaker hoses placed over the burlap, and all of that covered with plastic sheeting to keep the concrete wet.

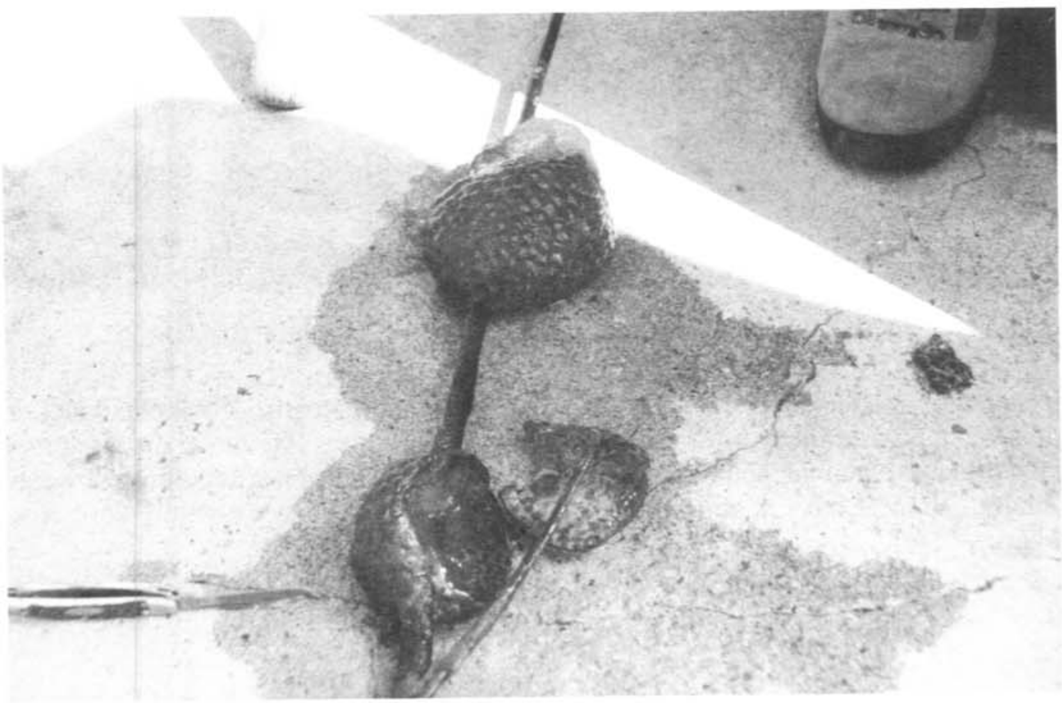
Rapid placement of silica fume concrete is extremely important to get adequate consolidation, to avoid shrinkage cracking, and to get a good finish. Mixing, placing, and finishing silica fume concrete requires more coordination, hard work, and skill than conventional concrete.

"MOSS ANIMALS" SIGHTED IN THE PACIFIC NORTHWEST

By Bill Bouley[1]

No, the "moss animals" are not the offspring of the science fiction "Swamp Thing." These invertebrate (spineless) animals were observed during a Review of Operation and Maintenance examination of Black Canyon Diversion Dam, on the Payette River, On July 7, 1992. The examination team first saw one of the animals carried by the current through the canal headworks trashracks. Another "moss animal" was captured on the trashrack debris.

At the intake structure for the power penstocks of the diversion dam, several of these creatures were found in communal bliss. They were attached to cattails, sticks, and other floating debris to form a gelatinous mass. Some of the sticks were removed to get a closer observation. We cut open one of the critters with a pocketknife. Their insides are like a bad batch of gelatin. Their exterior skin is bubbly in appearance with no identifiable features.

