WATER OPERATION AND MAINTENANCE

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IN THIS ISSUE

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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:

Amphibious excavator improving Rio Grande Floodway.

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AMPHIBIOUS EXCAVATOR RESTORES RIO GRANDE[1]

by David O. Allen[2] and Bill Bouley[3]

The delta area of Elephant Butte Reservoir is covered by wet, unstable beds of clay, silt, and sand. Boggy conditions limit the use of most conventional excavators to maneuvering on mats. Relocating mats for the excavators reduces the productiveness. On occasion, equipment has slid off the mats to be mired in the delta material. Amphibious excavators provide an effective method of constructing channels in soft, unstable terrain and for removing sediment plugs to improve floodways during the runoff season.

Flow of the Rio Grande was significantly above normal between 1979 and 1987. Elephant Butte Reservoir filled to capacity in the spring of 1985 and remained essentially full through 1988. Sediment deposition during the filling of the reservoir caused complete destruction of conveyance system facilities within the upper reach of the reservoir and aggradation of the river channel for a considerable distance upstream. Loss of a suitable outfall has halted operation of the Low Flow Conveyance Channel, which is used to deliver water through the Elephant Butte delta during low flows on the Rio Grande.

Runoff for the 1989 and 1990 seasons was below normal. Under these conditions, the reservoir pool dropped 20 feet and receded approximately 6 miles. Due to the sediment deposition and the lowering of the reservoir, the means for efficient transport of water and sediment into the Elephant Butte Reservoir pool no longer existed. Above the reservoir, the decrease in river channel capacity caused by aggradation of the river threatened further destruction of the Low Flow Conveyance Channel and its protecting levee. The estimated floodway capacity in the area south of San Marcial was 2,000 ft^3/s. On the average, a flow of 7,200 ft/s occurs at San Marcial every other year. Peak flows at San Marcial often result from thunderstorm activity in uncontrolled tributary drainages and are not correlated with predicted snowmelt runoff.

The work had two objectives. First, increase the Rio Grande channel capacity in the area of the lower portion of the conveyance channel levee. Second, provide effective conveyance for water and sediment into the main pool of the reservoir. The two objectives are related to the extent that efficient sediment transport would promote channel degradation upstream.

Efficient sediment transport required a relatively deep, approximately 6-mile-long, narrow channel through the delta with maximum flow of water. The lower 4 miles of this channel was to be constructed through unstable, wet, clayey material and tamarisk (salt cedar) brush. Hydraulic dredging for this channel could not be used due to environmental consideration and thick salt cedars in the area. Conventional track-type excavators could not be used because they would sink in the muddy terrain.

Faced with the challenge of obtaining equipment which would construct this channel under unstable conditions and meet environmental requirements, Socorro Field Division personnel researched the use of amphibious track-type excavators used for work in

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1 Extracted, in part, from the supplement (dated August 1991) to the Bureau's "Guidebook for Enhancement of Existing Project Operations," October 1990.

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3 Bill Bouley is a Civil Engineer, Bureau of Reclamation, Facilities Engineering Branch, Denver, Colorado.

swamps and marshes. These machines can work in soft, unstable areas in up to 5 feet of water with flows up to 8 ft/s, where conventional track-type excavators cannot work. The Division purchased two amphibious excavators to perform this work.

The new channel provided for effective transport of water and sediment to Elephant Butte Reservoir and moved sediment which had plugged the river in the San Marcial area. This increased the river capacity in this reach from 2,000 ft^3/s to 6,000 ft^3/s and reduced the threat to the Low Flow Conveyance Channel.

These machines have proven cost effective in accomplishing this project. The amphibious excavators are also used to remove sediment plugs in the river during runoff and to restore other channels. They will be used to extend and to maintain the channel into Elephant Butte Reservoir.

In addition to the amphibious excavators, the Socorro Field Division has also procured an amphibious personnel carrier. This enables mechanics to perform repairs and maintenance to equipment in the delta, which is inaccessible by automobiles. A rock undercarriage with conventional tracks was also purchased for the excavators to allow work on rock and other firm terrain, thus increasing the versatility of the equipment.

The total cost for restoring the floodway is about $1 million. The source of funding is a combination of appropriated funding and funds allocated by the State of New Mexico under a cooperative agreement. Under a similar agreement, the excavator will be used to restore channels, construct nesting islands, and enhance wetlands in a waterfowl refuge in New Mexico.

Video tapes of the amphibious equipment working in soft terrain are available from David Allen, Socorro Field Division, PO Box VV, Socorro NM 87801-0678; telephone (505) 835-1202.

Photo 1. – Amphibious excavator being used in Elephant Butte Reservoir delta. 11/28/90

Photo 2. – Looking downstream upon pilot channel excavation in the Elephant Butte Reservoir delta. 11/28/90

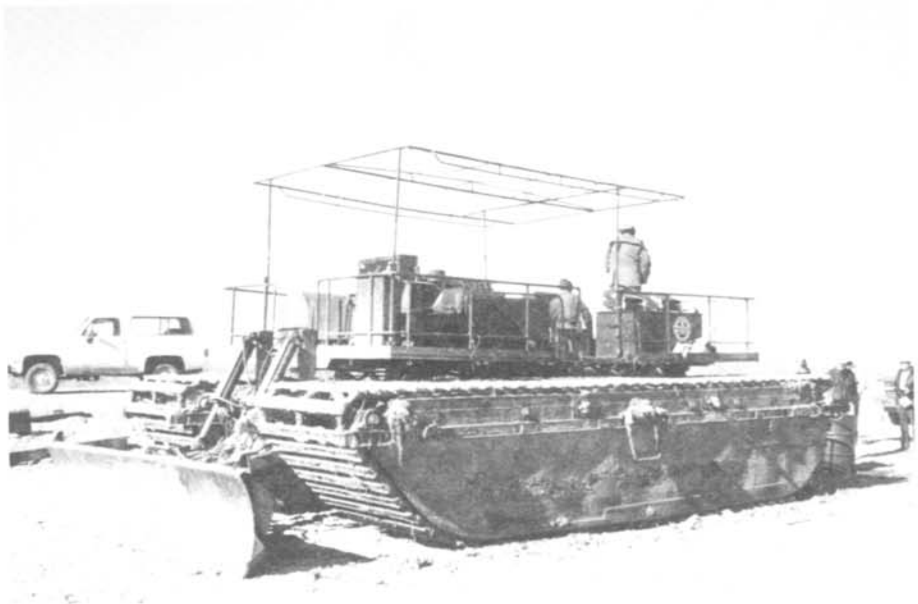

Photo 3. – Amphibious personnel carrier. 11/28/90

Photo 4. – Conventional excavator mired in Elephant Butte delta after slipping off mats.

