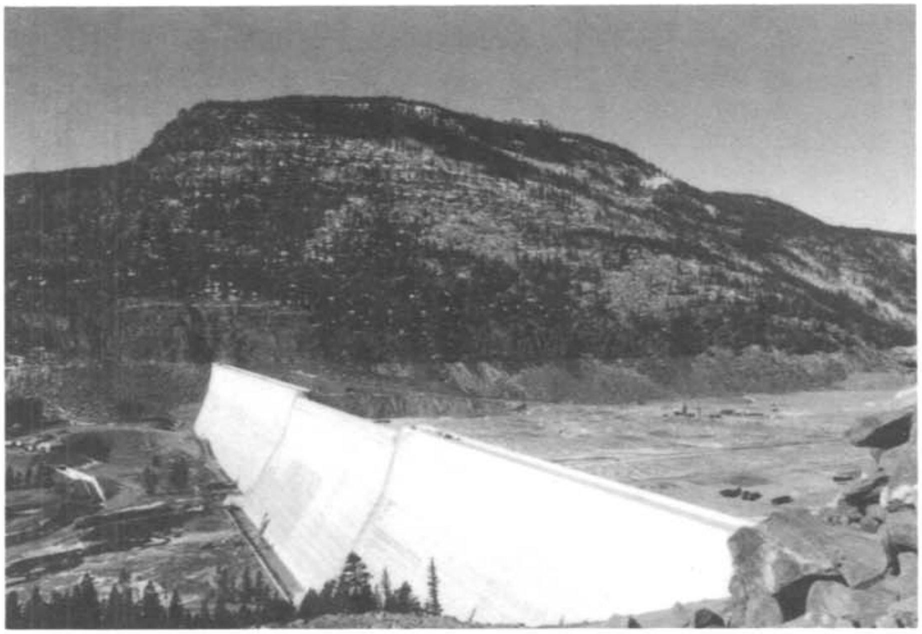
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 144

June 1988



IN THIS ISSUE

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

The Water Operation and Maintenance Bulletin is a technical publication prepared by the Bureau of Reclamation for use by its personnel and water and user groups for maintaining project facilities. The principal purpose of the bulletin is to provide technical information to water operating entities through the dissemination of Reclamation standards, criteria, and directives on acceptable operation and maintenance practices for storage and diversion dams or structures, conveyance facilities, and other appurtenant works.

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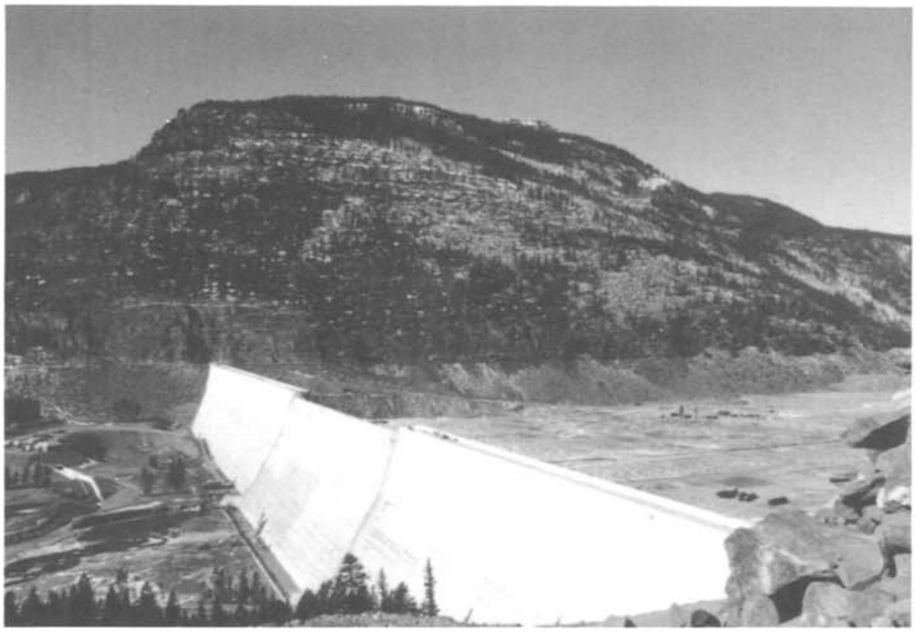

Cover photograph:

Upper Stillwater Dam, Bonneville Unit, Central Utah Project, is the spotlight of this issue.

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WATER OPERATION AND MAINTENANCE BULLETIN

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BUREAU OF RECLAMATION'S NEEDLE VALVE INVESTIGATION PROGRAM AND NEEDLE VALVE REPLACEMENT PROGRAM

Foreword

The Bureau's Needle Valve Investigation Program and Needle Valve Replacement Program are discussed in the following two articles.

The first entitled "Reclamation Replaces Needle Valves, Promotes Safety, and Saves Money" gives a general overview of both programs, stating the problems and steps toward a solution.

The second entitled "Investigation of Outlet Works Needle Valves" discusses the findings from investigating 47 needle valves at 20 dams. It contains a technical discussion of the existing conditions of needle valves, reasons for their unreliability, and modifications required to alleviate risk until the valves are replaced.

RECLAMATION REPLACES NEEDLE VALVES, PROMOTES SAFETY, AND SAVES MONEY

by Carol DeAngelis[1]

**As the Needle Valve Program Manager,
"I believe that we have taken a potentially hazardous situation, dealt with it at an immediate level to alleviate the hazard, and provided a long-term solution that is cost effective."**

The Bureau of Reclamation's Needle Valve Investigation and Replacement Programs are improving safety to operators and increasing the reliability of outlet works while realizing considerable cost savings.

The Bureau is in the process of replacing all of the hydraulically water-operated needle valves under its jurisdiction. Replacement of these obsolete valves was the result of an intensive investigation of needle valve operation. The Needle Valve Replacement Program was initiated to replace these valves within a 5-year period.

On January 7, 1984, a needle valve failed (photographs 1 and 2) at Bartlett Dam in Arizona while the operator attempted to reduce the flow from the valve. This failure resulted in the death of the operator.

The Division of Water and Land Technical Services took the lead in alerting all operators of these valves at Bureau facilities of this accident and cautioned them to follow operating instructions. The current status of each needle valve was requested along with any unusual operating problems. The responses indicated that an intensive investigative effort involving onsite inspection and operation was necessary, and the Needle Valve Investigation Program was initiated. These investigative efforts indicated that the valves were complex and expensive to operate and maintain, and there was a potential risk involved with anyone operating the valves. Modifications to the existing needle valves were required to reduce the possible risk to operators until the needle valves could be replaced.

Additional emphasis was placed on the Needle Valve Investigation Program on December 5, 1984, when erratic movement of a needle valve caused a penstock to rupture at a non-Federal facility. This incident resulted in the death of four employees of that facility.

Accidents at both facilities resulted from air being trapped in the operating chambers of the valves due to operator error. Therefore, the objective of the Needle Valve Investigation Program was to reduce situations of confusion and possible misoperation which could contribute to adverse situations to the operator.

Workshops on needle valve operation were conducted to alert operators to the operating characteristics of the valves, the possible risks of misoperation, indications of operating

[1] Carol DeAngelis is a Civil Engineer at the Bureau of Reclamation's Engineering and Research Center in Denver, Colorado.

problems, and proposed modifications to reduce risks to operators. These modifications would include installing automatic air venting systems which would ensure that the operating chambers of the valve were maintained full of water, and removing existing equipment which, if misoperated, could remove water from the operating chambers.

Analysis of the various needle valve designs indicated that the original concepts were sound; however, the valves are now considered to be obsolete in terms of maintenance requirements and potential safety hazards from operator error. Vern Yocom who was in charge of the Needle Valve Investigation effort observed, "The various needle valve designs were unique and served their intended function for 40 to 70 years. They fulfilled the original intent of providing a large outlet works valve that would operate without the use of electric power." These water-operated valves were utilized in remote areas where transmission of electricity was considered infeasible at the time.

The Bureau designed 68 needle valves which were installed at 24 damsites between 40 and 70 years ago. Onsite investigations and operation of the valves found 49 percent to be inoperable and 20 percent to be operable with restrictions. Thirty-one percent had been removed or replaced prior to this investigation. Onsite operational tests by members of the investigating program indicated that the valves were unreliable due to operating difficulties, the downtime of the valves associated with the intense level of maintenance required to keep them operational, and a lack of understanding of the complex internal workings of the valves. These difficulties provoked operators to change operating procedures or physically modify the equipment to force a problem valve to operate. The operating instructions, at most sites, did not reflect the changes made in operating procedures or physical modifications made to the valves. In many situations, these changes increased the potential for operator error. The unreliability of these valves also creates a serious concern in the event of the need for reservoir evacuation under an emergency condition.

Extraordinary costs would be required to return the valves to original design specifications, and to perform an acceptable preventive maintenance program. Some of the needle valve installations are not conducive to dismantling or overhauling for maintenance purposes. In most cases, access to the valves would account for additional expenses. The prohibitive costs of the long-term maintenance program required to keep the old equipment operational has justified replacement with modern equipment.

On May 17, 1985, the Commissioner determined that the Bureau's water-operated needle valves should be replaced by the end of fiscal year 1991, due to the complexities of operation and maintenance and the possible risk to operators associated with these valves. The above-mentioned modifications to the existing needle valves are required as an interim measure until the valves can be replaced. Needle valve investigation reports are being prepared for each facility and include an individual analysis of each valve, drawings showing the new modifications and any required changes to the control system, revised operating instructions, and a recommended date for accomplishment of the modifications. Upon completion of the modifications, the valves are retested and reevaluated in terms of condition and performance. Operation of the modified needle valves will be allowed until the valves can be replaced.

Under the Needle Valve Replacement Program, jet-flow gates have been chosen to replace the needle valves to reduce the number of modifications necessary to the structures. The discharge characteristics of the water jets exiting from the jet-flow gates and the needle valves are similar. Because of this similarity, the stilling basins or discharge channels require little, if any, modification. Discharge coefficients for the jet-flow gates are more efficient than for the needle valves. Therefore, a needle valve replaced by the same-sized jet-flow gate would discharge more water. This flexibility allowed the various-sized needle valves to be grouped into only five sizes of jet-flow gates. This grouping facilitated ordering large quantities of one size of gate for a considerable cost savings (approximately 30 percent) over procuring the gates separately for each facility. In most cases, jet-flow gate installations will require little, if any, structural modifications to the existing valve houses.

Maintaining the needle valves (using a specified program over 50 years) is estimated to cost about 40 to 60 percent more than the total costs of removing and replacing the valves and maintaining the jet-flow gates over 50 years. Maintenance costs for the jet-flow gates are minimal as has been the experience at one Bureau facility for over 40 years.

Separate fabrication and installation specifications were issued for the replacement process to facilitate timeliness and cost savings. The first contract for procurement of eight 60-inch jet-flow gates saved an estimated 30 percent per gate over procuring the gates separately for each of the four dams involved. The second contract for procurement of eleven 48-inch jet-flow gates is expected to realize similar savings. While the gates are being fabricated, specifications for the installation of the gates are prepared for each separate facility.

Needle valves have been replaced at Pathfinder Dam in Wyoming (photographs 3 through 7) and Echo Dam in Utah (photographs 8 through 12). It is expected that all Bureau water-operated needle valves will be replaced by the end of fiscal year 1991.

These programs have generated interest from several non-Federal entities in several states and countries with water-operated needle valves. The Bureau has alerted these organizations to the problems that they have experienced. The needle valves at each of the Bureau facilities were different and investigated on a case-by-case basis. Therefore, it would be wrong to assume that needle valves at non-Federal facilities would be similar to the Bureau's without further investigation. However, general operational procedures considered critical to the safe performance of the valves have been transmitted to assist these organizations in their own investigations. The Bureau is pleased to share its expertise and information in this area.

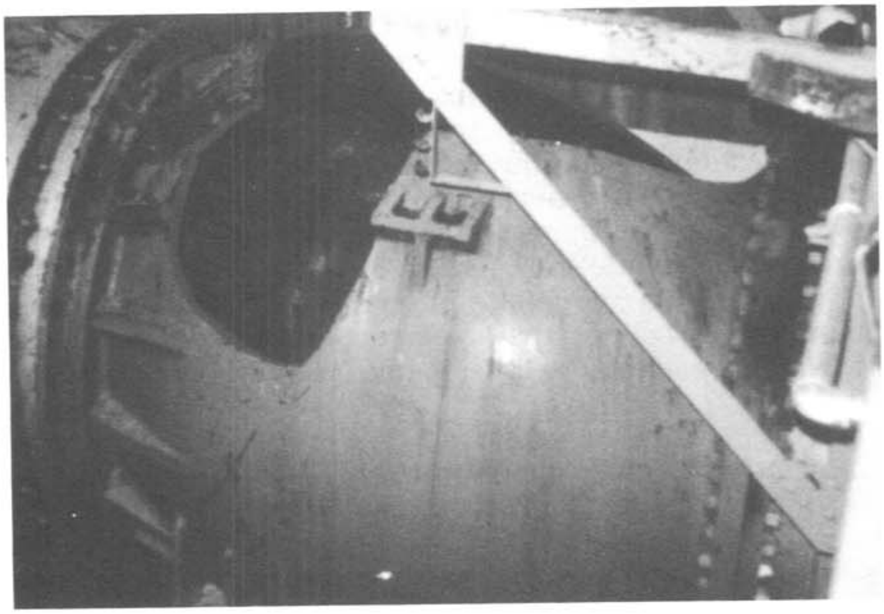

Photo 1. - Bartlett Dam, Arizona

66-inch needle valve after failure. Large sections of valve body were blown out.

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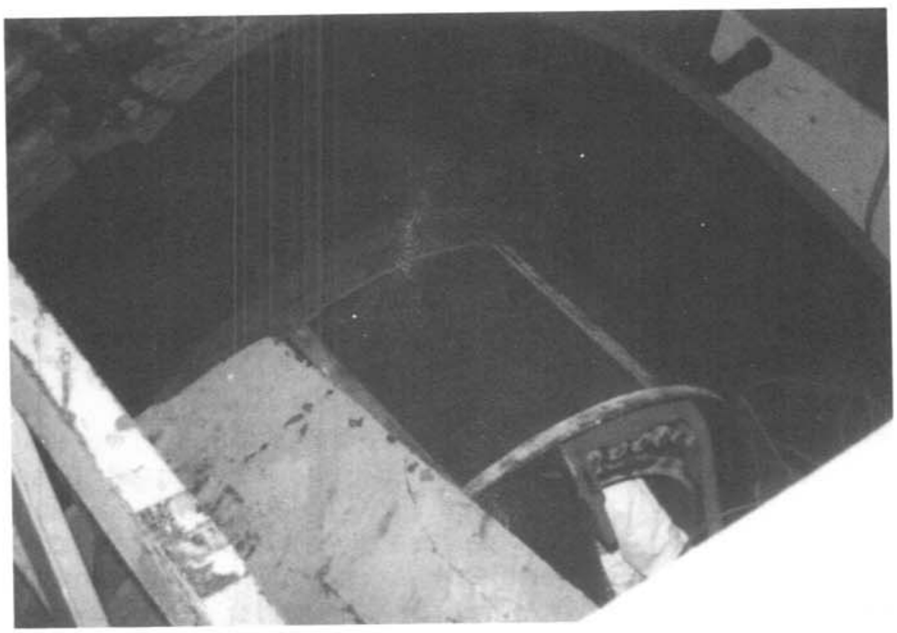

Photo 2. - Bartlett Dam, Arizona

66-inch needle valve failure as viewed from above. The valve casing is made of 1-7/8-inch-thick semi-steel. The operator stand was directly above this hole.