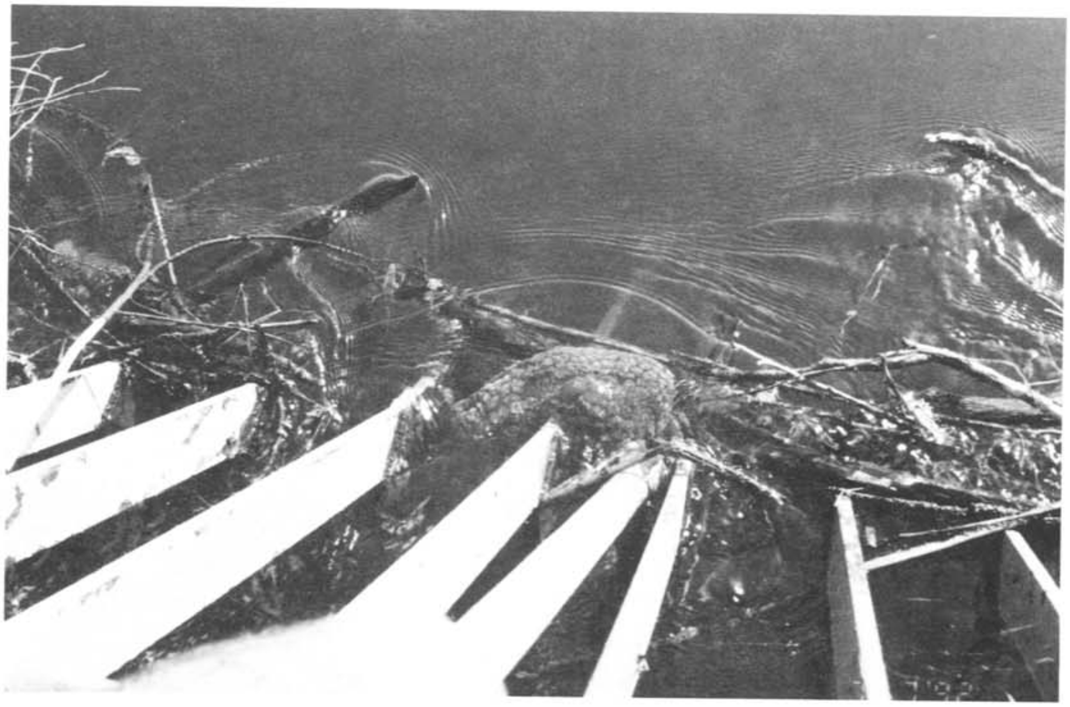


"Moss animals" on a stick (photo by Hope Cox, CSPO).

Hope Cox, a Mechanical Engineer in the Central Snake Projects Office (CSPO) contacted the biology department at Boise State University for information regarding these animals. They are members of the *phylum Ectoprocta* (Greek *ecto*, "outside"; *procta*, "anus"). Literal translation in science is generally unacceptable. Another way to describe these critters is their intake and outtake ports are very close to each other. Each creature consists of sessile colonies of zooids living in marine and freshwater environments. They reproduce asexually which is acceptable as long as you do not have a split personality.

[1] Bill Bouley is a Civil Engineer, Bureau of Reclamation, Denver Office.

It is their general plantlike appearance that earned them the common name "moss animal." Their exterior texture can be either gelatinous or chitinous (with overlap[ping transverse plates). These animals are found in shoreline regions throughout most parts of the world. They have even been found in Antarctica on floating pieces of ice.



"Moss animal" at canal headworks (photo by Hope Cox, CSPO).

Needless to say, these creatures posed no threat to the examination team. CSPO personnel removed the accumulations of sticks and "moss animals" from the intake structure. After later discussions with CSPO personnel, it was determined that these animals have been found in the past at other freshwater reservoirs in central Idaho. I hope I have supplied you readers with new high-point value words for your next "scrabble" game.

SPRING CLEANING[1]

Vacuum cleans reservoir without draining the water.

When San Joaquin Reservoir's water quality deteriorated last year, one of the major problems was traced to silt collecting on the reservoir's floor.

In the past, Metropolitan Water District drained the reservoir and hauled away the silt, but federal regulations prohibit releasing the water or working in a streambed without obtaining permits — a process that can take years. And Metropolitan didn't want to lose the water stored in the reservoir. That left few options. The challenge became to remove the silt without draining the reservoir.

District divers, accustomed to diving in San Joaquin, vacuumed the lake about twice a week to remove the silt from the outlet screens.