TURBINE AND LARGE PUMP SEAL RINGS (WEARING RINGS)

By Dennis Christenson[1] and Bill Duncan[2]

Turbine Seal Ring Evolution

From about 1950 to 1970, many Bureau of Reclamation seal ring specifications required a martensitic, type 400 series, stainless steel material for both rotating and stationary seal rings. The rotating rings and matching stationary rings were specified at different hardness values. The theory appears to have been that the hard martensitic stainless steel was required to resist wear and cavitation and the difference in hardness would help prevent galling and seizure in the event of contact between stationary and rotating rings.

In 1978 at Flaming Gorge Powerplant, a stainless steel stationary seal ring, held in place with caulking, came loose and contacted the rotating stainless steel seal ring. During shutdown the unit seized at both the upper and lower seal rings. Approximately 200 work-hours were required to saw the turbine runner free for removal. At Flaming Gorge the stationary, caulked in, stainless steel seal rings were replaced with aluminum-bronze stationary rings made in three 120-degree sections that were bolted in place. The ring sections were rolled from bar stock.

Beginning in 1978, replacement of stainless steel, caulked in, stationary rings with aluminum-bronze rings became part of major unit overhauls. In most cases the caulking strip was eliminated and radial fasteners were used to hold the new rings in place. The rings were rolled from aluminum-bronze bar stock, CA954 or Ampco 18.

In 1982 a type 410 stainless steel rotating seal ring failed at Granby Pumping Plant. Metallurgical evaluation revealed the fabricated, welded ring had failed due to stress corrosion cracking. Fortunately, the stationary seal ring was aluminum-bronze and the unit did not severely gall or seize. Investigation revealed that the broken ring had been tempered near 900 °F, a temperature that must be avoided if the ring is to be used in a water environment. Tempering the type 410 stainless steel between 700 °F and 1,050 °F imparts low resistance to corrosion and low toughness. The California State Department of Water Resources informed Reclamation of similar seal ring failures on types 422 and 410 stainless steel seal rings as early as 1976. The source of the problem appears to be specifications requiring material hardness that implied tempering at approximately 900 °F. The martensitic stainless steel rings are being replaced with rings of austenitic stainless steel type 304 (fabricated), CF8 (single-piece cast) or Armco Nitronic 60. The rings are a shrink fit to the runner, and fasteners are usually not required.

In 1982 the Bureau of Reclamation performed laboratory galling and cavitation tests on a variety of materials ("Wrought Stainless Steel Fasteners for Civil Works Applications," by E.G. Segan, published by the U.S. Army Corps of Engineers, March, 1982). The test results verified that types 300 and 400 series stainless steels were certain to fail due to galling or seizure under loaded moving contact. The tests indicated that cavitation

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resistance was not totally dependent on material hardness. The softer austenitic type 304 stainless steel performed significantly better than the hardened martensitic type 410 stainless steel. The aluminum-bronze was more resistant to cavitation damage than either type 304 or 410 stainless steel. In addition, the galling test results indicated that aluminum-bronze moving against stainless steel did not seize or gall.

The Bureau of Reclamation established aluminum-bronze matched to austenitic stainless steel as materials of choice for seal rings. On most new stainless steel runner specifications we eliminated separate removable rotating seal rings. The seal surface was made an integral part of the runner casting. Restoration of seal clearances on future overhauls will depend on installation of smaller-diameter stationary seal rings and clean-up cuts if required on the runner seal surfaces.

In 1985 we recognized that the stationary ring design using the rolled aluminum-bronze ring segments held in place with radial fasteners was not the long-life seal ring design we require. Within 10 years of installation, radial fasteners have failed on four out of five of the designs monitored. Several of these failed in less than 1 year of service. Mechanisms of failure have been identified as over-torquing during installation, flaws in the screws, effects of thermal expansion, higher than anticipated tension forces on the bolts, and fatigue due to vibration due to incorrect ring dimensions. The rings themselves cracked prior to or in conjunction with fastener failure on eight units at one powerplant. In rolling the aluminum-bronze bar stock to size, cracks were introduced on the outside diameter. In addition the rolled bar stock exhibited a tendency to lose its rolled dimension. After installation there was often clearance between the ring and the retainer allowing the ring to flex and eventually develop fatigue cracks.

To improve the stationary seal ring design, we changed materials to nickel aluminum-bronze UNS C95500 or C95800. Whenever possible we decided to make the rings as a single piece by sand casting, centrifugal casting, or ring rolled forging. If the ring must be made in several sections, each section is usually cast. Single-piece rings are shrunk in place. If fasteners are required, they are made from Nitronics 60 gall-resistant stainless steel. On some units the steel seal retainer and seal ring assembly have been replaced with a single-piece, nickel aluminum-bronze casting.

In 1988 an aluminum-bronze, rolled-bar-type, stationary ring failed in service at Glen Canyon Powerplant. To return the unit to service as soon as possible, the ring segments were removed and the stationary seal surface was renewed by weld overlay on the existing stainless steel retainer. Using MIG process, nickel wire was used as a buffer layer for a first pass, and AMPCO wire 46 (nickel aluminum-bronze) was used to build a seal ring approximately 0.6 inch thick. The method of seal ring restoration was highly successful but required approximately 2,000 work-hours of welding and 1,100 pounds of weld wire to build the two 165-inch-diameter rings. The stationary seal rings on all the units at Glen Canyon are now being replaced with a cast, nickel aluminum-bronze, integral ring and retainer.

In summary, Reclamation's Engineering Division now recommends the following material combination for general service:

Stationary Rings: Nickel Aluminum-Bronze, UNS C95500 or C95800
Rotating Rings: Austenitic Stainless Steel, UNS S30400 or Nitronic 60

Stationary seal rings small enough to be economically cast or forged in one piece (below approximately 160 inches in diameter at this time) are specified as single-piece castings or ring-rolled forgings. If the ring is too large for economical single-piece casting or forging, Reclamation specifications require that individual ring segments be cast and assembled. When practical, both stationary and rotating rings are installed with a shrink fit to prevent flexing and fatigue failure and to eliminate fastener problems.

Turbine Seal Ring Replacement At Hungry Horse Powerplant

The four 75-MW hydro turbines at Hungry Horse Powerplant were completed in 1948. The turbine seal rings were typical of seal or wear rings constructed in the late 1940's and 1950's with the caulked insert design. The steel holder or retaining ring was manufactured and welded in place for the stationary ring. Bronze inserts were held in place using a dovetail design and hammered in lead-nickel caulking. Reclamation experience has proven the caulked insert design only lasts 20-30 years with a high potential of the inserts coming loose out of the retaining ring due to caulking failure. The insert can then contact the rotating ring with the potential of causing binding and seizing of the rotating parts, and turbine bearing damage.