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Photo 3. - Pathfinder Dam, Wyoming

58-inch needle valve as viewed from above. The front portion of the valve body is being removed using mechanical and hydraulic jacks.

12/4/86

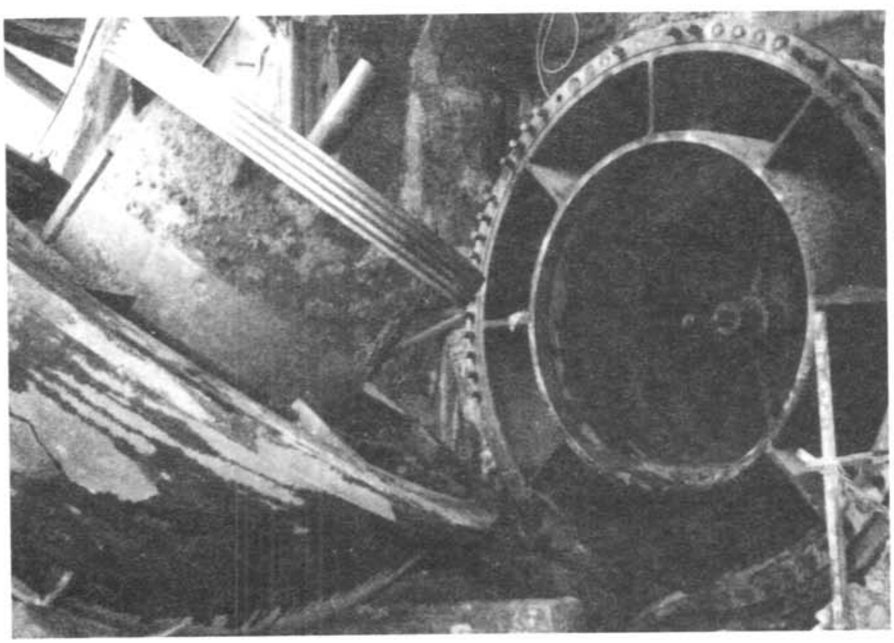

Photo 4. - Pathfinder Dam, Wyoming

58-inch needle valve. Needle and front portion of valve body removed from rest of valve. Note condition of interior surfaces of valve.

12/4/86

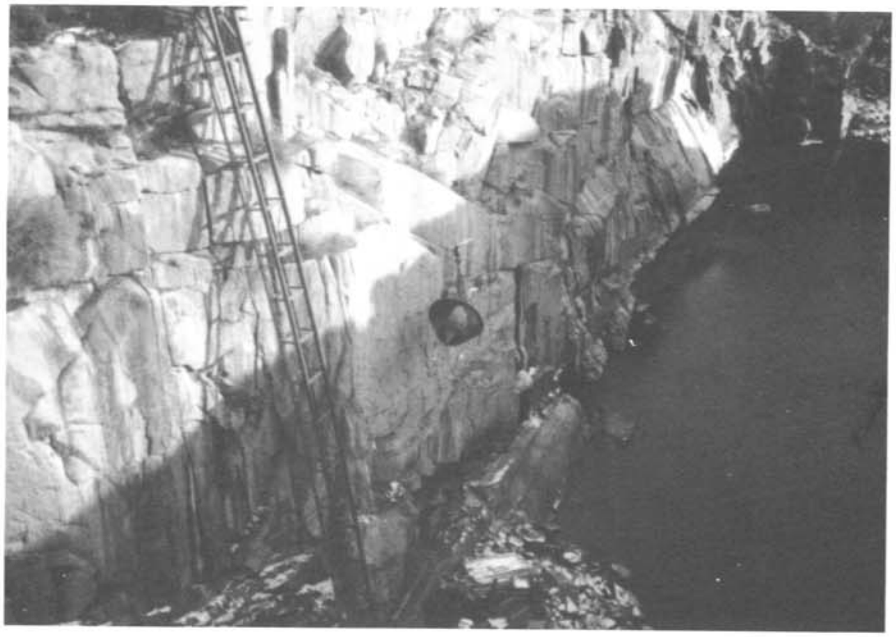

Photo 5. - Pathfinder Dam, Wyoming

Removal of front portion of valve body and needle as shown in photo 4. This piece weighs about 17 tons.

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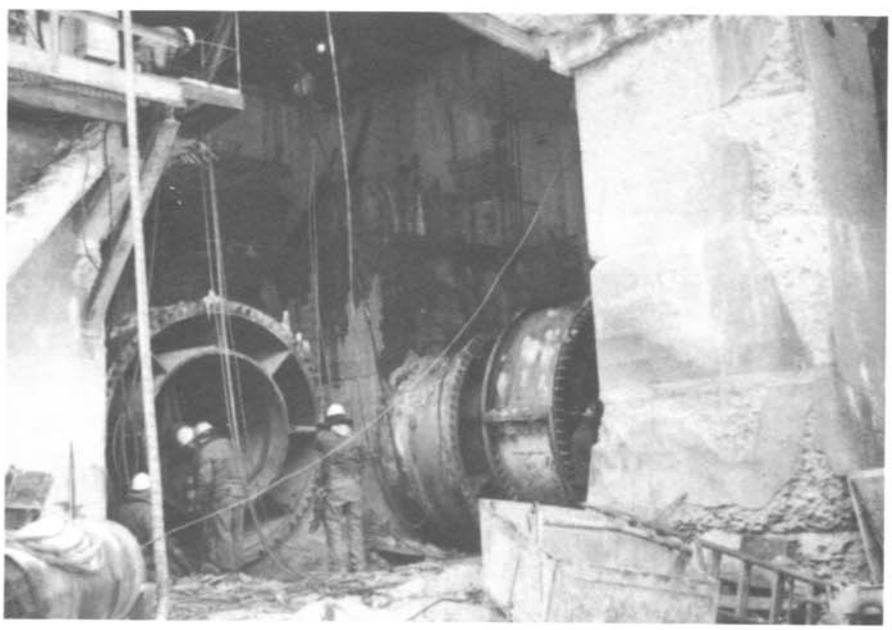

Photo 6. - Pathfinder Dam, Wyoming

58-inch needle valves in process of removal. The middle portion of the valve body (in background) was freed from the rest of the valve for removal.

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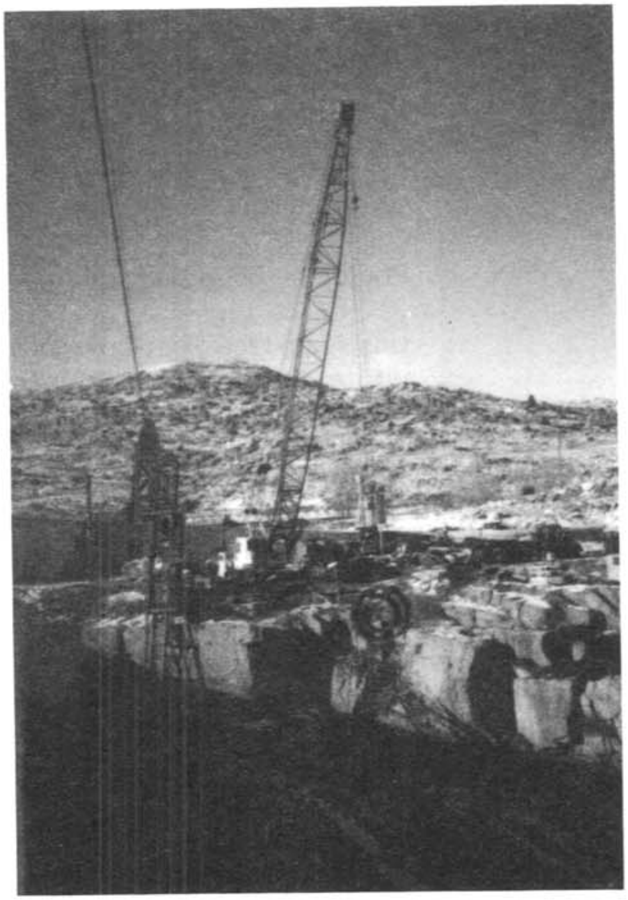

Photo 7. - Pathfinder Dam, Wyoming

Removal of middle portion of the valve body. This piece weighed just under 12 tons. The entire weight of one of the valves was in excess of 44 tons.

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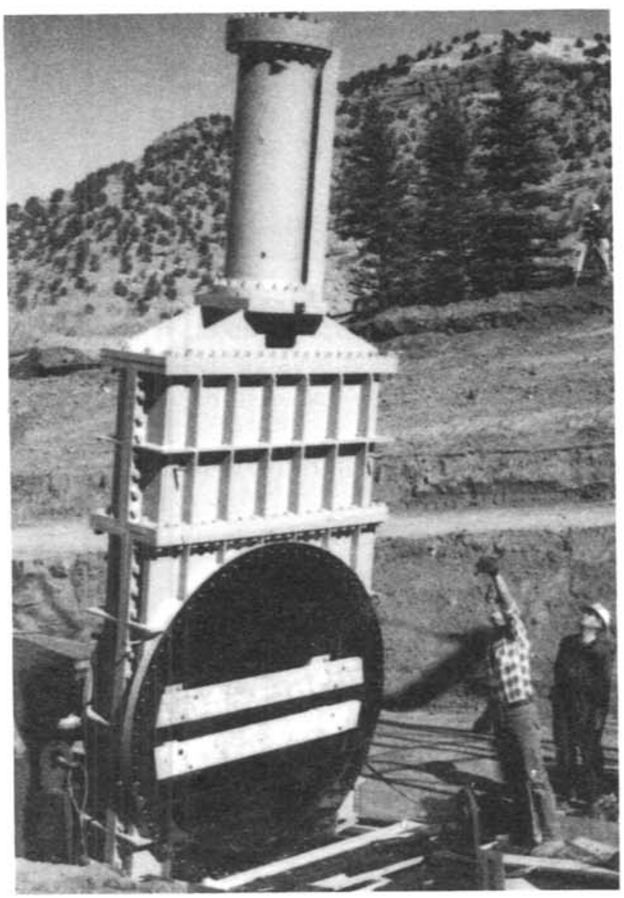

Photo 8. - Echo Dam, Utah

Downstream face of 60-inch-jet-flow gate as it is lifted from shipping crate.

10/29/86

Photo 9. - Echo Dam, Utah

Upstream face of jet-flow gate while being lowered into valve house.

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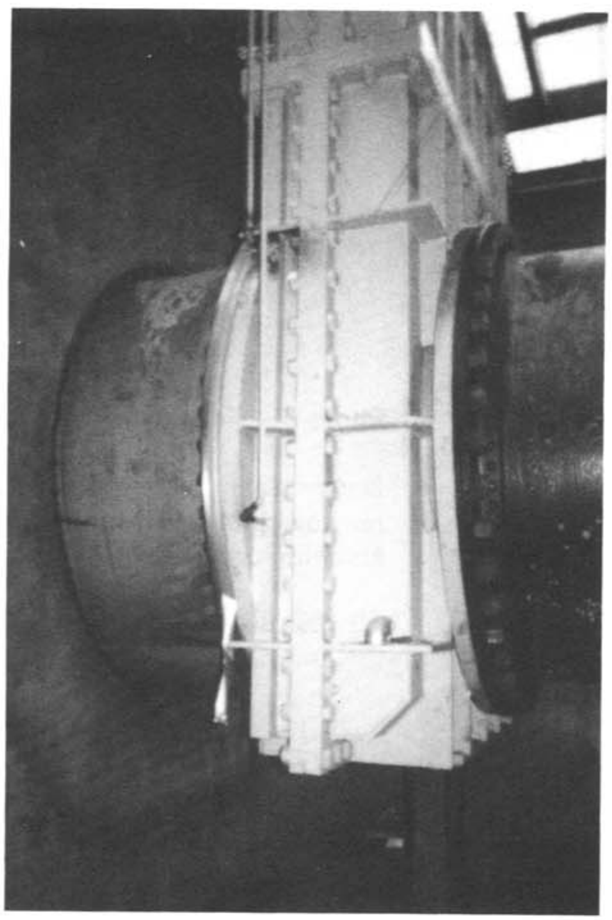

Photo 10. - Echo Dam, Utah

60-inch jet-flow gate in place. This gate replaced a 60-inch needle valve. Note additional pipe extension necessary to convey discharge from gate through the wall.

2/24/87

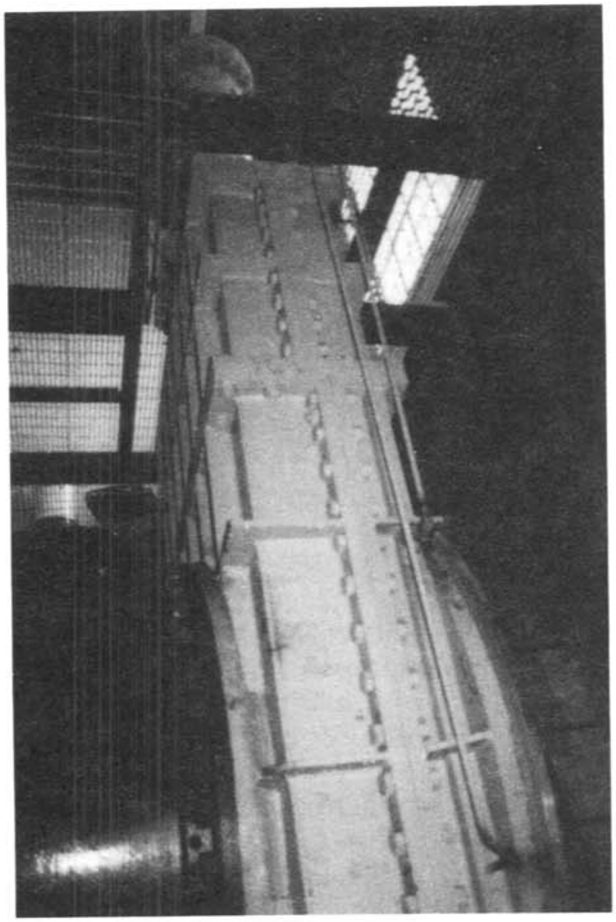

Photo 11. - Echo Dam, Utah

60-inch jet-flow gate in place in existing valve house.