"One of the divers came up with the idea of using that principle on a larger scale," says Kent Brownsberger, who oversees the divers' activities. "Rather than a pump or motor, this process uses the natural pressure of the water in the reservoir.

1 Reprinted with permission from the Editor, FOCUS, Metropolitan Water District of Southern California, Los Angeles, California, issue Number 3, 1993.

The vacuum resembles a flattened funnel on wheels with a 4-foot mouth. Scooting across the floor of the reservoir, it gobbles up tons of silt and debris each day.

From the reservoir, the silt moves to a settling basin where it is pumped to a belt press and the excess water is squeezed out before the solids are shipped to a landfill. Since mid-April, Sajal Mitra, engineer in charge of field services, says the process has removed nearly 400 tons of silt.

"This process is unique to Metropolitan," says Mitra, who points out that permit delays are not the only reason this is a better way to go. "Draining a reservoir to clean it, as has usually been done, involves a lot of time and loses a lot of water."

With Southern California being a region that has no water to waste, the vacuum was developed as an all-around better way to clean a reservoir. And other agencies are indicating they may think so too. The Orange County Water District, for instance, wants to see if the process can be adapted to remove silt from groundwater recharge basins.

PROBING THE DEPTHS OF RECLAMATION TUNNELS

By Bill Bouley[1]

With over 275 miles of water distribution tunnels administered by the Bureau of Reclamation in the western United States, the pressure is on operation and maintenance personnel to keep the system running. To ensure that there are no unanticipated emergencies, the Review of Operation and Maintenance (RO&M) Program and annual project reviews are used to examine tunnel interiors after water deliveries have been concluded each water year to identify areas needing special attention prior to initiating waterflows the following water delivery season.

On the Colorado-Big Thompson Project, Gene Price of the Eastern Colorado Projects Office uses a diesel-fueled jeep equipped with a detergent exhaust scrubber to transport examination personnel into the larger tunnels in their projects area. The automobile is generally reliable, except once when a television news crew was allowed to film the tunnel trip through Alva B. Adams Tunnel. On that occasion, after the RO&M team completed its examination, the news crew climbed aboard to film the tunnel. Unfortunately, for the crew, the radiator fan broke free of its mounting and damaged the radiator, shutting the jeep down. The group had a choice – walk 5 miles uphill in the tunnel to the locked west portal or walk 8 miles downhill to the open east portal. Naturally, they chose to walk downhill, with the wind at their backs.

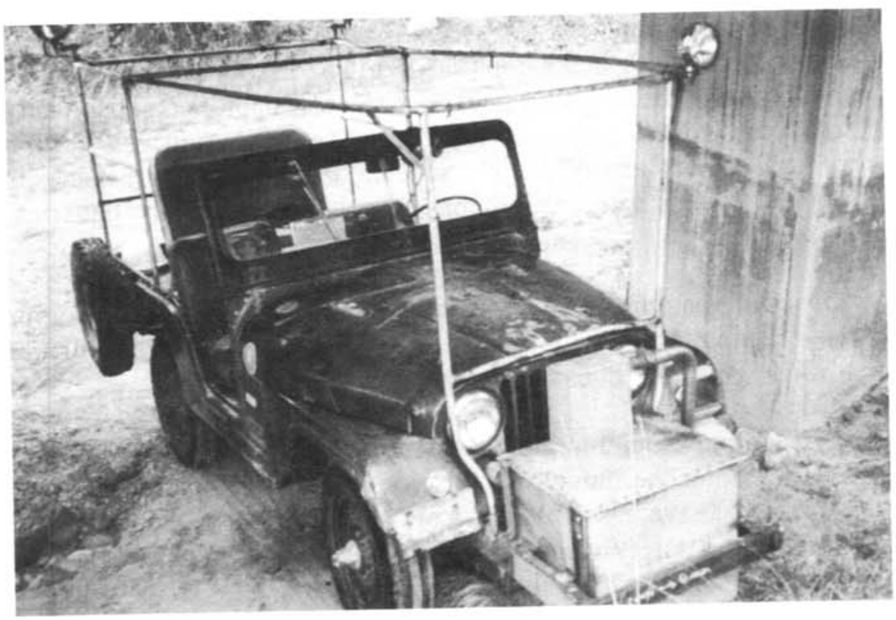


Photo 1. – Diesel-fueled jeep used in larger tunnels.