The rotating turbine seal rings consisted of one-piece rings made of medium carbon steel. They were heat shrunk to a tongue and groove surface on the runner and bolted radially to the runner. The wearing rings, and retaining rings were rolled, ends welded, and machined.

In 1990 we began disassembly of the units for generator rewind and uprate. As part of the outage we decided to overhaul the turbines. Our objective is to maximize turbine efficiency and reliability by inspection, restoration, and replacement as required of bushings, bearings, and turbine seal rings and restore original clearances.

Inspection revealed that the caulking for the stationary seal inserts was severely eroded and the seal inserts were worn to the level of the steel retainer. The sealing effect of the turbine seal rings is based on the shearing forces generated between the two surfaces being greater than head pressure exerted across the gap between the wearing rings. As turbine seal ring clearances increase to 200 percent of the manufacturer's initial design, we can expect up to a 2 percent turbine efficiency loss. The optimum radial seal ring clearance for a 100,000 hp Francis turbine which turns at 180 r/min in the 400-500-foot head range is 0.035 inch. In replacing the seal rings we decided to modify the design to incorporate the material selection and design practices discussed previously.

Reclamation's Denver Office designed the new seal rings around the premise that the rings are to be made of metals that have very good properties of anti-galling and anti-seizing against each other. Even in the event of unlubricated spinning contact they should not sieze the unit. Other material qualities needed are; high cavitation resistance, erosion resistance, and corrosion resistance. The following ring materials were selected:

1. Rotating Rings.–A one-piece ring made of Armco Nitronic 60 stainless steel.

Composition

Carbon	0.10%
Manganese	7 - 9%
Silicon	3.4 - 4.5%
Chromium	16 - 18%
Nickel	8 - 9%
Nitrogen	0.08 - 0.18%

Properties

Machinability 23%
- Requires power and rigidity at about half the rates used for type 304
- Tooling-coated carbides required
- Finish: 0.025-inch-depth cut required

Anneal at 1,950 °F with water quench
Heat treatment will not harden

The Armco Nitronic 60 was selected for the following properties:

a. Greater corrosion resistance than type 304 in most media.
b. Pitting resistance is superior to type 316.
c. Yield strength is about twice that of type 304 at 20 °C.
d. Excellent low temperature impact resistance.
e. Outstanding galling resistance even against itself.
f. Lower cost than cobalt and high nickel alloys.

2. Stationary Rings.–A one-piece ring made of nickel aluminum-bronze (UNS C95500) tempered, annealed, and heat treated, with a Brinell hardness >200.

When using a nickel aluminum-bronze-based material for the stationary rings consideration had to be given to the high coefficient of expansion compared to the steel material the ring is to be fastened to. Shrink fits were used in the design to account for the maximum temperature differential that may be encountered (i.e.; watering up a turbine that has been unwatered for some time). Without appropriate shrink fit design, fasteners would have to take the temperature differential loads which could be very high and may cause fastener failure or weld cracking.

The appropriate shrink fit for a nickel aluminum-bronze wearing ring at 150-inch-diameter is 0.075 inch. The stress in the seal ring should not exceed 1/3 the yield strength of the material, and the temperature required to install the ring should not be lower than the temperature of dry ice, -109 °F.

To maintain seal efficiency and minimize pumping forces on the ring, no more than 30 percent of the seal ring clearance was allowed in out of roundness or off center. Beyond 30 percent, ring fasteners may tend to fatigue and break. There would also be an increased danger of wearing ring contact, higher turbine bearing loads, and abnormal bearing runout patterns.

The seal rings had to be rigidly mounted so that no flexure can take place from pumping forces caused by out of roundness or off center between the wearing rings. Should flexure or movement take place, fasteners may be broken and materials of aluminum-bronze base will work harden and fracture over time. We decided to avoid aluminum-bronze base fasteners due to the work hardening properties.

The various methods of manufacturing a single-piece large turbine seal ring are:

1. Roll and weld ends together.
2. Roll or cast segments and weld ends together.
3. Static cast in one piece.
4. Centrifugal cast in one piece.
5. Ring rolled forging.

Each method has its advantages and disadvantages with the desired end results as follows:

1. A ring of good internal integrity
2. A ring of good shape for installation ease and close dimensions

A good fit is required so the rings are rigidly backed on the full contact diameter, especially on the thin ring designs. The new seal rings were designed so that material had to be machined out by the use of a boring bar on the foundation ring and head cover retainer. This helped reduce the machining on the stationary ring inside diameter, achieve proper roundness, and achieve proper center.

Heat treating of the nickel aluminum-bronze materials was necessary for stress relief and hardness requirements. If the segment-welded manufacturing method had been for the rotating ring, post weld treatment would have been required. The object is to have a ring with the least internal stresses possible to aid in the machining and installation processes.

The casting manufacturing process was selected for the rings instead of the rolling and welding process. We consider the casting process superior partially due to problems encountered in the ring machining process. As material is removed from inside and outside diameters of the rolled rings, the material that was elongated and compressed to achieve the round shape from a flat bar is removed. The stress on the segment welds is greatly increased requiring the ring to be held rigidly to the boring mill table to maintain the round shape. A method must be used that will keep the ring round while allowing machining on both inside and outside diameters before the restraint is removed. All measurement work must also be completed before the restraint is removed. The shape the ring assumes after restraint removal may make a good installation job more time consuming to almost impossible. Cracks may also be induced in the rolling process depending on the state of the material used.

The machining of Nitronic 60 stainless steel required special consideration. The machinability is rated at 23 percent compared to annealed mild steel. Coated carbide tooling was used. The finish cut should be 0.025 inch to obtain the best finish. The Nitronic 60 metal tends to compress and roll on lighter cuts. Machining was done at 50 percent of the speed used for type 304 stainless steel and closely watched for heating that can cause ring deformation in the machining process. The finish dimensions were achieved in several stages alternating between inside and outside diameters in machining the rings.

The installation process on the stationary rings requires cooling for installation. To obtain a 1/8-inch installation clearance on the 150-inch-diameter nickel aluminum-bronze ring with a 1.5-inch maximum cross-section thickness for a final 0.075-inch shrink fit, the ring had to be cooled to 150 °F below ambient. This was accomplished by immersing the ring in an acetone and pelletized dry-ice bath. Alcohol could have been used as a liquid heat transfer medium instead of acetone. An insulated ring trough with insulated blankets to cover the bath was used. Special safety considerations must be utilized using acetone, dry ice, and installing the cold ring. The ring had to be totally within the solution for about 30 to 40 minutes to achieve the base temperature. The stationary wearing rings were skip welded in place on the top and bottom using Ampco-Trode 10 for dissimilar metal joining.