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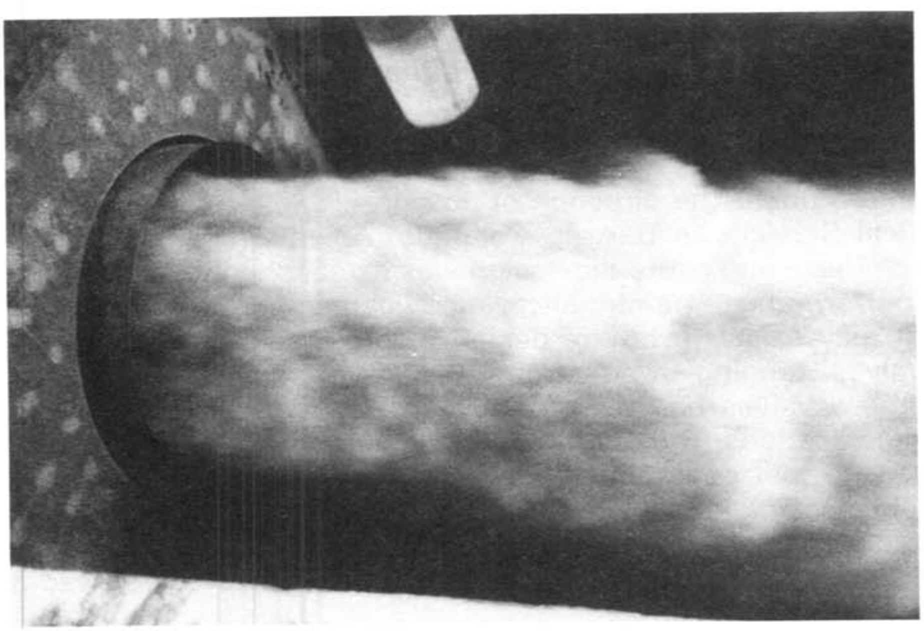

Photo 12. - Echo Dam, Utah

60-inch jet-flow gate operating at 100 percent open.

2/24/87

INVESTIGATION OF OUTLET WORKS NEEDLE VALVES

by Vern Yocom[1]

State-of-the-art, modifications, and obsolescence renders the Bureau of Reclamation's 40- to 70-year old needle valves potentially hazardous to operating personnel. The Commissioner of Reclamation directs their replacement by 1991.

This article contains complete details of the investigation program on needle valves in support of the Commissioner's decision for replacement. On-site conditions observed of needle valves clarified numerous conditions for operator error and subsequent failure of needle valves.

Bulletins No. 116 and 139 also contain information in regard to needle valves.

Introduction

On January 7, 1984, a 66-inch outlet works needle valve at a Bureau of Reclamation dam failed when operating personnel were changing the discharge. The valve failure resulted in the death of the dam tender. Failure of the valve was attributed to an open drain valve between the gooseneck piping and paradox control which permitted draining of the operating chambers within the needle valve. The presence of air in the operating chambers resulted in failure of the needle valve casting due to violent movement of the needle.

On December 5, 1984, four employees of a privately owned and operated dam lost their lives when a penstock ruptured. Rupture of the penstock was caused by pressure transients that developed as a result of erratic movement of a needle valve. The erratic needle movement was due to the presence of air in the operating chambers resulting from improper air venting procedures.

As the Bureau of Reclamation has 23 dams with outlet works needle valves, an immediate investigation was implemented under the direction of Joseph L. Miller, Chief, Division of Water and Land Technical Services in Denver, Colorado. An investigation team of technical specialists in mechanical and hydraulic design was established to review each installation for history of performance, maintenance, modifications, malfunctions, and any other abnormality that may exist. Review of design records indicated the Bureau had installed 68 needle valves, ranging in size from 10 to 86 inches in diameter, at 23 dams. Twenty-one of these valves had been removed or replaced over the years in conjunction with other modifications. The remaining 47 needle valves were inspected; and where possible, they were test operated by the investigation team in 1985 and 1986. At the time of the field inspections, 14 valves were found in an operable condition and 33 were inoperable for a variety of reasons, which are discussed later in this article. Although 14 valves were determined to be "operable," deficiencies were observed at all installations that required modifications.

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Performance of needle valves prior to this investigation had been rated through a range from good down to unreliable. In general, the higher the rating, the better the valve had been maintained. But, this is not always true as the water quality and other conditions can significantly influence the amount of maintenance required on these water-operated valves. Results from this investigation reinforce this statement, with stronger findings toward their unreliability, and the potential hazard to operating personnel through misoperation.

Based on the results of the needle valve investigation, the Commissioner of the Bureau of Reclamation is requiring all needle valves to be replaced by the end of fiscal year 1991. Interim modifications, training of operating personnel, and improved operating instructions at each installation of needle valves have been implemented to reduce the risk to the operators until replacement can be achieved.

Background

The evolution of needle valves for the Bureau of Reclamation began with the invention of the Ensign valve in 1908 by O. H. Ensign, then the Chief Engineer of Reclamation. Figure 1 is a section through an Ensign valve and a portion of the discharge conduit. Parts of the valve are a stationary cylinder called the body, a hollow cylindrical plunger with a needle tip and seal ring at its downstream end, a ribbed support ring holding the valve in position in front of the discharge conduit and forming the seat, and a discharge throat liner connected to the conduit. At the outer diameter of the plunger and about midlength is a piston-ring arrangement, called a bullring, which fits the stationary cylinder. An Ensign valve is usually mounted on the upstream face of the dam, below the waterline, so that it operates completely submerged. Water flows between the support ribs and is diverted into the discharge conduit by the shape of the needle tip. Flow is regulated by varying the position of the plunger. The bullring fits the cylinder with sufficient clearance to equalize pressure inside and outside the cylinder when a valve in the control pipe is closed. With the pressure thus equalized, the plunger will move to the closed position because the area at the back of the plunger exposed to the pressure is greater than the effective area of the needle tip. Opening the valve in the control pipe reduces the pressure in the cylinder. The unbalanced pressure then causes the needle to withdraw, opening the valve and allowing the discharge of water. The Ensign-type valves were not entirely satisfactory, partly because of cavitation erosion, which damages the needle tip and throat liner, and partly because it was necessary to lower the reservoir water level to gain access to the valve for maintenance or repair.

The needle valve for reservoir outlet service was developed in the 1915-20 era in an effort to overcome the difficulties which had been experienced with Ensign valves. Needle valves were designed to operate at the downstream end of a conduit, where discharge into the open air was possible, thus eliminating the opportunity for cavitation within the conduit and other destruction to the dam. A considerable evolution occurred in the design of needle valves, each redesign being an attempt to improve the hydraulic characteristics, reduce the size, or reduce the cost of the valve. Though frequently modified in design, a needle valve remained essentially a globular body, supporting and enclosing a stationary cylinder, mating with a movable needle which effects the closure. An annular water passage surrounds the needle and cylinder. Movement of the needle, by which waterflow is regulated, is effected by changing the water pressure within the hollow cylinder as discussed for the Ensign valve. The construction of a needle valve is such

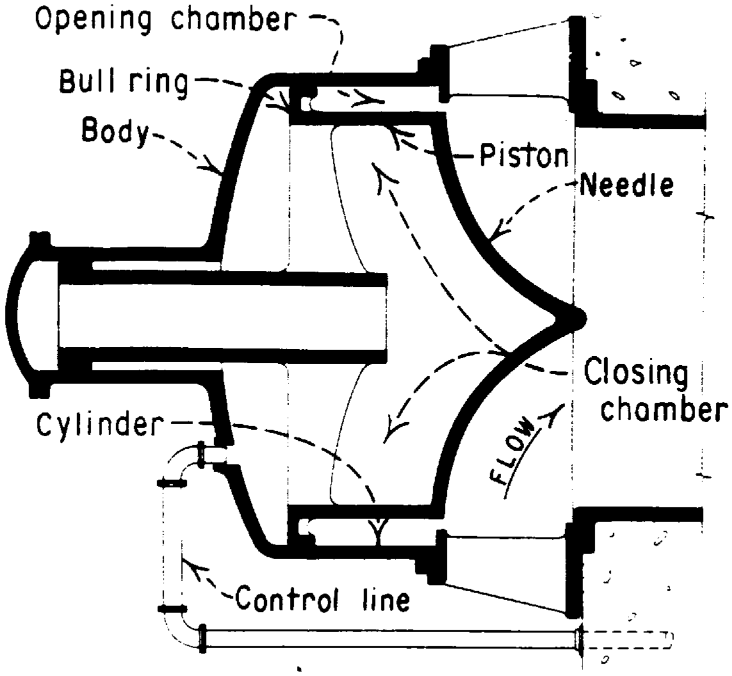

Figure 1. - Ensign (balanced) valve.

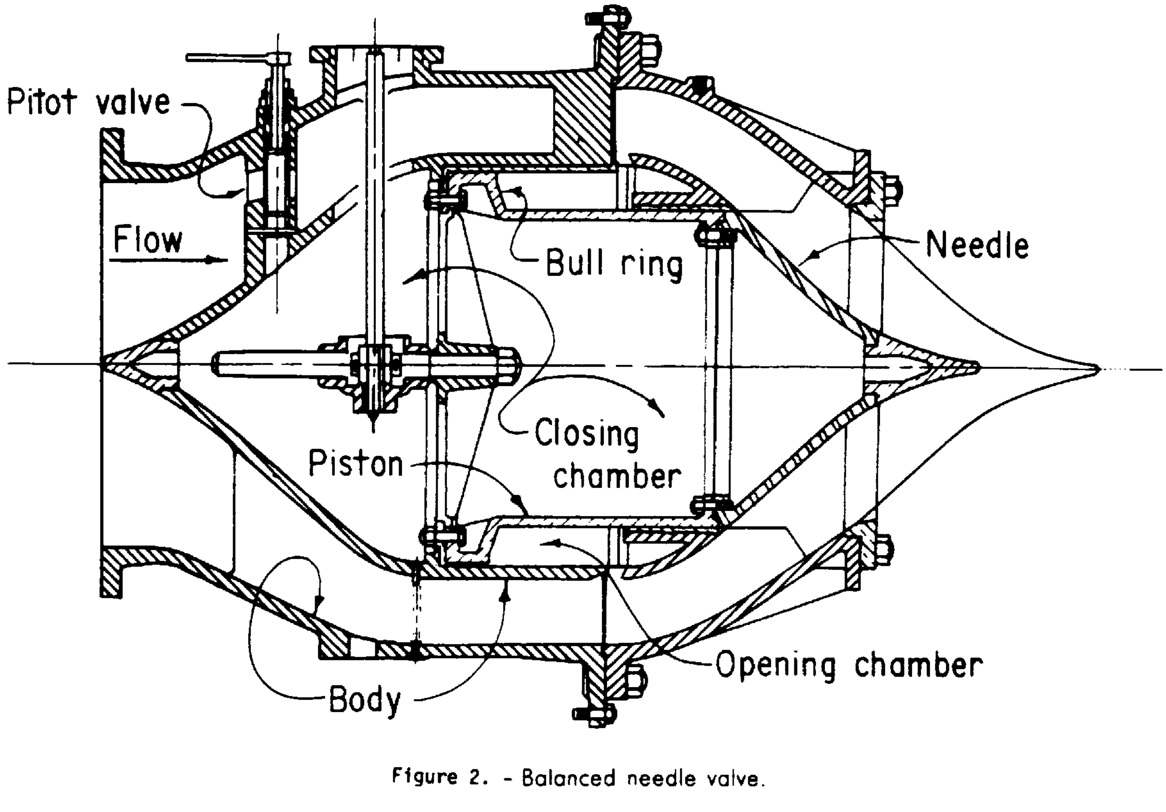

Figure 2. - Balanced needle valve.

as to guide the waterflow smoothly through the valve. Figure 2 represents the original needle valve design, referred to as a balanced needle valve.

Operation of the valve is by means of the regulation of pressure within the interior body. The interior of the valve body and the interior of the needle-piston assembly form one large water chamber (closing chamber). Water enters the closing chamber both by designed leakage around the bullring and through the pitot valve located in a splitter of the valve body. Balance of the needle is controlled by throttling discharge from the closing chamber. The throttling device or control unit is usually mounted on top of the needle valve body and consists of two concentric sleeves. One sleeve is rotated by movement of the control handwheel and the other by movement of the needle. Overlapping ports in these sleeves control the flow of discharge water.

Figures 3 and 4 represent needle valve designs that followed the earlier balanced-style discussed above. The basic concept of differential pressure for movement of the needle remains; however, the major change involves supplying operating water to the chambers from an external source. The "Internal Differential" design shown in figure 3 has the needle movement occurring within, or internal to the valve body and nozzle. The "Interior Differential" design shown in figure 4 has the needle movement occurring over and within the interior of the body extension.

Investigation

Subsequent to the January 7, 1984, needle valve failure, and the later malfunction at a private installation previously discussed, the Bureau of Reclamation initiated the Needle Valve Investigation Program. All operating personnel at dams where needle valves are in service were immediately informed of the incident and cautioned to follow the operating instructions provided for their needle valves. Information was requested from each installation on the current status (operable, inoperable, removed, or replaced), along with any unusual operating problem, past maintenance records, and current operating instructions. Based on the preliminary analysis of information received, it was apparent that there was limited knowledge available on the intricate design features of needle valves and ramifications of modifications to the operating systems. A more extensive investigation was implemented that would include an on-site inspection and operational tests of each needle valve by members of the investigation team. It was also determined that the team should provide detailed training to operating personnel to reduce the possibility of operator error. Since the needle valves have been in service for 40 to 70 years, technical background on the design of these valves was lacking. In order to accomplish the above objectives, the first effort of the team was to review the design characteristics of needle valves.