The largest tunnel in the California Central Valley Project is the 17.5-foot-diameter, 10-mile-long Clear Creek tunnel. Water flows from the Trinity River watershed through the tunnel to the 150-megawatt Judge Francis Carr powerplant and the Sacramento River near the city of Redding. At one point, the tunnel is 2,735 feet below the surface and it passes through five significant fault zones. There are approximately 3,000 joints in the reinforced-concrete lining. Ridges tend to grow at each joint. The ridges grow to no more than 1/2 to 3/4 inch high; however, the sum of their resistance is enough to reduce the

[1] Bill Bouley is a Civil Engineer, Bureau of Reclamation, Denver Office.

maximum output of the powerplant by 6 megawatts. For the above reasons, it is important to periodically inspect the tunnel.

The mode of transportation for inspecting Clear Creek Tunnel is a 1941 diesel-fueled jeep equipped with a catalytic exhaust gas scrubber. The jeep is lowered down the air shaft near the inlet of the tunnel and driven in reverse for 10 miles to the Crystal Creek Adit. The inspection team can exit the tunnel at that point and the jeep is normally driven back the next day.

The following is a true story of one inspection as described by Bill Nixon, Mid-Pacific Regional Office:

> Safety is the number one item. The tunnel was dewatered. The job hazard analysis had been laboriously reviewed many times. The oxygen sensor was working; it always worked "before" starting down the tunnel. The air velocity was measured and recorded. The jeep was placed in the tunnel. A ladder was attached to the jeep so that the top of the tunnel could be examined. The men with all sorts of safety equipment were on board. The engine started and the party drove away. One hundred yards down range, the engine died. Extensive investigation determined that no one had thought to put **fuel** in the jeep!

The San Juan-Chama Project has a series of tunnels totaling over 26 miles in length. The Chama Field Office uses a three-wheeled modified electric cart to inspect the tunnel interiors. On a recent RO&M, the Albuquerque Projects Office also rented a four-wheeled electric (golf) cart to assist in the inspection which required a survey of tunnel invert erosion (see Bulletin No. 162, pp. 48-50), and cracks in the concrete lining. Because of the circular cross section, a template was used to measure eroded and offset lining. The three-wheeled cart with headlamps is excellent for viewing the system, but echoes of expletives were heard whenever the middle wheel encountered an eroded section deeper than 6 inches. The four-wheeled cart straddled the eroded invert sections; but, when driven by an operator unaccustomed to tunnel work far from the light of day, it had a tendency to ride up the sides of the tunnels. The other disadvantage to electric carts is that if someone forgets to recharge the batteries, one may have to walk out of the tunnels.

The Provo Projects Office uses a more environmentally conscious approach in examining tunnels in its projects area. They use mountain bikes (hopefully going downhill). The disadvantage to this method may be the wet streaks one gets if he does not use raingear.

Other tunnels, such as Tecolote Tunnel in the Cachuma Project, are walked on foot due to the number of hot water springs which enter the tunnel. Because of the hot springs, there is a potential hazard of hydrogen sulfide gas and explosive gases. A physical examination is required to certify fitness for the tunnel examination walk, but a safety wagon is still brought along in case someone succumbs to the effort required to walk through the heat and humidity of the tunnel.

Air quality is evaluated prior to any tunnel inspection to determine the need for personal breathing apparatus. Canister-type air-monitoring devices are more effective where water spray is a problem. Monitors detecting levels of explosive gases, oxygen content, and presence of hydrogen sulfide have been used to ensure air suitability. It is no fun being a "mole" if you cannot stop and smell the concrete or rock lining.

Itineraries are left with surface crews to watch for the exit of the examination teams from the tunnels. This is because radio communications from inside a tunnel are not usually feasible. On shorter tunnels, air horns could be used to broadcast a predetermined distress signal to crews waiting at the exit portal.