The installation process on the Nitronic 60 stainless steel rotating rings required an even preheat to 250 °F above ambient. This allowed a 1/8-inch installation clearance over the tongue and groove surface on the turbine. The tongue and groove surfaces were designed with a difference of less than 0.050 inch on the diameters. The above parameters applied to a stainless steel ring that is about 149 inches in diameter with a maximum cross-section thickness of around 1.25 inches. The desired shrink fit was 0.075 inch on the diameter for the rotating seal ring.

When installing the new rotating seal rings, the fastener holes were shifted to an area between the old holes so new holes could be drilled and tapped. The fasteners were considered redundant to the shrink fit in holding the rings in place. The size fastener selected for the ring was 7/8 X 14 with a head diameter of 1.600 inches.

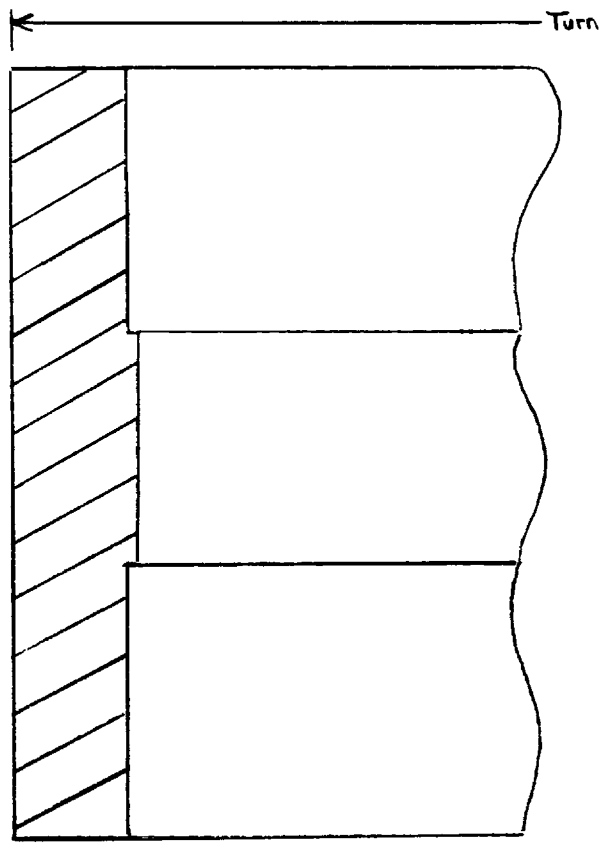
The fasteners for the rotating rings were made of an annealed stainless steel with a twist-off head design to break at 80 percent of the yield strength of the cap screw material. We used a thread locking compound to hold the fasteners in place. The heads of the twist-off cap screws were machined flush at the same time the finish surfaces of the rotating seal rings were turned. The counter bore for the cap screw heads was about 9/16 inch deep to allow for adequate bolt head strength.

The final diameters of the rotating seal rings on the turbine were machined after the final boring of the stationary seal rings was completed to obtain the proper design clearance between the rings. Measurements were taken using a tube-type micrometer for large inside diameters and a pi-tape for the outside diameters. All items were measured at room temperature.

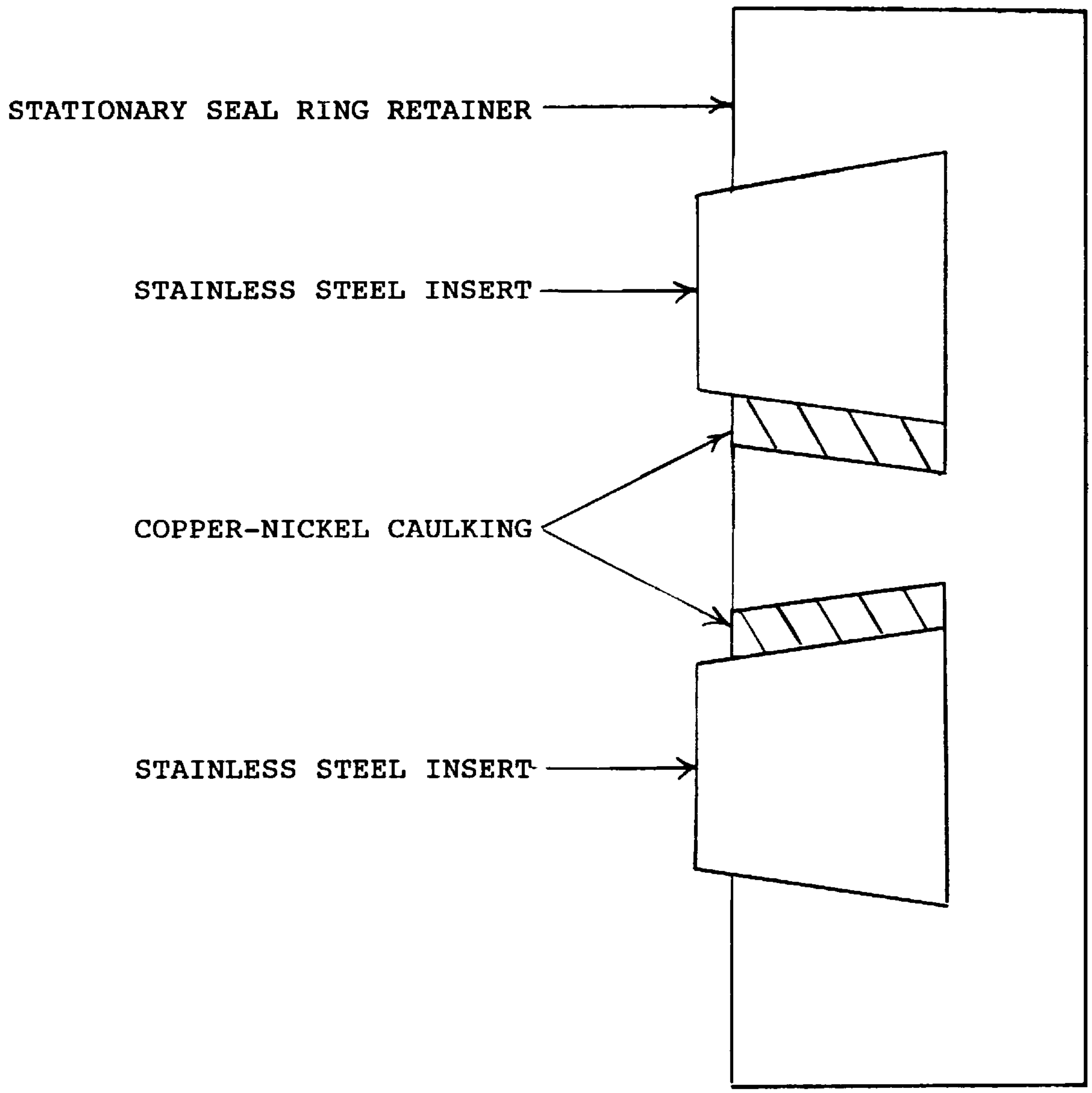
When boring stationary seal rings after installation in the head cover and bottom ring, the unit centerline must be accurately determined. The centerline can be established by hanging a single tight wire through the unit and locating centering points at several elevations through the turbine and draft tube. The boring bar is set plumb and concentric with the turbine bearing and the generator stator. The stationary seal rings are bored to be concentric with each other and the centerline of the unit to within 0.1 multiplied by the diametrical seal ring clearance.