In simplified terms, the standard configuration of all needle valves has the axis of the valve in line with the axis of the outlet pipe. The working parts are in the center of the valve located along the axis and are attached to the outer body by ribs. The body must be enlarged to form a water passage between the internal parts and the body, and then gradually reduced to the seat on the downstream end. The movable control element is called a needle, as the downstream end is tapered to a point (figures 1, 2, 3, and 4). The needle is held against the body seat to close off flow and is moved upstream to allow flow. Water contained in chambers inside the valve and acting on

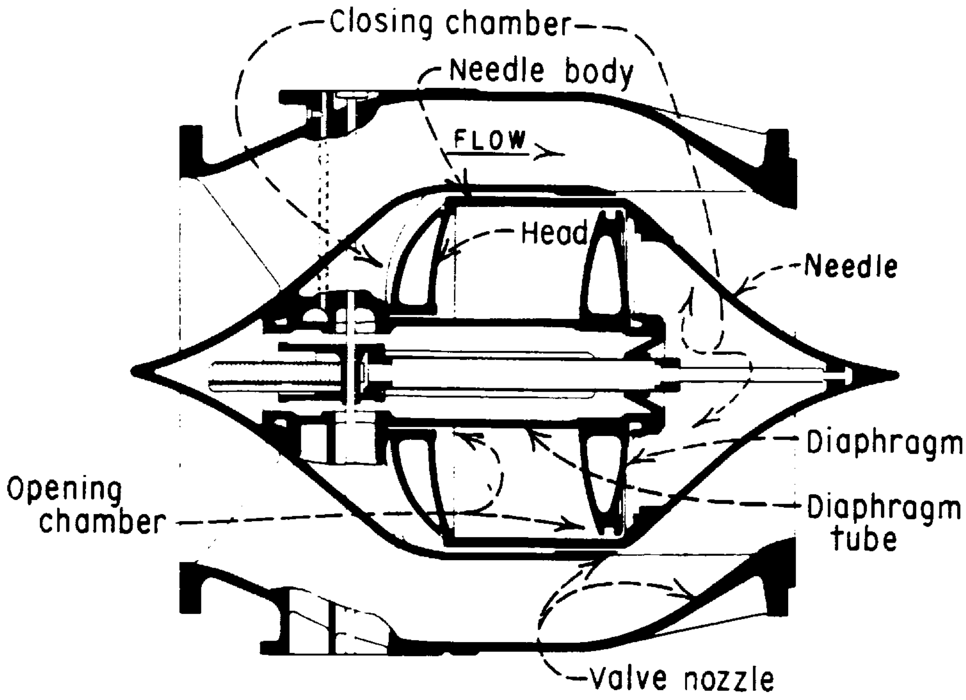

Figure 3. - Internal differential needle valve.

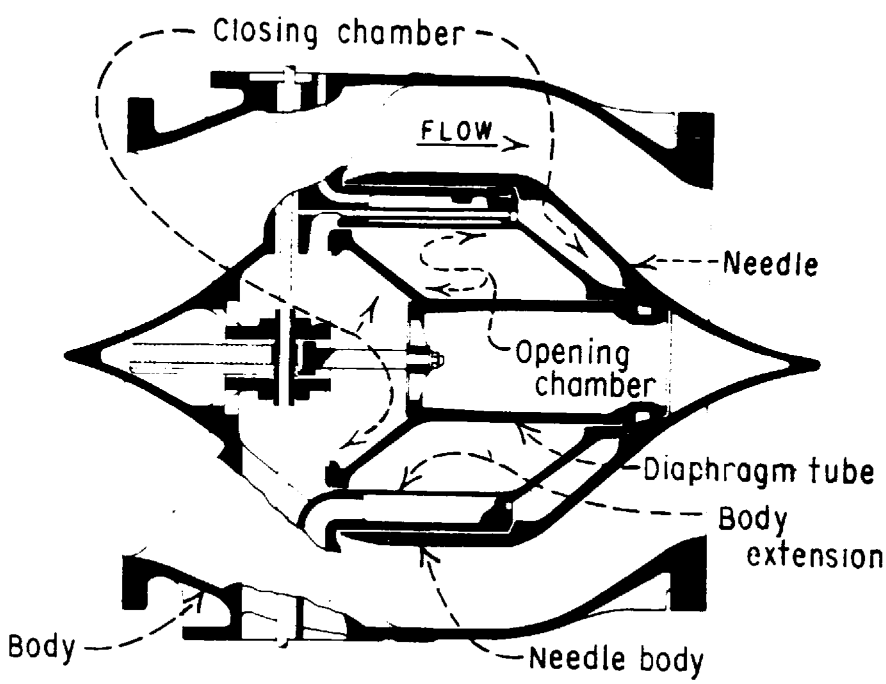

Figure 4. - Interior differential needle valve.

plungers or pistons, controls the movement of the needle. A control valve or unit is provided to control the flow of water into and out of the chambers.

The control unit is actuated by a handwheel and by the movement of the needle. When the handwheel is turned, the control unit is actuated to produce needle movement in the desired direction. The needle movement returns the control unit to a neutral position, or position of hydraulic balance within the operating chambers of the needle valve. If the needle drifts from the set position, the control is actuated to return the needle to a balanced condition. The arrangement of the chambers is different in each type of valve and there are even more variations of control units, but this general principle of operation applies to all needle valves.

From the above discussion, it should be apparent that needle valves are hydraulically water-operated valves, with movement of the needle dependent on creating sufficient differential pressure within the operating chambers. A study of the operating chamber arrangement on all types of water-operated needle valves reveals that designers provided a larger force to close the needle than to open it. What was not a design consideration, but adds an extra closing force, is a subatmospheric pressure created on the needle by the discharging water. As a result, difficulties with the valves will often appear first during the opening cycle, rather than the closing cycle. The needle on any of these valves is held in an intermediate position only by a balance of hydraulic forces and the friction load on the needle. The position is not positively held, as it would be on a mechanical valve, but is influenced by any condition that upsets the balance of hydraulic forces.

Successful (safe) operation of needle valves is dependent on several conditions (refer to figure 5).

1. Design tolerances between the needle valve and body sliding surfaces being maintained. Scale buildup on bronze surfaces will increase the differential pressure required for movement of the needle to the point that the valve will not operate.

Also, if the clearance is too great, leakage from the operating chambers may exceed the water supply capacity, rendering the valve inoperable.

2. The condition of the control (paradox) unit is equally critical for correct operation. The sliding surfaces of the control liner and piston must be maintained at specified tolerances. Wear allows excess water leakage into, out of, or between valve chambers. Leakage, in this manner, can pass the piston going directly to drain, never entering the valve operating chambers. The quantity of water available to operate the valve is decreased by the amount of leakage. Or, in some cases, leakage into a chamber may result in too much water, reducing the differential pressure enough that sluggish operation results.

3. Buildup of an organic material between the surfaces of the control liner and piston of the paradox control for the internal and interior valves (figures 3 and 4), and the two concentric sleeves of the control unit for the balanced valves (figure 2), can result in inoperable needle valves. Experience has shown that these controls must be dismantled and cleaned yearly, as a minimum.

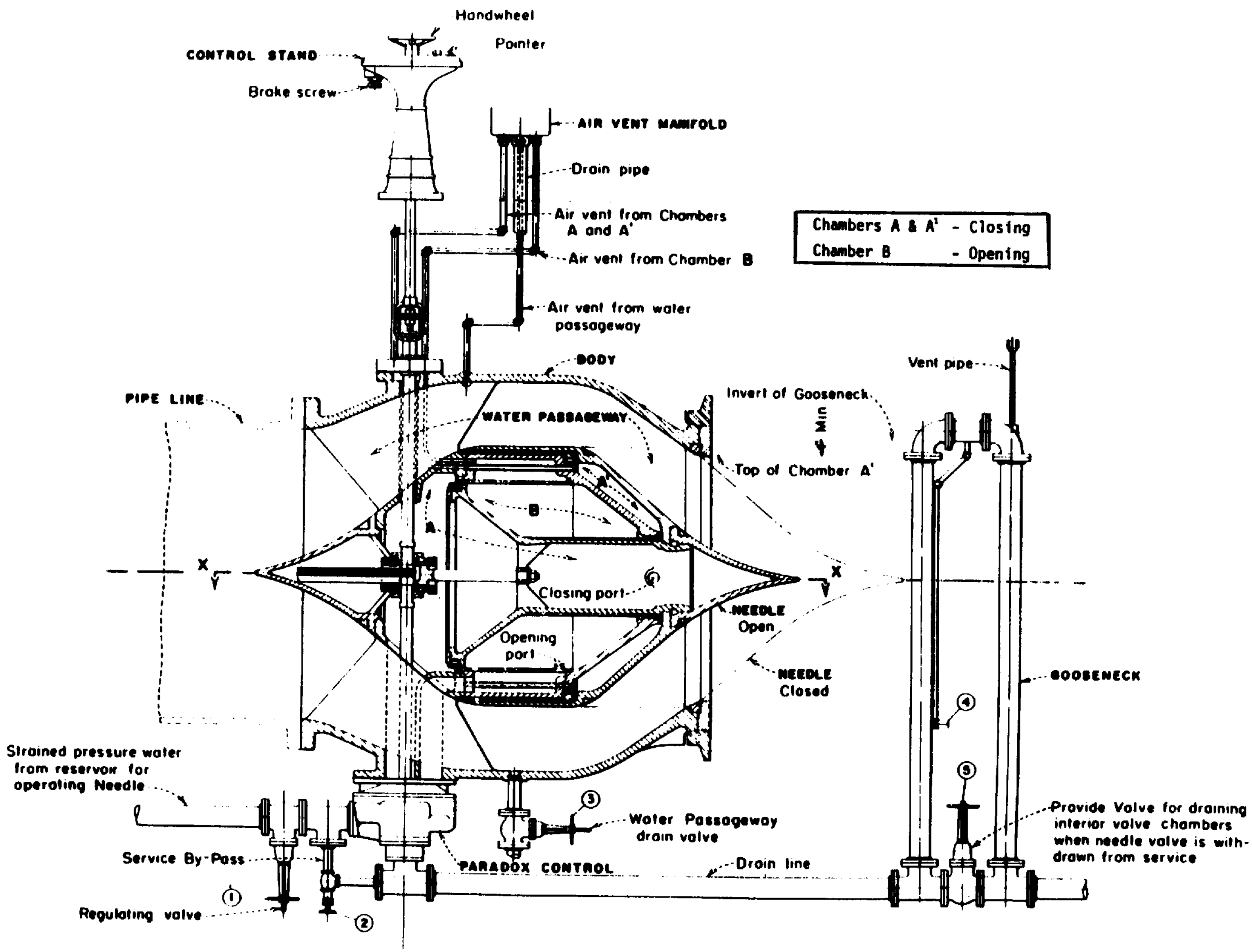

Figure 5.

LONGITUDINAL SECTIONAL ELEVATION OF NEEDLE VALVE AND SCHEMATIC ARRANGEMENT OF OPERATING EQUIPMENT

4. The operating chambers must be maintained full of water at all times that the needle valve is in service. Partially drained chambers permit the presence of air which provides a compressible gas that could result in uncontrolled rapid needle movement. Two features were designed into each needle valve system that were intended to ensure that the chambers remain full of water - an automatic air vent manifold and a "gooseneck" piping arrangement on the operating chamber discharge. The automatic vents consisted of a poppet-type valve from each operating chamber. These devices have proven to be unreliable and, in most cases, have been replaced with manual valves. With manually operated air vent valves, air can accumulate in the chambers during normal operation.

The top of the gooseneck piping is set above the elevation of the internal operating chambers to insure that the chambers remain full. A vent connection was provided on the top of the gooseneck for admitting air into the drainpipe to break the siphoning action within the gooseneck. If the siphoning action is not interrupted, draining of the needle valve operating chamber could occur, resulting in uncontrolled rapid needle movement during subsequent adjustments of discharge from the needle valve.

5. The water supply line to the operating chambers of internal or interior designed differential needle valves must be unrestricted to provide sufficient volume to the chambers to maintain them full. Takeoff connections from the supply line for other purposes should not be permitted.

6. A shear pin was designed into the coupling between the handwheel stem and paradox control drive shaft. The purpose of the pin was to prevent excessive force from being applied to the control unit.

7. Specific operating instructions for each needle valve installation were not provided. Each needle valve design included a standard set of instructions that were universally used.

8. The valve house size and lack of handling equipment at some of the needle valve sites severely restricted the extent of maintenance that could be performed. At several sites, the needle valve body was embedded in the downstream concrete wall.

The early century designers of needle valves produced designs that were innovative for the intended purpose of controlling releases from reservoirs in remote locations. The needle valves have proven durable and cost-effective, in terms of the 40 to 70 years of service. Unfortunately, the technical understanding of the design principles of these valves has been lost and has resulted in poor maintenance practices, detrimental modifications, and consequently, misoperation – placing operating personnel in hazardous situations. If the needle valves were to be retained in service, major overhaul including new materials and modified designs would be required. The estimated cost of accomplishing this effort, plus performing routine annual maintenance, and annual training of operating personnel would be prohibitive. Replacement with a "state-of-the-art" designed regulating gate (jet-flow gate recommended by Reclamation), with its low maintenance requirements, proves to be more cost-effective.

Existing Conditions

During the 1985-86 investigation period, the existing conditions of 47 needle valves remaining in service at 20 dams were inspected and test operated where possible. Only 14 valves out of the 47 were found to be in an operable condition. "Operable" condition should not be interpreted here to mean "acceptable," as deficiencies were observed in all cases that could impact safe performance of the valves. The remaining 33 inoperable valves suffered from a variety of symptoms - broken spiders, broken operating shafts, sliding surfaces corroded together, sheared pins, frozen paradox controls, sheared lugs on paradox control screws, and other unknown internal problems. It should be emphasized that our investigation effort dealt primarily with the external features of needle valves, where misoperation directly contributed to the two accidents described earlier in this report. These external features can be described as (1) venting system for each operating chamber of the valve, (2) water supply system to the operating chambers, and (3) water discharge system from the operating chambers. Following is a general discussion on the findings from the on-site inspections:

1. The original air venting system consisted of automatic poppet-type valves designed to vent all air from the operating chambers, then seat as the water floated the poppet into the seat. These automatic valve manifolds were found defective from corrosion in all cases. The corroded sliding surfaces between the sleeves and poppets prevented free movement, resulting in air entrapment within the needle valve-operating chambers. At some installations, the automatic poppet valves had been removed and replaced with manual valving. The manual valves would vent off air during initial filling, if the operator remembered to operate the manual valves; however, no venting would continue during normal operation. In addition to the poor condition of the poppet-type automatic air vents, the air vent piping, in many cases, was original equipment, being 40 to 70 years old. Some of the piping was found totally plugged with silt from the water, or plugged with corrosion. Other piping was found leaking at joints and couplings. The air vent passages internal to the needle valves at several installations were found partially or totally plugged. These conditions prevented the required venting of air, assuring that the operating chambers of the needle valve remain full of water.

2. The water supply for the paradox control of internal or interior differential needle valves is normally supplied from a single supply line beginning upstream of the emergency gate of the outlet works. The water supply line is usually several hundred feet long, and sized to supply sufficient water supply to operating chambers of all needle valves. The water supply line was originally provided with a strainer for removal of debris and protection of the paradox control. Most of the strainer installations proved to be more trouble than good, with rapid plugging and crushing of the strainer wire. Wire would enter the paradox control, lodging within the control piston and liner.

   Inspection of the internal surfaces of the water supply piping at many installations revealed obstructions of corrosion (iron bacteria) restricting flow by as much as 50 percent. In addition takeoff connections supplying water for service purposes, sump eductors, turbine-generators, and irrigation needs were observed. These conditions all reduce the quantity of water available to operate the needle valves.