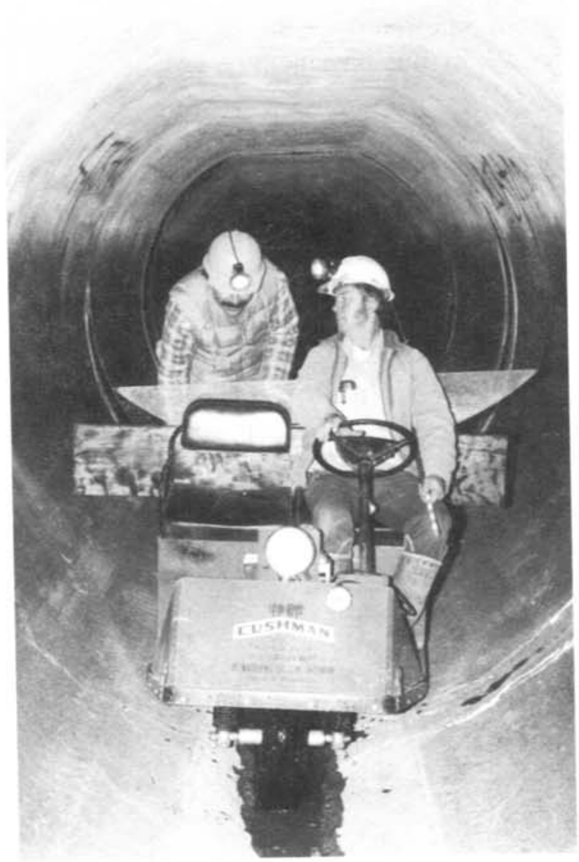


Photo 2. – Modified electric cart used in RO&M exam.

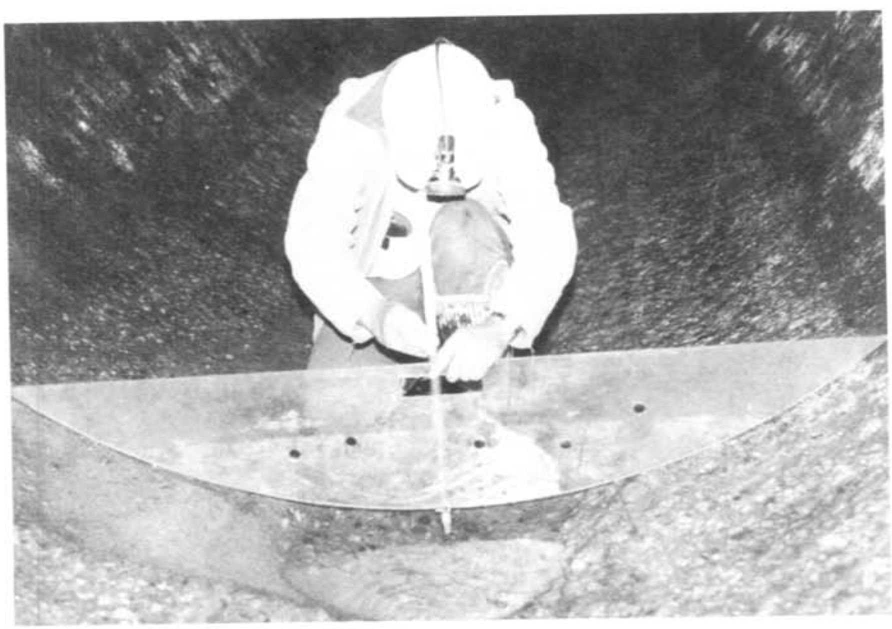


Photo 3. – Measuring the tunnel invert erosion using template and measuring device.

Additional technical information on tunnel examinations may be found in Reclamation's "Review of Operation and Maintenance Program Field Examination Guidelines," October 1991. This publication is available from the "Publications for Sale" booklet, Bureau of Reclamation, Attention: D-7923H, PO Box 25007, Denver CO 80225; price $3.30 plus postage.