A 2 percent turbine efficiency loss for a 100-MW hydro-unit could equal $1.09 million in revenue loss per year if operated 11 months out of the year at full load at replacement power costs of 68 mils.

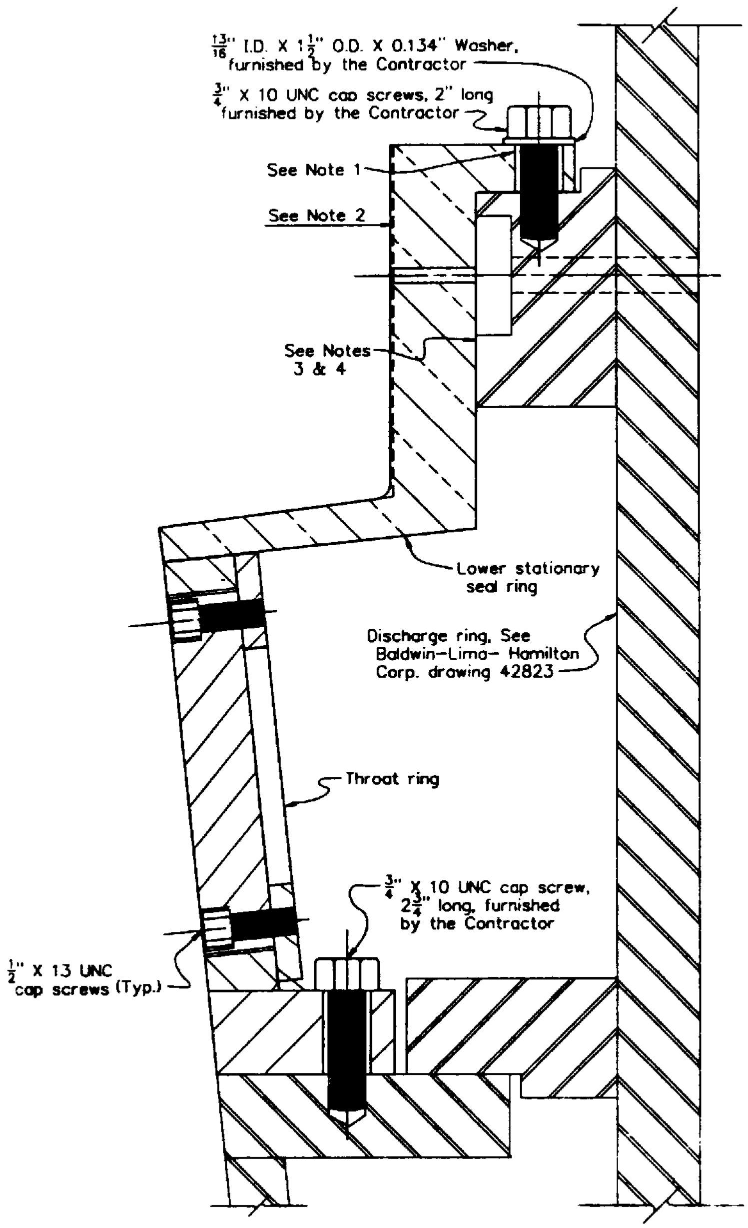
May your turbines run efficiently!



Typical rotating seal ring design — shrink fit.



Typical caulked-in seal ring design.



ASSEMBLY SECTION

New integral stationary seal ring and retainer design.

TEMPORARY BULKHEAD AFFORDS REPAIRS IN THE DRY AT LEMON DAM

by Craig Kjar[1]

During the 1988 annual inspection of the high-pressure gates and outlet tunnel at Lemon Dam, Mr. John Ey, the Reservoir Superintendent of the Florida (pronounced Floreeda) Water Conservancy District, determined that repairs were required to the cavitation damage downstream of both regulating gate frames and the concrete tunnel immediately downstream of the left gate. Both guard gates, located upstream of the regulating gates, leaked profusely, keeping damaged areas wet with water spray. To effectively accomplish the repairs, it was necessary that the work area stay dry for the repair material to cure properly.

Mr. Ey devised a temporary bulkhead to afford dry conditions in the work area and not break the district's repair budget. A fiberglass shield was placed immediately downstream of the guard gates to deflect gate leakage. A wooden framework covered with a heavy plastic sheet was then placed in the 2.25- by 2.25-foot gate frame to stop any overspray. An aluminum and plywood bulkhead was also installed using silicone and large truck inner tubes for gasket material and screwjacks to compress the gasket material to the gate frame. A 4-inch irrigation flexi-hose was inserted through the bulkhead to convey all accumulated gate leakage away from the work area. Minor leakage past this bulkhead at the left gate body was controlled by using an additional set of screwjacks, a 2 x 4, and caulking downstream of the bulkhead. This system was successful in completely drying the areas needing repairs.

Cavitation damage on the gate frame immediately downstream of the regulating gates was repaired with a Devcon ceramic metal applied in thin layers and cured with a heat lamp between applications. Heat lamps were important to the repair process since the work was accomplished in April 1988 at elevation 8000 feet. The repairs to the concrete floor downstream of the left regulating gate were performed with Probond, an epoxy-concrete material manufactured by the Protex Company. The repaired areas are inspected each fall with additional repairs made as needed. The reason the repairs have been so successful at Lemon Dam can be attributed to Durango Projects personnel's and Mr. Ey's contacting the manufacturers of the repair materials for proper application procedures in the Durango area.

Materials used to construct the bulkhead are readily available in most hardware stores. Each bulkhead was constructed for less than $250.

A similar application of this technology was applied in the Belle Fourche Projects area. The drainpipe and screwjacks were left out of the assembly because gate leakage was not as severe as that at Lemon Dam.

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[1] Craig Kjar is a Supervisory Hydraulic Engineer, Bureau of Reclamation, Belle Fourche Projects Office, Newell, South Dakota.