3. The drain piping from the operating chambers of the needle valves contains a gooseneck piping arrangement (figure 5), with its invert slightly above the top of the

operating chambers of the needle valve. This arrangement insures that the chambers of the valve remain full of water during all operating conditions. Investigation of historical records and on-site inspection confirmed that the gooseneck piping arrangement was being bypassed by leaving valve No. 5 (figure 5) open during normal operating conditions. This procedure, while increasing the differential pressure across the operating chambers of the valve to obtain movement of the needle, will permit draining of the operating chamber directed to discharge and, therefore, the presence of air in the chamber. When a future adjustment in flow is made, the air can be compressed resulting in rapid uncontrolled movement of the needle.

The gooseneck piping is also provided with a vent connection at the highest point of the pipe. This vent connection is essential for admitting air in order to break the siphoning action within the drain piping. If the siphoning action is not interrupted, draining of the needle valve operating chambers could occur, resulting in rapid, uncontrolled movement of the needle. Findings of the investigation revealed several of the vent pipes to be totally plugged from rust and corrosion. Also, most of the vents proved to be sized too small for providing the required quantity of air to break the siphon.

The three items discussed above are the main contributing factors to misoperation. However, the absence of correct and detailed operating instructions and appropriate training of operation and maintenance personnel must be considered major factors leading to the problems associated with misoperation of these complex designed valves. Standard operating instructions were developed for the three basic types of needle valves; therefore, these instructions did not represent the actual needle valve installation for each individual site. The instructions were very general and did not show numerous changes made to the systems over the 40 to 70 years of service. Lack of detailed instructions and poor training of operators were contributing factors to misoperation and poor maintenance practices.

As the result of findings of the investigation, the Commissioner of the Bureau of Reclamation determined that all water-operated needle valves should be replaced by the end of fiscal year 1991. As an interim measure, specific modifications to existing needle valves were recommended to reduce the risk to personnel operating the needle valves. Needle valve investigation reports were prepared for each installation, which included drawings showing the required modifications. Following completion of modifications, each needle valve was retested for satisfactory performance. The modifications consisted of the following work:

1. The old original manifold style of air vent system, or manual valving, was replaced. The new automatic venting system consists of an automatic air release valve, sight glass flow indicator, check valve, and purge valve on the air vent pipe from each operating chamber. All air vent pipe was also replaced with new pipe.

2. The gooseneck bypass pipe valve No. 5 (figure 5) was removed and replaced with blind flanges.

3. Supply and drain piping were disassembled and inspected for obstruction. All piping either was cleaned or was replaced.

4. All unnecessary takeoff connections on the water supply line to the paradox control were removed and plugged. Several water supply systems included the addition of a booster pump to increase pressure on the supply side of the valve. These booster pumps were also removed.

5. Additional drain piping and valving were added over the years to assist in draining the valves during periods of shutdown. These fittings were removed and plugged to prevent accidentally leaving them open.

6. An operation manual was developed specific to each needle valve installation. The manual includes a complete schematic diagram of the entire outlet works system, with a step-by-step checkoff system designed to reduce the risk of operator error. The step-by-step checkoff manual included procedures for filling the needle valve operating chambers, filling the outlet pipe, and subsequent operation of the needle valve, while assuring all air is properly vented. Nametags were added to each valve of the system, in accordance with the schematic diagram for ready identification.

7. Training workshops were presented to all personnel involved in the operation and maintenance of needle valves. Symptoms of unsatisfactory operation and required maintenance were discussed, as well as the design concepts of needle valves.

In summary, the Bureau of Reclamation has found 49 percent of the needle valves to be inoperable and 20 percent to be operable with restrictions. Thirty-one percent had been removed or replaced prior to this investigation. On-site operational tests indicated that the valves were unreliable due to operating difficulties, extensive downtime of the valves associated with the intense level of maintenance required to keep them operational, and a lack of understanding of the complex internal workings of the valves. These difficulties provoked operators to change operating procedures or physically modify the equipment to force a problem valve to operate. In many situations, these changes increased the potential for operator error. The modifications made to the needle valve systems described above are for the purpose of reducing the potential for operator error. It should be recognized that these modifications will not make a needle valve that is in poor condition operable. Complete overhaul, including returning all sliding surfaces of the needle valve and paradox controls to specified tolerances, may be required. It is the intent of the Bureau of Reclamation to obtain satisfactory performance of needle valves, while reducing the potential of subjecting operating personnel to hazardous situations, until the needle valves are replaced by the end of fiscal year 1991.

CONTROLLING SOIL EROSION AROUND BUREAU FACILITIES USING SELECTED PLANT SPECIES

By John E. Boutwell[1]

Introduction

Native plant coverage of an area is often destroyed during the construction or repair of a Bureau facility. This plant coverage can also be disrupted as a result of normal operating procedures such as water fluctuations of Bureau reservoirs and overgrazing of leased lands. Reestablishment of native plants or the establishment of new plant species is one of the best ways to protect disrupted areas against soil erosion of all kinds [1][2]. The planting of vegetation in these areas will help stabilize soil, create windbreaks, control unwanted weed growth, and improve forage for livestock as well as wildlife. Revegetation in many of these areas will also enhance recreational potential and improve the esthetics of Bureau projects.

Because all plants have biological limitations, assessment of geographic factors for each area must be made prior to revegetating the problem site. Some of these factors to be considered include altitude, length of growing season, precipitation, temperature, and humidity [2]. After determining these geographic factors, specific requirements must be considered. Will these plants be exposed to flooding or extreme desiccation? Will this area be grazed by livestock or will it have to endure heavy recreation traffic? Upon answering these geographic and specific questions it will be possible to establish which native and introduced plant species to select and test for use as erosion control agents for the particular situation. One such test is currently underway at the Environmental Sciences Section at the E&R (Engineering and Research) Center in Denver, Colorado.

The problem area under consideration is located at Buffalo Bill Reservoir near Cody, Wyoming. The reservoir is drawn down seasonally as water is needed. These drawdowns expose many acres of shore area which are barren of vegetation and therefore susceptible to all forms of erosion.

Methods and Materials (Laboratory Study)

Four plant species were selected for this initial study based on their natural ability to establish in riparian areas. They are all common and most are native to the Western United States. These are, slender spikerush, *Eleocharis acicularis*, found growing naturally in a canal near Valentine, Nebraska, in north-central Nebraska; black grass, *Juncus gerardii*, found growing in monoculture stands along the shores of Boyd Lake near Loveland, Colorado; a willow, *Salix sp.*, which grows along the shores of Buffalo Bill Reservoir near Cody, Wyoming; and the fourth species (although not native to the United States) Garrison's creeping foxtail, *Alopecurus arundinaceus*, has been in this country since 1902 and is established in North and South Dakotas, Montana and Wyoming.

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[2] Numbers in brackets refer to references at end of article.

It was determined from previous vegetative plantings that individual sprigs of slender spikerush would grow and disperse more quickly than clumps or sod mats; therefore, this procedure was used in culturing slender spikerush as well as the black grass for greenhouse studies. Using this technique, slender spikerush sprigs planted at a rate of five sprigs per square foot completely covered the planted area within 60-90 days (figure1). Garrison's creeping foxtail was started from seed stock and the willows were obtained from cuttings collected at Buffalo Bill Reservoir.

After stock cultures were established, greenhouse studies on these four species were performed. The plants were inundated with water in one experiment and were desiccated in another experiment to determine their tolerances to extreme moisture conditions. During these initial studies, techniques for future studies were established.

Inundation Study

Six jars of each of the four plant species were planted 2 to 3 weeks prior to treatment. The test jars were marked in 5-centimeter (2-inch) intervals above the soil level enabling accurate raising or lowering of the water on a twice weekly basis. A water inundation/recession scheme was established duplicating a natural rise and fall of water levels in a reservoir system. With this regime, the maximum water depth occurred halfway through the test period; therefore, the maximum depth of inundation for the 5-week test occurred at 2-1/2 weeks into the study. At the end of this inundation/recession interval, no standing water remained in the test jars. Figure 2 further explains this gradual inundation and recession of water. Controls and test plants were watered weekly following their test period.

All plants were observed and rated for injury on a weekly basis. A numerical rating was used to evaluate injury of the plants due to inundation or desiccation. The rating scale ranged from 0 to 10, with 0 indicating no apparent injury and 10 indicating a dead plant.

Desiccation Study

The test plants were cultured 2 to 3 weeks prior to treatment as in the inundation study then dehydrated for a period of 1 to 6 weeks. The 1-week dehydration test jar represented the control, as it was watered weekly as in the inundation study. At the end of each dehydration period, the test plants were watered on a weekly basis for the remainder of the study along with the control.

Results and Discussion (Laboratory Study)

Inundation Study

Slender spikerush is known to survive submerged indefinitely in water. Therefore, as expected, the spikerush tolerated inundation better than the other plant species. Slender spikerush showed only slight stress after 4 to 5 weeks of inundation (figure 3). Willows flooded by water developed adventitious roots in the water and the black grass, tall enough to remain partially exposed during inundation, developed seed heads which matured after the completion of the study (figure 4). Although the Garrison's creeping foxtail was injured by inundation more than the other plant species, most of the test samples recovered well, within 1 or 2 weeks after flooding.

Desiccation Study

Slender spikerush faired better than the other plants tested in the desiccation study as well. The black grass and Garrison's creeping foxtail did not endure desiccation as well as the spikerush but better than the willow which tolerated the desiccation the least.

Methods and Materials (Field Study)

Having completed these initial greenhouse studies, field sites were selected and experimental plots were planted the end of May 1986 on the mud flat areas of Buffalo Bill Reservoir. Each plot contained an area approximately 5 feet by 5 feet planted with 8 to 12 sod mats of slender spikerush. Sod mats were used in this case rather than individual sprigs to keep plant starts from washing away. Four willow sprigs and a black grass tuft were planted along the perimeter of these spikerush areas (figure 5). Garrison's creeping foxtail was not used in this initial field study because it was feared it might create a noxious weed problem if it were to establish in unwanted areas. It has been found since that this is uncharacteristic of this grass species; therefore, it was planted at a later time. Each of the plots was separated by an elevation difference of approximately 5 feet and a horizontal difference of several hundred feet. These plots remained inundated for a period ranging from 2 to 3 months depending on their elevation along the shore.

Results and Discussion (Field Study)

The field plots were inspected in September 1986 (3 months after planting) after 2 to 3 months of inundation. Slender spikerush had survived in many of the plot areas but had not spread or grown. The black grass and the willow survived only in the uppermost plot being inundated for the least amount of time, approximately 2 months and to a lesser depth of approximately 20 feet. After 1 year of exposure, much of the spikerush had failed to survive the desiccation during the winter drawdown. It was decided at this time to set up some additional plots, starting them in late summer after the water level had receded rather than in the spring.

In late September 1987 (15 months after planting) only one willow and one tuft of black grass remained of all the plants planted in the original plots. In the newly planted plots (1 month old), Garrison's creeping foxtail and black grass had developed well, although neither had spread or developed seed heads. Slender spikerush in the new plot area was only surviving in those plots with appreciable moisture.

Conclusions

Although slender spikerush survived both the inundation and the desiccation well in the laboratory studies, it appears that it can only endure a limited amount of desiccation, as seen in the field studies. This is possibly due to its relatively shallow root system. The one surviving willow in the original field study is very stunted and will probably not survive an additional inundation. The black grass seems well suited in both the inundated and desiccated environment. Although only three tufts were planted in the original field plots, one continues to survive and has begun to spread. Garrison's creeping foxtail has yet to undergo an inundation demonstrating whether it will be capable of surviving this harsh artificial environment created by the regulated water system at Buffalo Bill Reservoir (figure 6).

Screening of possible candidate plants for biological control of soil eroded areas continues at the Bureau greenhouses at the E&R Center and observations of the field site for this particular study will reveal which, if any, of the selected plants will be able to survive and help in controlling the dust and soil erosion problems at Buffalo Bill Reservoir.

References

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2. "Methods of Quickly Vegetating Soils of Low Productivity, Construction Activities," U.S. Environmental Protection Agency, Office of Water Planning and Standards, EPA-440/9-75-006, July 1975.

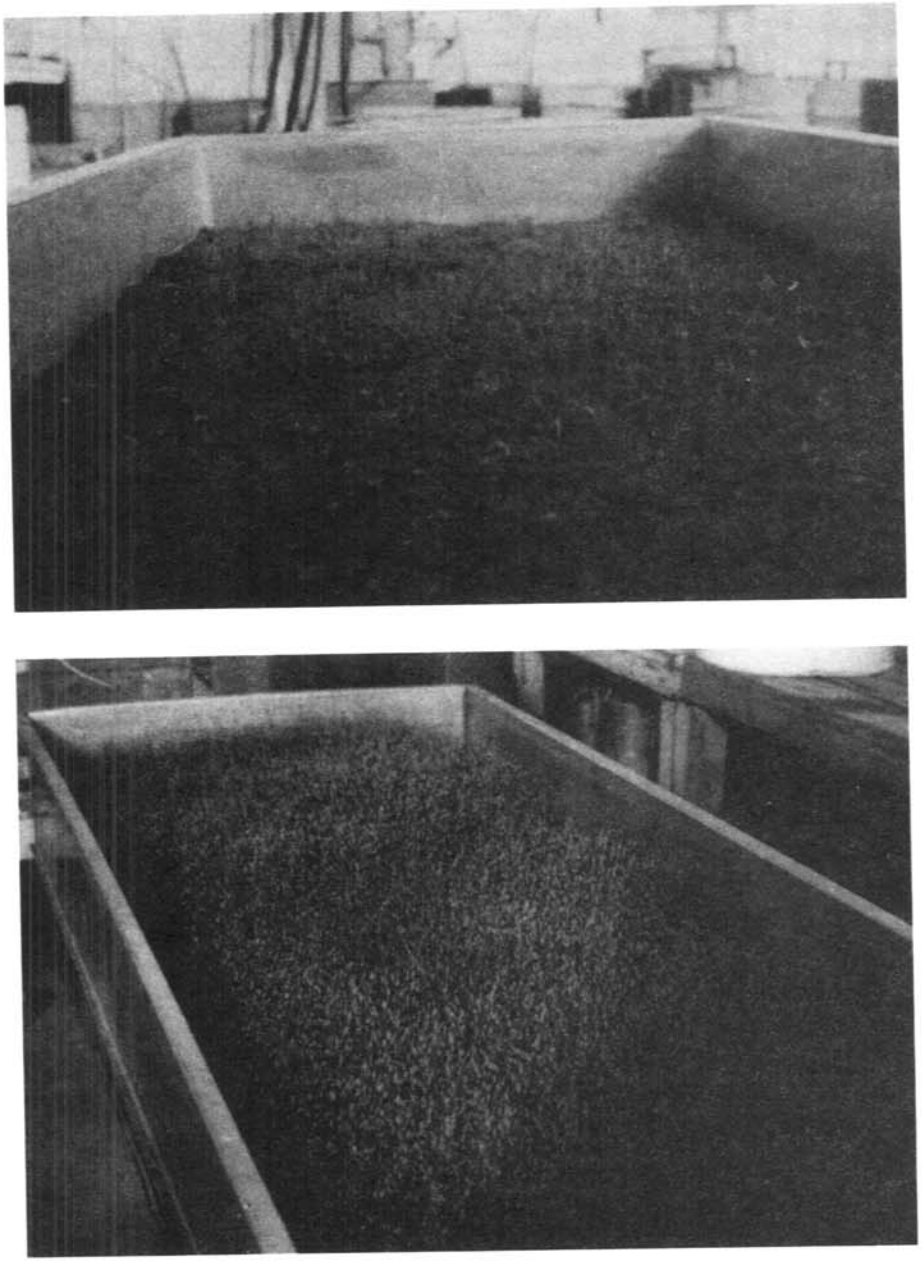

Figure 1. – Slender spikerush can spread quickly from individual sprigs as seen here. Top: one month after planting. Bottom: three months after planting.