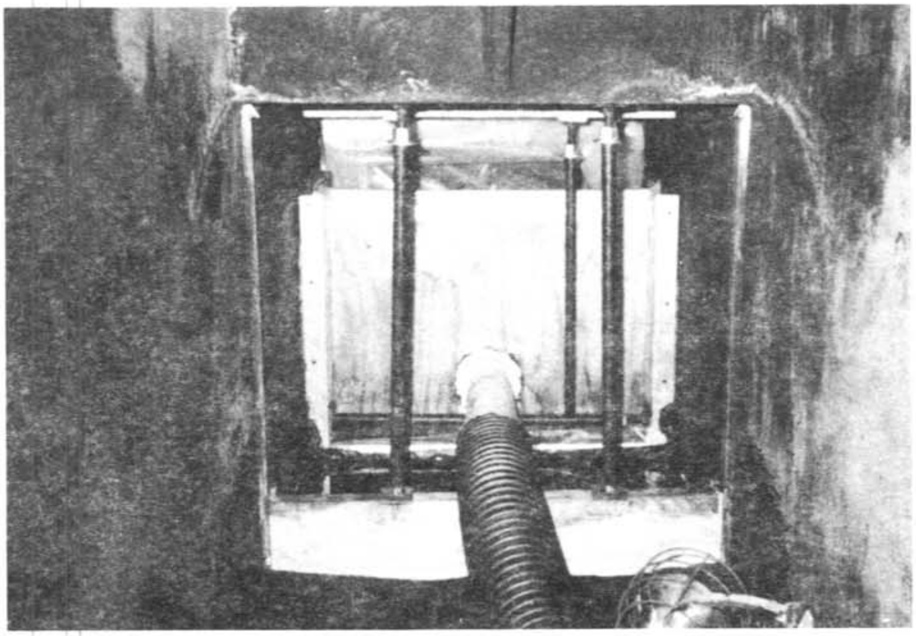

Photo 1. — Lemon Dam - Cavitation repair - Bulkhead installed in right outlet conduit between the regulating and emergency gates to control all leakage during repair work. 4/24/88

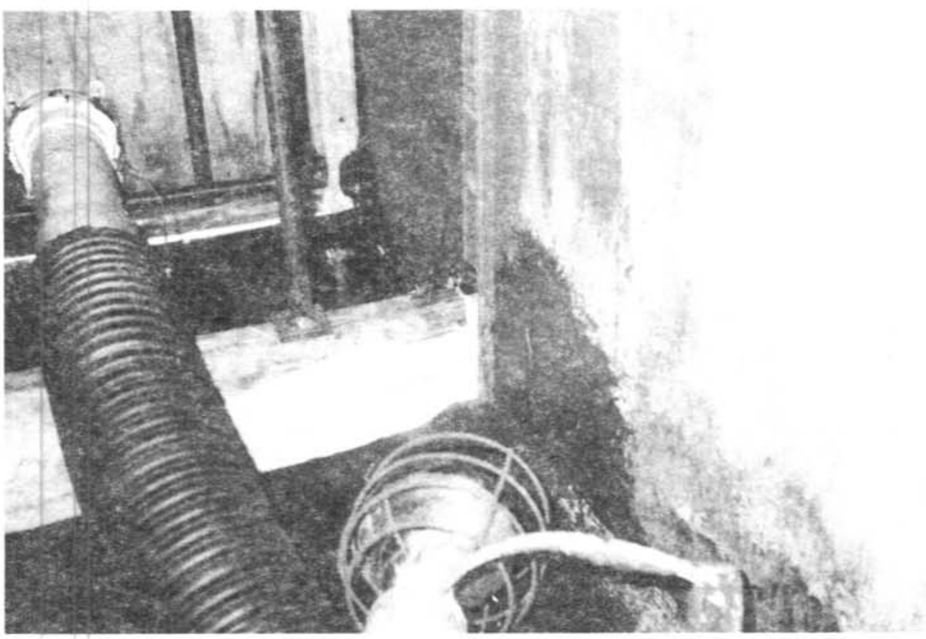

Photo 2. — Lemon Dam - Devcon ceramic metal repair to gate body below left regulating gate. 4/24/88

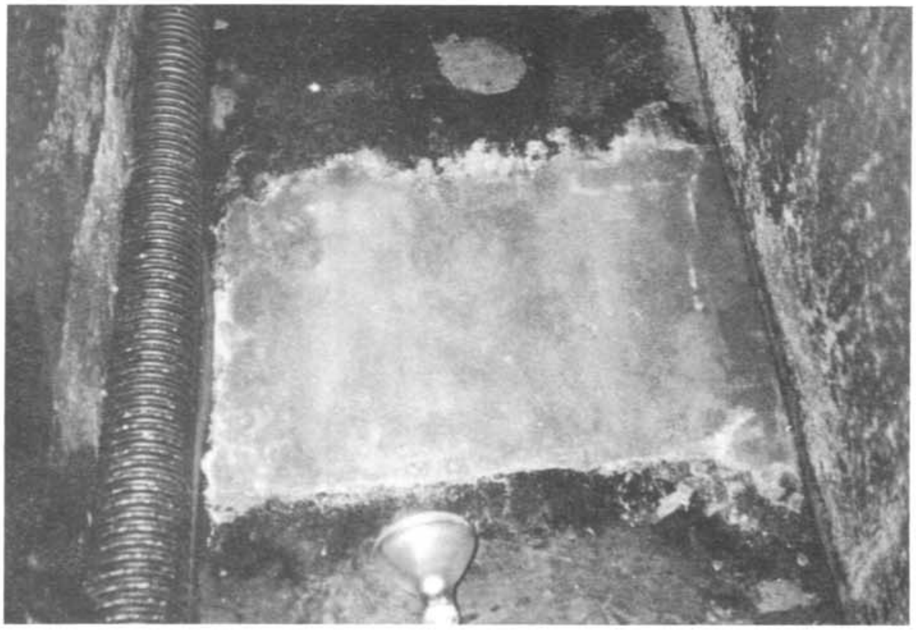

Photo 3. — Lemon Dam - Cavitation repair. Protex Probond epoxy concrete repair to the floor of outlet tunnel downstream of the regulating gate. 4/24/88

BEWARE OF BLOWBACK

by Tony Wahl[1]

This is not a warning for ships navigating whale migration routes, but a caution to avoid damaging reservoir intake structures at low water levels. Now that many parts of the western states are under drought conditions, reservoirs are likely to be drawn down to levels where gate openings should be controlled to prevent blowback from occurring.