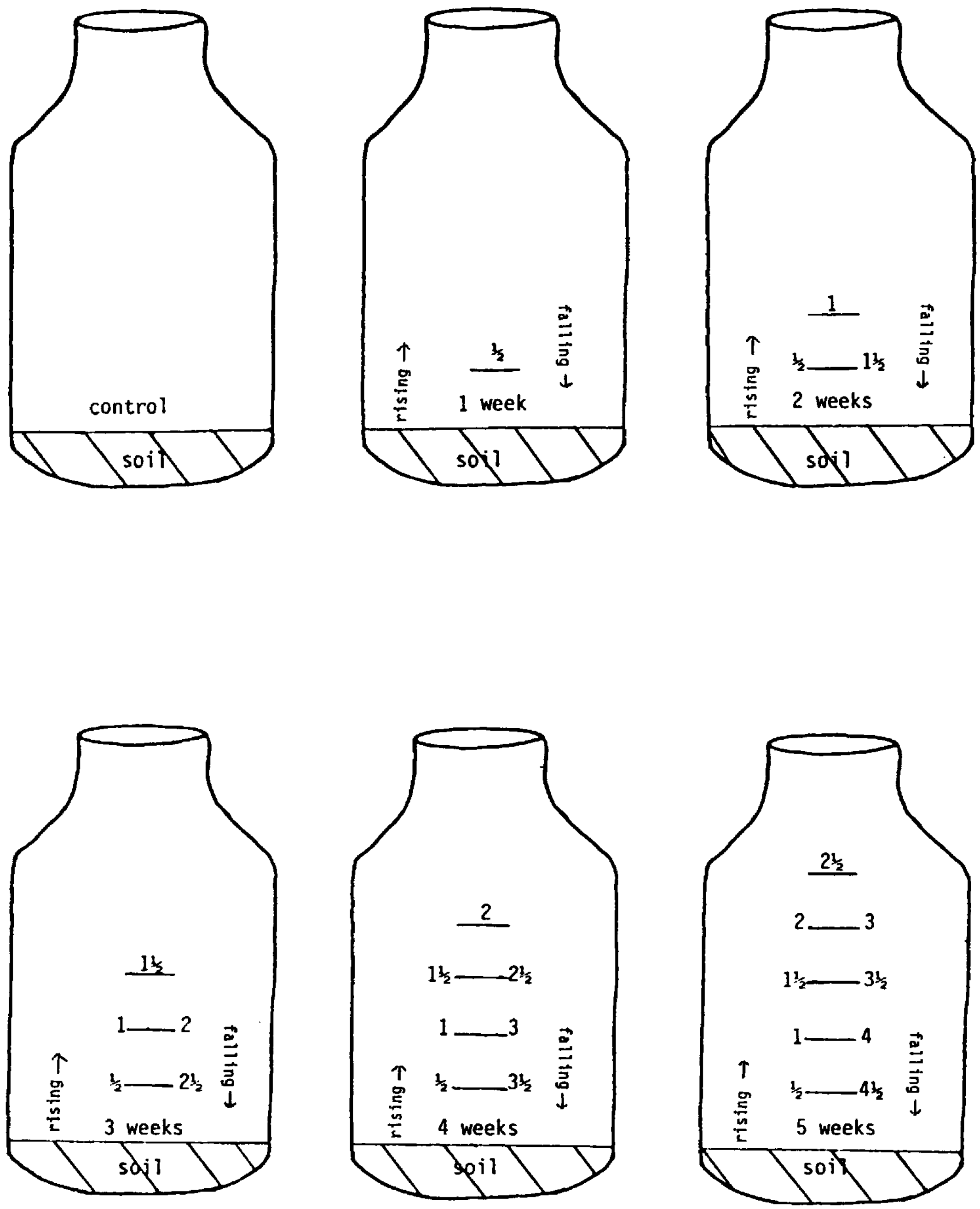

Figure 2. - Inundation scheme showing water levels in half-week intervals for inundation periods ranging from 0 weeks to 5 weeks.

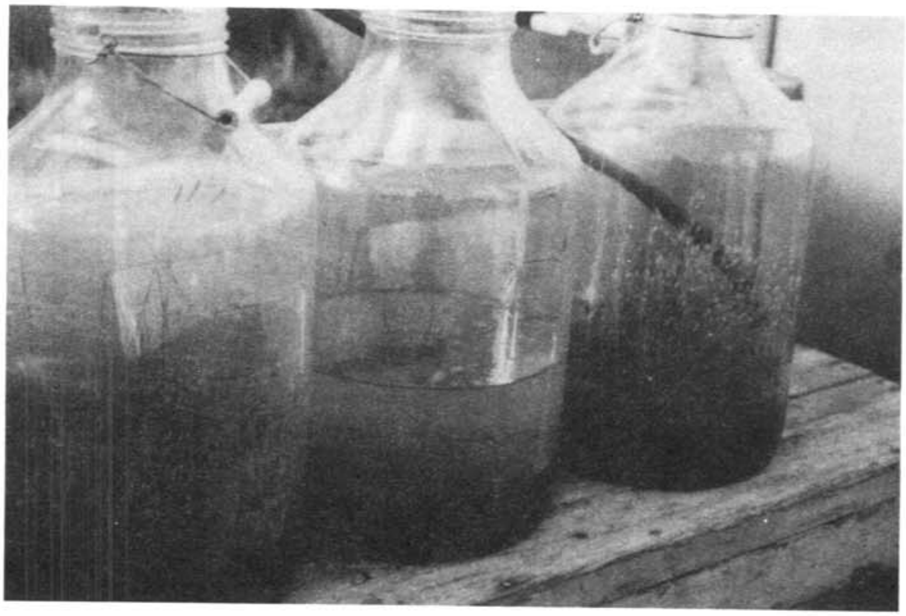

Figure 3. – Slender spikerush study - test jars: 4 weeks, 5 weeks, and control. Note lack of flowering spikes on the 4- and 5-week samples compared to the control.

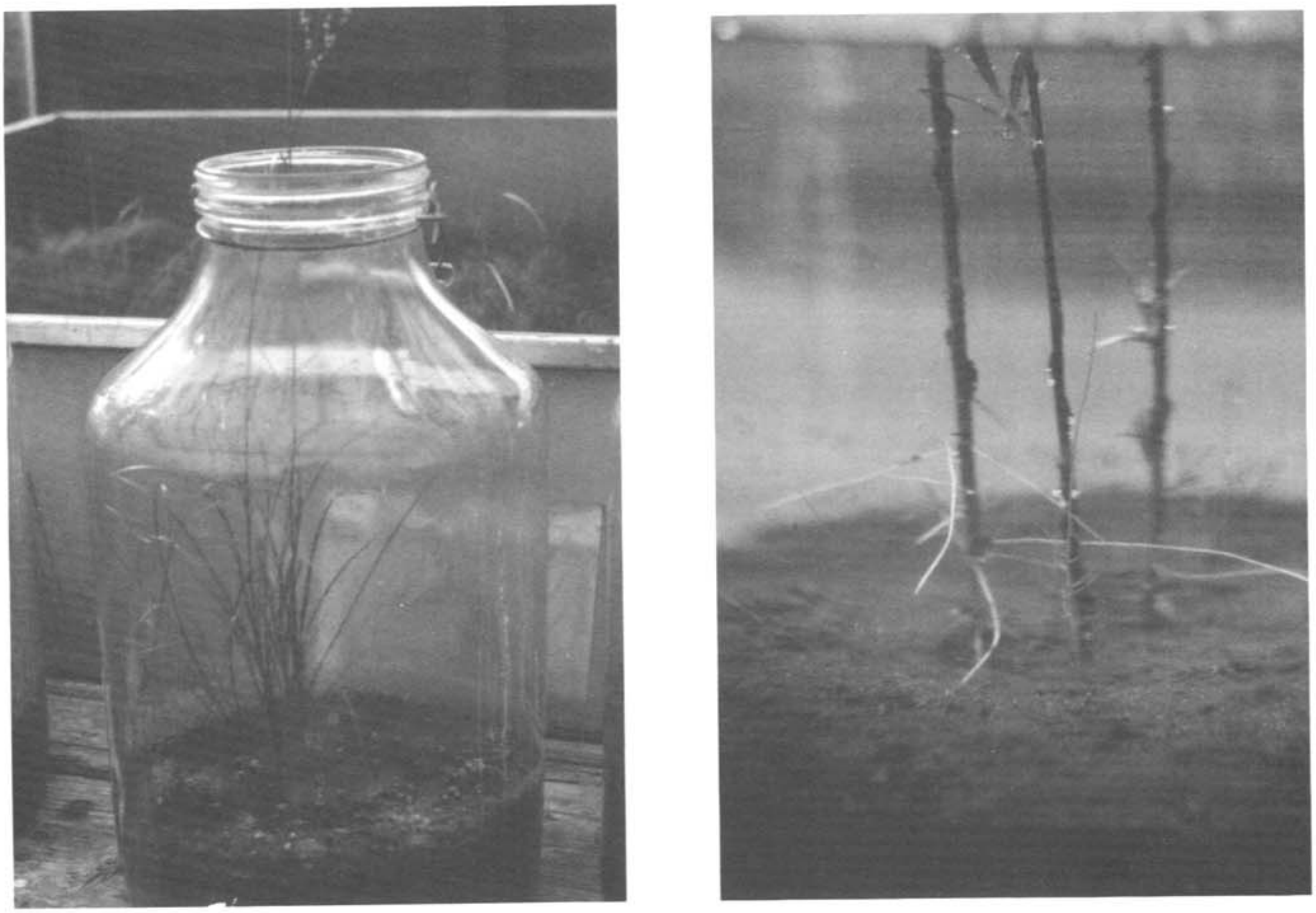

Figure 4. – Development of seed heads in the black grass and adventitious root development on the underwater stem portions of the willow are shown above.

Figure 5. – Appearance of one of the initial plots, immediately after planting. (Left: willow, center: slender spikerush, right: black grass.)

Figure 6. - Revegetation of a mud flat area such as this one at Buffalo Bill Reservoir would help abate dust problems and control soil erosion.

GRASS CARP

A Research Technique That Works

by Joan Thullen[1]

A research project is rewarding when a technique is developed and proves to be very successful. The aquatic botanists of the Environmental Sciences Section are part of a team who developed a successful technique for controlling aquatic weeds in irrigation canals which is currently saving an estimated $1 million per year for the IID (Imperial Irrigation District) and the CVWD (Coachella Valley Water District) in California.

The problem was the noxious aquatic weed, hydrilla [*Hydrilla verticillata* (L.f.) Royle]. It was first discovered in the IID in 1977. Within 3 years, it clogged half of the system's canals and laterals. An Interagency Task Force was formed to recommend environmentally sound methods to control the weed; and the Bureau's Lower Colorado Regional personnel requested aquatic botanists at the E&R Center to participate.

The initial cost estimate for controlling the infestation was $10.1 million. Seven years after research began, the hydrilla was controlled at an expense of only $3.5 million. The solution was the use of triploid grass carp (*Ctenopharyngodon idella* Val.), a fish with a hearty appetite for aquatic weeds. Triploid grass carp have three sets of chromosomes instead of the normal two, making it sterile.

In the summer of 1985, 7,800 triploid grass carp (8 to 10 inches long) were stocked in a portion of the IID. Within 8 weeks, all hydrilla had been removed from this stretch, so an additional 50,000 fish were stocked throughout the IID system. By September 1986, 99 percent of the hydrilla had been consumed. During 1986 alone, the grass carp provided a cost savings for the IID of about $400,000.

In conjunction with the southern California studies, these same E&R Center botanists have completed 3 years of investigation into the effectiveness of grass carp for aquatic weed control in the colder water canals of Colorado. The fish have been so successful in clearing out the aquatic weeds in a portion of a canal owned by The Consolidated Lower Boulder Reservoir and Ditch Company, that the Ditch company requested the use of the Bureau's grass carp for the following seasons, since the research investigation was finished. The superintendent has stated that using grass carp saved them 72 percent of their direct weed control costs the first year of the study.

Anxious to determine whether a small irrigation company could handle the implementation of using the fish themselves, the Ditch company was allowed to use 265 of the research grass carp in their irrigation canal west of Erie, Colorado, during the 1987 growing season (April through October). Although the aquatic botanists assisted in the capturing and stocking of the fish, the Ditch company personnel provided most of the labor, plus they prepared the canal and monitored the fish throughout the season. By fall, they were making plans to redesign the canal to accommodate structures to hold the fish during the spring flushings and to enable easier capture.

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The grass carp are very hardy fish. They have survived at least two dozen transfers so far. In Colorado, they thrive in water temperatures varying from 32 to 76 °F (but are even more effective in clearing weeds in water temperatures up to 90 °F). During the 1986 winter/spring period, the average fish lost 20 percent of its weight but regained that weight and more during the next summer. Forty of the fish were also able to survive the surgical implantation of a radio transmitter into their abdomens.

The use of grass carp for aquatic weed control in the United States has proven to be very effective, environmentally safe, and less expensive than the traditional use of herbicides; however, they are not a panacea. Grass carp must be managed to be effective. They can and will move out of any area where they are stocked unless they are restricted with screens, dams, or other barriers. They also need to be transferred when the canal, pond, or reservoir in which they are held is flushed, dewatered, treated with chemicals, or is so shallow it will freeze entirely. Grass carp can live in water underneath ice as long as there is adequate oxygen available to them.

There is still more research to be done on grass carp. Minimum stocking densities need to be pinpointed, especially in cool water irrigation canals; effective, yet economical, barriers need to be developed; their behavior patterns need to be better understood for use in managing the fish more efficiently; and other grass carp strains need to be evaluated for their effectiveness, particularly in cooler water environments.

Presently, most states allow the use of grass carp with the necessary permits, provided the fish are sterile. The sterile triploid grass carp are available from commercial fish farmers around the country. If you are interested in the use of grass carp to control aquatic weeds, the Colorado contact is the Colorado Division of Wildlife, 6060 Broadway, Denver, Colorado 80216, (303) 297-1192.

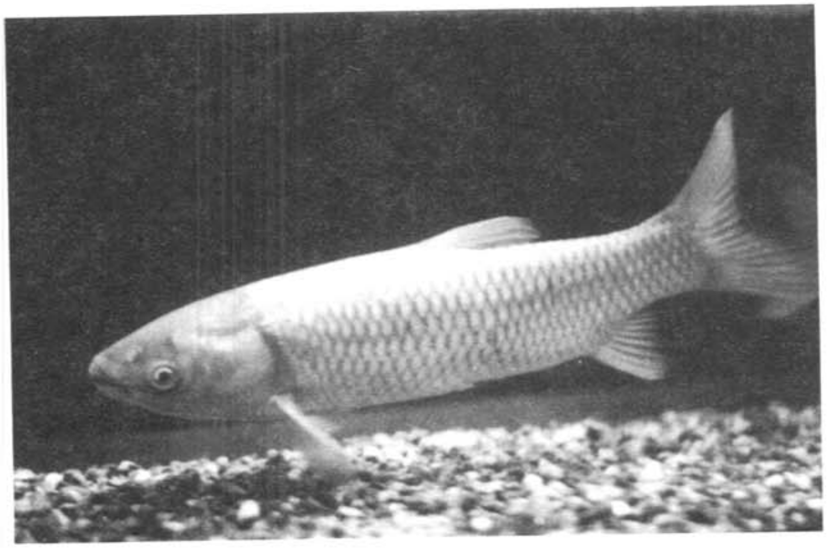

Figure 1. - The grass carp has a hearty appetite for aquatic vegetation.

Figure 2. - Section of canal in Colorado which was not stocked with the grass carp.

Figure 3. - Section of canal which was stocked with grass carp for 3 months. Note lack of vegetation.

OPERATING A DAM SAFELY

by Franklin E. Dimick[1]

The potential for damage to property and loss of life occurs more frequently from human errors or judgment in operating a dam than from natural disasters such as earthquakes. The proper operation of a dam is directly related to the safety commitment of the operator and owner. The operator must be well trained and be continually observant of changes in the dam. The operator must be knowledgeable of the consequences of each operating action and know that he cannot bypass safety limits of himself, the dam, or equipment. A dam can be operated safely within its design limitations, if steps are taken to eliminate human errors.

Introduction

People usually think of dam safety in terms of failures caused by earthquakes, overtopping, or improper design. The news media has done an excellent job of making the public aware of these potential hazards. However, a higher risk for potential damage to or from a dam exists because of human errors. This risk is rarely considered in its proper perspective. Failure to properly and safely operate a dam can and often does result in severe property damage and may even result in loss of life. Improper operation of a dam could, and in some cases does, cause the dam to fail with resulting catastrophic effects. The day-to-day operation of a dam presents frequent opportunities for human errors and so the risk must be reduced or eliminated as much as possible.

The degree to which a dam is operated safely is directly related to the commitment of the operators and their adherence to the operating criteria of the dam. Operating a dam is much more complicated than just opening or closing a control valve. As with the operation of any complex piece of equipment, failure to understand the operational criteria and not being fully committed to the concept of safe operations usually results in disaster or at least a "near miss" situation. Large dams such as Hoover Dam and Grand Coulee Dam are generally operated by a Government agency, public utility district, or similar organization that understands the need for alert, well-trained, and committed operators. They choose their operators carefully and continually strive to improve their abilities.

However, the majority of dams in the United States are considered to be small-to-moderate sized. The operators of these dams in the United States are generally selected due to their proximity to the dam, or a family member operated the dam, or they have some free time to operate the dam, or they are the only one on the water user board who will accept responsibility to do the work. In many of these cases, ability and commitment are not prime considerations. Operator training is minimal or nonexistent. Although these smaller dams are much simpler to operate, the risk of human error is still significant because of the lack of ability and training.

The safe operation of a dam, whether large or small, can be improved if a few basic ideas are understood and followed by the operators and owners.

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Training

The most important factor in operating a dam safely is to make sure that the operators are properly trained. Lack of proper training can cause confusion. Operating a dam "by the seat of your pants" is inviting trouble. Training can vary from the informal "hands on"-type training to a formal classroom setting. However the training is presented, it must be correct and thorough. The person giving the training must take care that he does not perpetuate an operating error that he has been committing for years. Training should be based on a written operating procedure for the dam. These operating procedures should be written by someone familiar with the dam, such as the designer who understands how each piece of equipment works and knows the consequences of operating actions. Being an operator at a dam does not automatically qualify an individual to write operating procedures or conduct training. A good training program should provide the operator with a thorough knowledge of each component of the dam (embankment, valves, piping, motors, waterways, etc.) and its specific purpose and limitations.

In 1977, the Bureau of Reclamation developed a program to improve the training of dam operators. The training program involves a general classroom session on proper operation procedures followed by an on-the-site session with each operator to discuss operating procedures at a specific dam. A manual developed by the Bureau entitled "Training for Dam Operators" is used to ensure that all facets of operations are covered thoroughly and correctly. The Bureau recommends a refresher course at least once each 3 years.

Being Observant

A second idea that will help increase safe dam operation is for the operator to be observant of his surroundings. Awareness of potential problems is the best way of preventing them from happening. An operator has an obligation to be aware of any changes that take place and the effect that those changes may have on the safety of the dam. The operator should develop a mental checklist of items to inspect each time he visits the dam. Such a list would include items such as toe drains, seeps, abutments, groins, downstream face, crest, waterways, mechanical equipment, etc. Particular attention should be given to new seepage areas, wet spots, depressions, misalignments of structure parts, and so on.

The operators of Bottle Hollow Dam in eastern Utah learned the value of being observant when a plugged intake structure for a pipeline caused a serious problem. Water for this offstream reservoir is diverted through a canal to a pipeline that drops the water into the reservoir. The operators failed to notice that the trashrack on the inlet structure for the pipeline was becoming clogged with tumbleweeds and other debris. Finally, the water was backed up in the canal enough that the water overtopped the canal bank and eroded a large gully alongside the pipeline. The pipeline was exposed and undercut for several hundred feet, requiring repairs that exceeded $10,000. Although this incident did not threaten the integrity of the dam itself, it was a definite reminder that the operators of dams must be continually observant.

In an effort to improve its dam safety program, the Bureau of Reclamation has developed written checklists for special situations at its dams. One situation the Bureau feels warrants a written checklist is during the initial filling of a new reservoir. Another situation that warrants a written checklist would be when an unusual condition such as abnormal seepage, or high flood flow occurs. It has been found that these written checklists prevent the possibility of overlooking the inspection of an important part of the facility. All observations and, in particular, any unusual conditions should be entered in the dam operating log book for future reference. These entries could well provide valuable information to an investigation of an incident and may even provide the owner and operators with a defense from legal actions.

Thorough observations at regular and frequent intervals are a valuable aid in operating a dam safely.

Understand the Consequences of Actions

Operators of a dam can significantly increase the safety of a dam by knowing and understanding the consequences of each action they take in operating the dam. An operator must continually ask himself questions such as: "What will be the sequence of events and the consequences of opening this valve?" Each time an operator performs an operation at a dam, he could cause significant property damage to the dam or to the area downstream of the dam if he makes an error. Errors can be as simple as pushing the wrong button. However, a simple error like that could rupture an outlet works pipe, causing extensive property damage and possible loss of life.

At Webster Dam in north central Kansas, a series of errors caused serious damage to the outlet works. During an inspection of the facilities, the 48-inch-diameter pipe was drained between the emergency gate and the operating gate. After the inspection was completed, the operator closed the regulating gate. He then left the area, failing to notice that the 2-inch air vent valve had not been closed and that the emergency gate had opened slightly. When he returned, he found the outlet works tunnel and the gatehouse flooded. The operator, reacting to the emergency, attempted to drain the water by opening the regulating gate. This drained the pipeline but did not drain the flooded tunnel through which the pipeline ran. The pipe became very buoyant as it emptied and floated to the top of the tunnel, damaging the pipeline and requiring repairs before the system could be operated. Failing to understand the consequences of this action turned an unfortunate situation into a very serious one.

A portion of the interior galleries and elevator shafts at Grand Coulee Dam in eastern Washington was flooded when an operator opened an outlet tube guard valve to place the system back in service after maintenance had been performed. The manhole door providing access to the area between the guard gate and the operating gate had not been properly secured when maintenance personnel had finished their work. The operator failed to check the manhole door; and when he started to pressurize the area between the two gates, the cover blew off and water began flooding the gallery where the operator was standing. The operator was not able to stop the flow of water so he left the area. A team of men later went back into the flooded gallery and closed the gate to shut off the flow of water.

An operator must be thoroughly trained on how to handle emergency situations and should think through his actions, being aware of the consequences of such action. This process of thinking through the actions to be taken may result in checking a potential problem area or using an alternate action to achieve the same goal without jeopardizing safety.

Bypassing Safety Limits

Another area that safety in operating a dam can be improved is to make sure that the operator does not try to bypass safety devices such as limit switches, safety tags, electrical breakers, etc. All such devices were installed to protect the equipment or the people operating the equipment. When a safety device shuts down a piece of equipment, the operator's first impulse may be to bypass it and restart the equipment. This act could be dangerous to the dam or the operator. The operator should search for the reason and correct it before continuing the operation.

Many gate operating systems use a momentary-type pushbutton to open or close the gate. This means that the button must always be held down while the gate change is being made. If the gate change is very large, the operators will sometimes wedge a matchstick or knife blade in the pushbutton to hold it down. This gives the operator freedom to do other things while the gate is being moved. However, the operator needs to think this action through and realize that it also takes the control of the gate away from him. Serious problems may occur if this practice is not forbidden.

The need to store more water or gain additional head on a generator will sometimes be enough incentive for an operator to exceed the safety limits of a dam. Dam operators may spill water over the top of the spillway gates rather than releasing water under them to gain a few more feet of elevation on the reservoir. Another poor practice is to install flashboards on a dam spillway or sandbag the spillway to gain additional storage. These practices may be tempting but should never be done without a careful engineering analysis of the added stresses it places on a structure. The operator who places the surcharge on a reservoir must realize that adding 2 feet of water over the top of a 10-foot by 20-foot-high spillway gate adds an additional 13 tons of force against the gate. This action of operating in the freeboard portion of the dam reduces the safety factor of the dam and its ability to handle flood flows. The operator is also gambling that a major flood will not occur during the time that the reservoir is being maintained above the normal maximum water level. Whenever an operator tries to extend the limits of a dam, the factor of safety for the dam is reduced accordingly.

The operators of Newton Dam in northern Utah placed an earthen fill over the sill of the emergency spillway and flashboards on top of the service spillway to allow them to store more water. The Bureau of Reclamation discovered this situation in 1979 during a routine examination. They directed the operators to remove the fill and flashboards, which they did. In February of 1980, heavy rains falling on frozen ground and snow caused a record runoff of water into Newton Reservoir. The service and emergency spillways were both used. Had the operators left the fill and flashboards in place, the rising waters may have caused the dam to fail. Having learned a valuable lesson, the operators have never replaced the fill or the flashboards.

Knowledge of Runoff Conditions

An operator who has a basic knowledge of the runoff characteristics of the watershed above the dam and the safe capacity of the channel below the dam has a good tool for operating the dam safely during floods and heavy runoff periods. The operator can anticipate inflows to the reservoirs and adjust releases as necessary to reduce or prevent flooding downstream. Failure to know these conditions can create a serious safety hazard to the dam as well as those people living downstream of the dam.

The February 15, 1979, issue of the Engineering News Record reported that hundreds of people had been killed when officials of the Minas Gerais State Power Company opened the floodgates of the Tres Marias Dam on the Sao Francisco River in southeastern Brazil. This action was taken when the reservoir, filled by heavy wet season rains, had risen to within 3 feet of the crest. The article points out that the gates were opened in the middle of the night, some 5 hours after the officials had told the state governor they thought they would not have to open them. Although officials say they warned towns below the dam, it appears there was a breakdown of communications.

The Bureau of Reclamation develops an Annual Operating Plan for each of its dams. This plan gives the operator a suggested course of action to take with three different runoff scenarios: minimum, average, and maximum. The operator can then use updated runoff forecasts to interpolate between these three scenarios to fine tune the operation of the reservoir. If large releases must be made, the Bureau of Reclamation has developed an Emergency Preparedness Plan for each dam that spells out the actions to be taken to prevent or reduce property damage and the possible loss of life.

Equipment and Instructions

Finally, an operator must be supplied with the proper equipment and instructions to ensure safe operations of a dam.

The proper equipment would include items such as a stopwatch and bucket to measure drains and seeps; a camera to create a historical photo file to compare and discover differences that occur slowly; a pair of binoculars to observe conditions closer; flashlight, tape measure, small hand tools; and personal protective and safety equipment.

The proper instructions would include such things as standing operating procedures, proper training, drawings, instruction manuals for electrical and mechanical equipment, safety manuals, emergency preparedness plans, and an emergency communications directory.

An operator who has the proper equipment and instructions and utilizes them correctly will reduce the chance of error. However, a smart operator is one who knows his own limitations and calls for operational assistance at the first moment he recognizes that an emergency situation may be beyond his control.

Summary

Knowing how to properly operate a dam and how to react in emergency or unusual situations is essential in operating a dam. It is possible to operate a dam safely if the operators are properly trained, understand the function of the dam and the consequences of the actions they take, and are personally committed to safe operation.

SPOTLIGHT ON UPPER STILLWATER DAM

Bonneville Unit
Central Utah Project

Upper Stillwater Dam is the first major storage facility constructed by the Bureau of Reclamation using RCC (roller compacted concrete). The primary difference between RCC and conventional concrete is the amount of moisture used in the mix. The dam is sited on Rock Creek at an elevation of 8,000 feet in the Uinta Mountains, approximately 100 miles east of Salt Lake City, Utah. Each year, 60,000 acre-feet of water will be diverted by the dam into Stillwater Tunnel for use on the Central Utah Project.

Upper Stillwater Dam is the headworks for the Strawberry Aqueduct which diverts water to the Strawberry Reservoir through a series of tunnels, pipelines, and reservoirs.

The dam will regulate the flow of Rock Creek, which will provide a reservoir having a seasonal fluctuation of 144 feet. The reservoir will remain full throughout the summer recreation season, and the stored water will then be diverted to the aqueduct during the fall and winter.

The design objective was to construct a dam similar in quality to a conventional concrete dam faster and more economically than could be accomplished with other methods of dam construction. Rapid concrete construction methods selected to achieve this objective required optimizing construction equipment usage and minimizing manual labor.