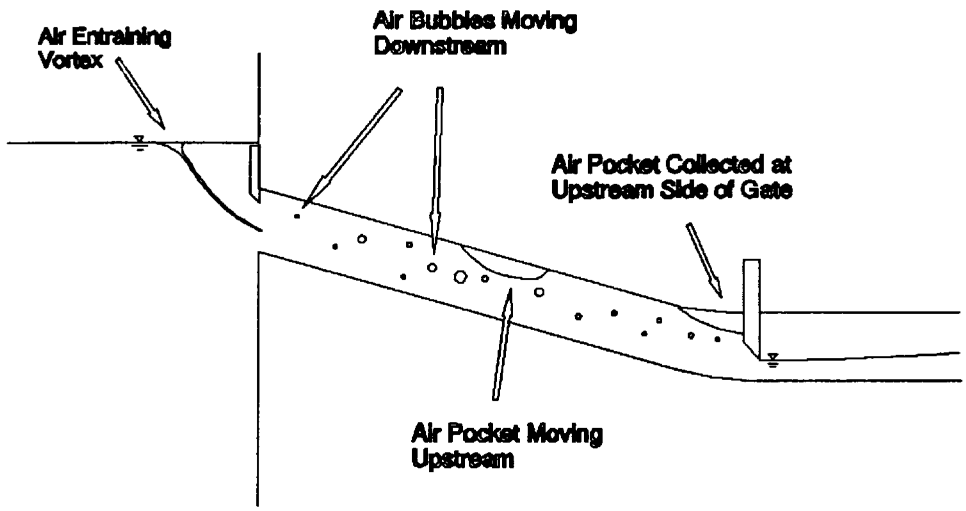

Figure 1. — Conditions that cause blowback.

What Is Blowback?

Blowback is the release of air back through the intake of a closed conduit. Figure 1 shows the conditions that combine to cause blowback. At low reservoir levels, air enters partially submerged intake structures, or may enter shallowly submerged structures via air entraining vortices. When air bubbles are small, they have little buoyancy relative to the drag forces acting on them, and are carried downstream by the flow. However, as bubbles collect at discontinuities in the pipeline (such as the upstream side of control gates), they combine to form larger air pockets. As the air pockets grow larger, their buoyancy increases faster than the flow forces acting to carry them downstream. Under certain flow conditions, these air pockets will begin to move upstream against the flow, though smaller air bubbles are still carried downstream. In a downstream inclined conduit, as the large air pockets move upstream, the pressure head is reduced and the volume of the air pocket increases. Eventually the air pocket may occupy a large part of the cross section of the conduit, so much so that the flow is affected. This causes surging flow and pressure pulsations in the conduit. Eventually the air pockets may move all

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the way upstream to the intake structure, where they are explosively released from the conduit. This explosive release of air is *blowback*. The pressure pulses caused by the surging flow and blowback are often severe enough to damage the tunnel or conduit lining and possibly the intake structure. Figure 2 shows blowback occurring in the morning-glory spillway at Owyhee Dam.

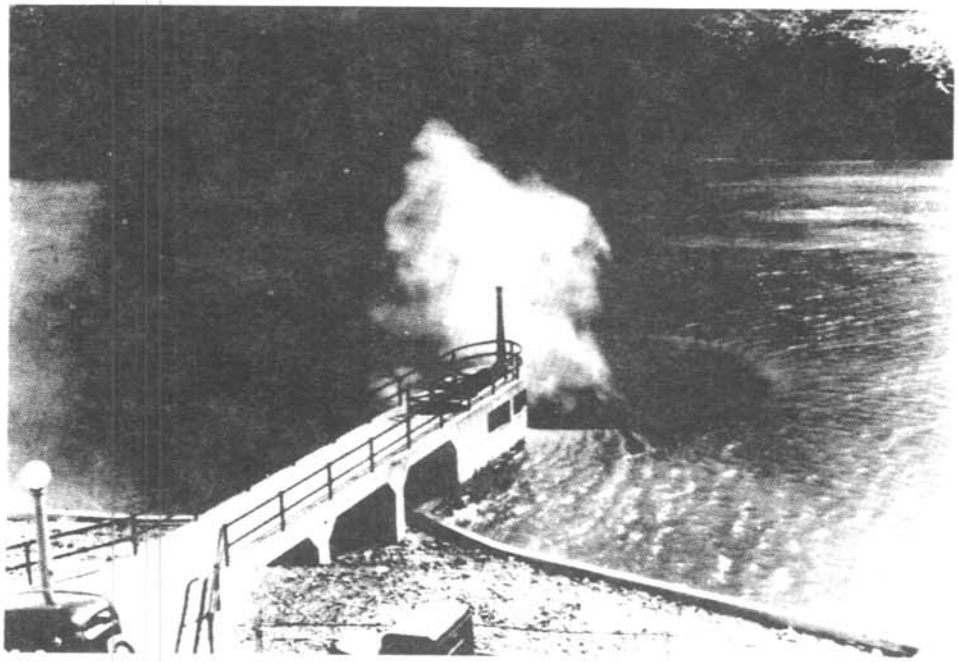

Figure 2. — Observed air blowback in morning-glory spillway at Owyhee Dam, Oregon.

How Can Blowback Be Avoided?

Two conditions must occur to have blowback. The first is the entrainment of air into the flow, either due to partial submergence of the intake structure, or air entraining vortices that carry air into a shallowly submerged intake. Second, the inclination of the conduit and the flow rate must be such that small bubbles are carried downstream, and large air pockets can still move upstream. Thus, the first way to avoid blowback is to avoid operations that will allow air to enter the conduit. This may be done by limiting gate openings to no higher than the reservoir water surface elevation. If air entraining vortices still carry air into the conduit, special rafts may be used to break up the vortices and prevent air flow into the vortices. If air entrainment into the flow cannot be eliminated, then flows should either be lowered so that air bubbles are not carried downstream, or raised so that large air pockets cannot travel upstream. Raising the flow rate may not be a satisfactory solution, since large air pockets carried downstream may still cause problems with downstream equipment.

Most recent projects have criteria in the Standing Operating Procedures or Designers' Operating Criteria for gate restrictions during low reservoir levels. If such criteria have not been established, the operating entity should consult the nearest Bureau of Reclamation office for assistance if low reservoir levels are anticipated. Allowable gate settings will be determined for the low reservoir levels expected.

WATER QUALITY PROBLEMS ARE AGING YOUNG LAKES[1]

Answers sought to what's happening and why

by Vicki Miller[2]

As lakes go, Willow Creek and Maskenthine in northeast Nebraska are youngsters, but water quality problems are aging them far before their time.

Their turbid waters are sometimes contaminated by chemicals and clogged with sediment. Excessive alga blooms are choking Willow Creek Reservoir, opened in 1984, southwest of Pierce.

Sediment is shrinking Maskenthine Lake, opened in 1979 north of Stanton.

UNL (University of Nebraska Lincoln) Water Center researchers seek scientific solutions to preserve the troubled lakes, and to help protect other Nebraska water impoundments.

UNL Water Center research team members maneuver a pipe used to collect sediment core samples from the bottom of Willow Creek Reservoir.

Although lake life spans vary, "these are rapidly aging lakes by anybody's standards," says Roy Spalding, UNL research hydrochemist and Water Center associate director who heads the interdisciplinary team studying the lakes.