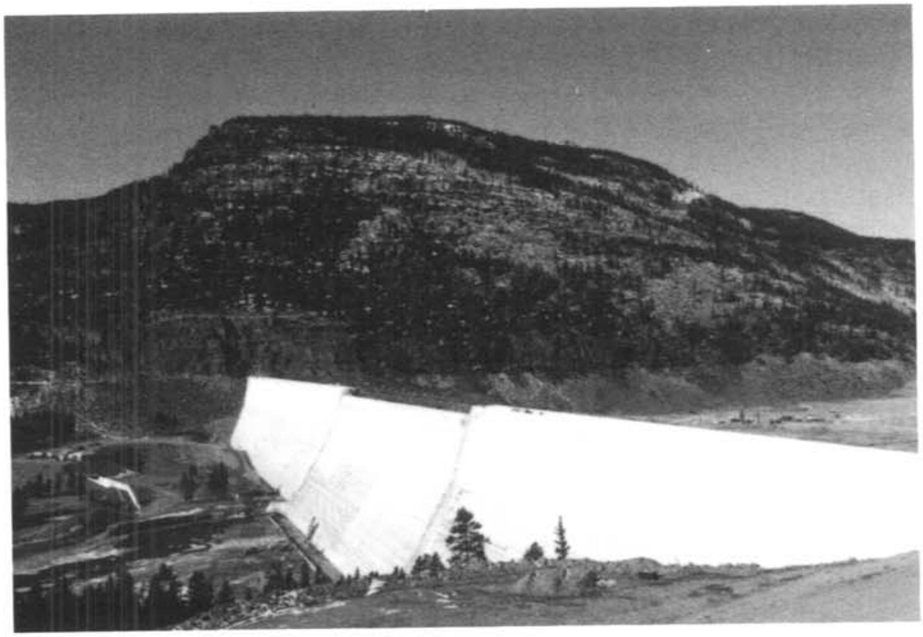
Upstream and downstream faces of the dam were formed by horizontally slipforming 2-foot-high interlocking facing elements ahead of the concrete placing operation. This replaced conventional forming operations and provided a high-quality durable concrete face for the dam. After slipforming elements on the upstream and downstream faces, two 1-foot-thick lifts of concrete were spread and compacted between the facing elements. This sequence was then repeated until a monolithic dam was constructed.

Conventional concrete, termed leveling concrete, was used to provide reliable bond with the foundation. In level areas of the foundation, the leveling concrete was placed in blocks. On sloped foundation surfaces, the leveling concrete was placed in sequence with the RCC.

A high flyash mass concrete mix design was used to minimize the heat of hydration and to provide a very forgiving concrete by retarding its set. This allowed elimination of contraction joints in the dam and minimized lift joint preparation. Strength developed by the mass mix exceeds design requirements.

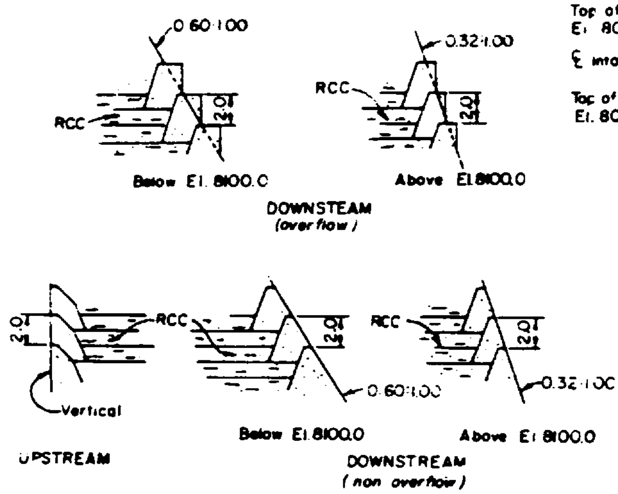
Placed at a consistency of zero-slump, RCC utilizes enough water to complete the hydration process, but does not require the additional water for placing and consolidation. Thus, conventional earth-moving equipment can be utilized providing increased production rates with a lower unit cost.

The dam was topped off in August 1987 and has an overall crest length of 2,673 feet, top elevation of 8,182 feet, top width of 29 feet, maximum structural height of 295 feet, and a maximum height above streambed of 202 feet.

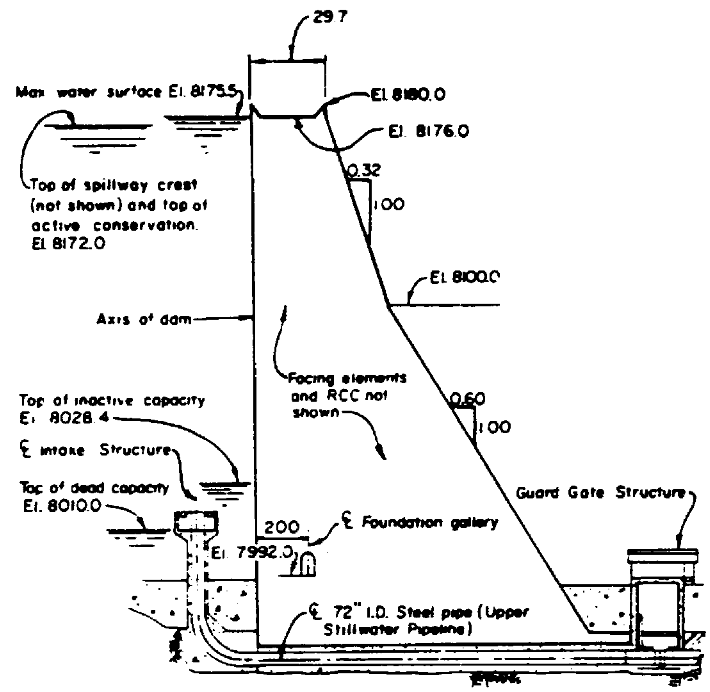


Aerial view of Upper Stillwater Dam. 11/23/87

Slip-formed concrete will be used to construct the upstream and downstream faces of the dam. The concrete will be bonded to a slightly richer RCC mix on the upstream side, and will serve as an integral part of the dam being durable enough for the extreme climatic conditions.

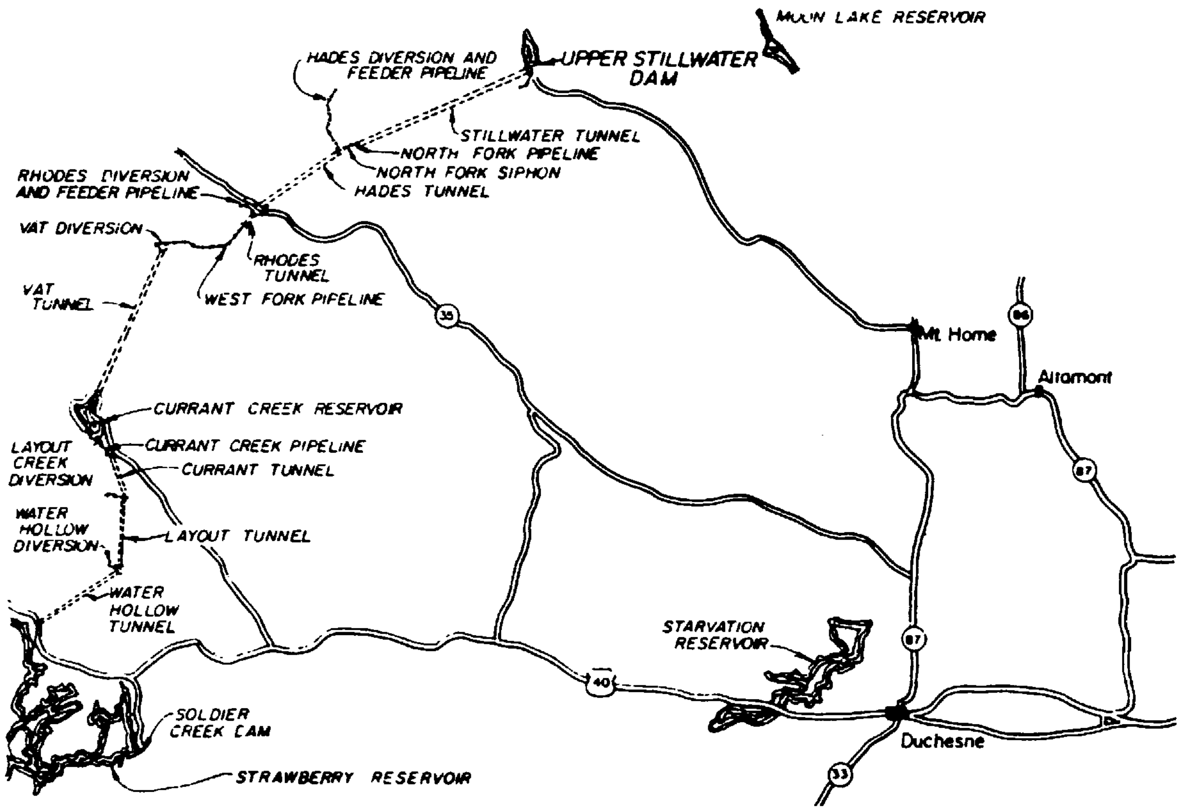


Facing Elements



Profile Along ℄ Outlet Works

STRAWBERRY AQUEDUCT



CASE STUDY

WEBSTER DAM — DETERIORATION OF SPILLWAY CHUTE FLOOR CONCRETE

Project:	Pick-Sloan Missouri Basin Program
State:	Kansas
Type:	Zoned earthfill
Completed:	1956
Function(s):	Irrigation, flood control, recreation, fish & wildlife
Crest length:	10,720 feet
Hydraulic height:	107 feet
Active capacity:	255,500 feet
Surface area:	8,480 feet

Design characteristics: The spillway is located on the left side of the dam. It consists of an inlet channel, a concrete crest, a gate structure containing three 33.33- by 39.51-foot radial gates, a chute, a stilling basin, and a discharge channel.

Evidence: Continuous spalling had occurred in the spillway floor concrete joints since construction was completed in 1956.

Incident: In November 1962, a Bureau of Reclamation examination report for Webster Dam documented the existence of "popouts" in the spillway floor which were thought to be the result of expansion of deteriorated particles. In the following years, the concrete continued to deteriorate. In a later examination report, a recommendation was made to patch the spillway slab spalls with epoxy-bonded concrete and apply linseed oil treatment to retard freeze-thaw deterioration.

After removing a large volume of deteriorated concrete, the reservoir superintendent at the dam became concerned with the depth and width of the affected areas. A 1973 analysis of concrete cores by the Concrete and Structural Branch at the E&R Center concluded that the problem was "D" cracking (deposit or deterioration) which is associated with poor-quality aggregates and freezing/thawing cycles. The reservoir superintendent was advised to stop all repair until further notice. An investigation of the condition of the concrete concluded that the bulk of concrete in Webster Dam spillway was sound and of an acceptable quality. The affected areas of concrete were partially repaired using various sealants and epoxy-bonded concrete.

In a 1982 report, a recommendation was made to remove and replace concrete approximately 3 feet on each side of the contraction joint. During the excavation, it was decided to remove only the unsound concrete from either side of the joint.

Causes: "D" cracking is associated with poor-quality aggregates that have fractures and/or clay seams which can absorb a significant amount of water. When the water freezes, it causes an expansion in the aggregate, cracking the concrete. The cracks are characteristically along joints through which water penetrates into the concrete. The Webster Dam spillway is particularly affected by this action since each spillway slab is depressed 1/4 to 1 inch below the slab upstream at the contraction joints. This was standard practice at the time the dam was built, but is not in accordance with current guidelines for high-velocity flow surfaces. This recess acts as a reservoir to hold water which eventually seeps into the joint.

Remedy: In 1973, test areas were selected and several different sealants were used to treat the "D" cracking. Areas of advanced deterioration were chipped out, cleaned, and patched with epoxy-bonded concrete, containing low-alkali cement.

The perimeters of deteriorated areas were sawed to a depth of 2 inches so replacement concrete would have no feather edges. The deteriorated concrete was then removed to a depth of 3 inches. New concrete was placed with vertical sawed joints being epoxy-bonded. New concrete was then covered with salvaged carpeting and kept wet for a period of 30 days.

Areas replaced, to date, have been on the flat section of the spillway apron and were relatively easy to repair. However, the sloped section of the spillway chute is also deteriorating and will be much more difficult and time consuming to repair.

Conclusion: Repairs to be made on a yearly basis until all the deteriorated joints have been repaired. "D" cracking can be prevented by proper petrographic testing of aggregates.

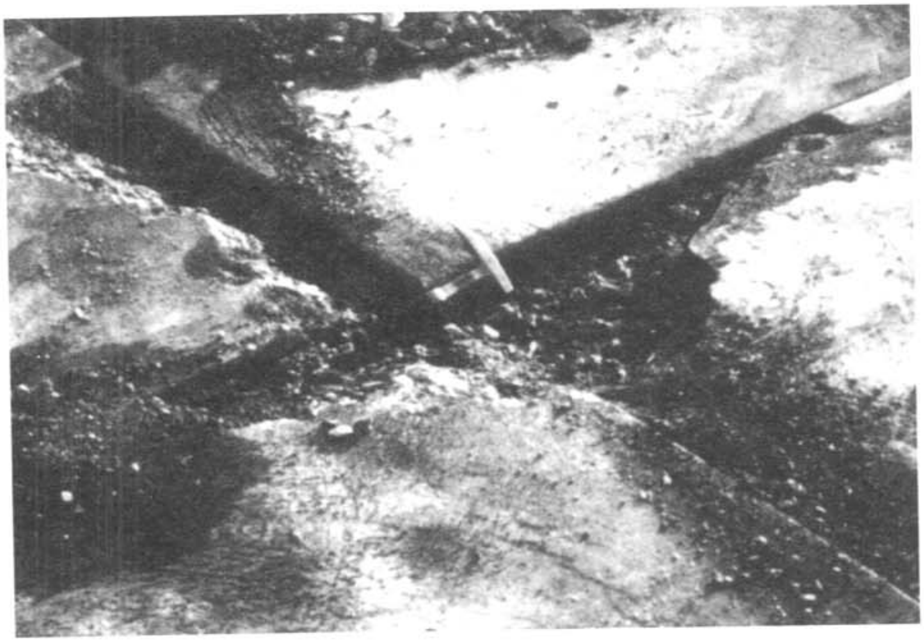


Photo No. 1. - Webster Dam - example of localized severe deterioration. 10/72

Photo No. 2. - Webster Dam - example of "D" cracking present on many slabs. 10/72

Photo No. 3. - Webster Dam - cores No. 1, 5, and 8 fractures near the top are from edge of floor slabs adjacent to areas of visible deterioration. Cores No. 2, 3, 4, and 9 are from centers of floor slabs and appear to be sound. Core No. 6 from toe of wall and No. 7 from cover over gallery also are sound. 11/2/72

GPO 856-506

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-822A, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.