"They're extremely vulnerable. It's going to take a massive management effort to preserve the lakes for any sort of normal aging process."

Researchers want to understand what's happening to each lake and why. When the 2-year project ends in 1992, they'll report to the Lower Elkhorn Natural Resources District,

[1] Reprinted with permission from the Editor, Nebraska Farmer, September 1991 issue.
[2] Vicki Miller is on the staff of the University of Nebraska Ag Communications Department.

which built both lakes and funds the study through a grant from the U.S. Environmental Protection Agency's Clean Lakes Program.

"Our purpose is to define the problem and go a step further and offer some potential solutions," Spalding says. "In the end, we hope to advise the NRD as to management strategies for combating chemical loading, utrification (rapid aging), and siltation of those resources."

Scientifically contrasting the two environmentally and topographically divergent lakes only about 30 miles apart is unique and useful, Spalding says.

The 100-acre Maskenthine is surrounded by steep, glacial till hills, somewhat similar to southeast Nebraska's Salt Valley lakes, while 700-acre Willow Creek is a sandhills-type impoundment. Both provide recreation and flood control.

The Lower Elkhorn NRD manages Maskenthine; the Nebraska Game and Parks Commission operates Willow Creek State Recreation Area.

Although the lakes' problems differ, Spalding says, they're receiving similar scientific scrutiny.

Researchers want to determine how much siltation has occurred and estimate the siltation rate; identify the types, amounts and potential sources of chemicals; and explore scores of other factors that might accelerate aging.

Thousands of tests and lab analyses, including sampling the lakes' water and sediments for chemicals and other substances, checking water temperature, mapping the bottoms, and monitoring the amount, speed and contents of water entering and leaving the lakes, will provide a broad scientific picture.

Ultimately, life-extending strategies and a computer model of each lake will emerge.

Results of this research, coupled with EPA Clean Lakes Program monitoring efforts by others on several Nebraska lakes, could change how lakes are built.

"I honestly feel that this research is going to help institute basic design changes in lakes," Spalding says.

Developers may start checking water quality as well as quantity in streams before they are dammed, he says. "I think that has been one of the big things that has been missing," Spalding says. Historically, "it's all been quantity."

Surface water research is relatively new in Nebraska, he says. Ground water takes priority because of widespread irrigation and potential contamination of domestic and municipal water supplies.

Surface water and ground water, however, can't be strictly delineated, Spalding says.

"As we degrade the surface water, we in essence degrade our own drinking water."

TWELVE STEPS IN SELECTING COMPUTER MAINTENANCE MANAGEMENT SYSTEMS[1]

by Terry Wireman[2]

Evaluating the sizable number of computer maintenance management systems (CMMS) on the market can be a confusing experience. But it is not an impossible task. These 12 steps outline a procedure for choosing a package to meet specific needs:

Twelve Steps in Selecting CMMS

1. Determine the organization's present status
2. Determine project goals and objectives
3. Identify the project team
4. Document requirements
5. Contact the vendors
6. Evaluate the systems (vendors)
7. Narrow the vendor list
8. Conduct site visits and additional evaluations
9. Select the vendor
10. Implement the system
11. Monitor the (system) operations
12. Evaluate the results

1. *Determine the organization's present status.–*

This procedure is an objective look on how the organization presently does business. It should include all areas that will be involved in the computerization project — for example, maintenance, inventory and purchasing, plant management, engineering, and production/facilities areas.

Maintenance journals, trade publications, and textbooks contain guidelines that may be used to compile an analysis. Some companies have used consultants to evaluate their status. Some consultants, however, will spend time developing a complex manual system and then want to develop a customized computerized maintenance management (CMM) package. This evaluation can be expensive and have a long development time.

2. *Determine project goals and objectives.–*

Once the present status of the organization has been established, determine where the company would like to be. What are the goals? What should be accomplished? Where is improvement needed? Asking these questions of all individuals or groups involved in the selection process will help to set the scope of the project.

[1] Reprinted with permission from the Editor, Maintenance Technology, February 1989 issue.
[2] Terry Wireman (Wireman & Associates), an Eaton, Ohio consultant has conducted seminars worldwide on implementing computerized maintenance management systems. He is currently affiliated with SCI Software, Inc., Crystal River, Florida.

3. *Identify the project team.–*

Decide which members from the groups involved should form the project team. From this point to the conclusion, the team should work closely to collect data, compile information, and present recommendations to the decision making group, which in many cases is the project team itself. If the project team makes the decisions, it does expedite the project.

4. *Document the requirements.–*

The project team will examine the information compiled previously and identify requirements for the organization and the software. This process combines present policy and procedures with identified changes required to achieve the organizational goals. It is usually best to subdivide these requirements into the various areas of responsibility, such as maintenance, inventory, or engineering. This subdivision will permit easier negotiations. At this point ask, "Has the hardware platform been decided upon?" This question is important to the next step.

5. *Contact the vendors.–*

Contacting vendors is an easy step. Attending seminars and trade shows may provide a basis for information. A trade journal's list of maintenance management software vendors is another source. Making a decision on a hardware platform first will provide a shortcut to the vendor selection process. If PC or PC-LAN-based software will be used, about half of the vendors can be eliminated. Running a system on a minicomputer will eliminate 75 percent of the vendors. If a mainframe version will be run, up to 90 percent of the vendors can be excluded.

However, selecting the hardware first, and then the software is not the preferred method. It is best to select software first. The issue is merely raised here because many times management specifies the hardware platform and the project team contacts vendors who do not develop products on that platform.

Initial contact with a vendor is generally in the form of a brief letter or a telephone call to express interest in the computerization of your organization. The vendor will need information including what the organization does, what types of processes are involved, the size of the organization, and what parts of the organization will be included in the computerization. More questions may be asked later, but this basic information tells the vendor quickly whether or not there is a good fit between the organization and his product.

As literature from various vendors arrives, or when phone contacts start, you should keep a file on each vendor containing literature received and notes on telephone conversations. Good recordkeeping at this stage will pay dividends later.

6. *Evaluate the vendors.–*

Form your company's viewpoint, then confirm whether or not there is a good fit between the vendor's product and your organization's requirements. Examine major items. Does the vendor's product include inventory and purchasing? If not, and this was a requirement, the vendor can be eliminated. The first evaluation should not be too detailed. The object is to reduce the list of vendors and then do an indepth analysis on packages that seem to have the best fit.

Usually, vendors will fall into one of the following categories: maintenance, software, consultants, or system integrators.

Maintenance vendors have a strong maintenance background, but little software expertise. Their packages reflect this flaw, with strong maintenance philosophies, but poor programming techniques.

Software vendors have a strong programming background, but little maintenance expertise. Their packages have good programming, tight coding, and maximum use of the hardware environment, but the programs do not have a strong maintenance philosophy.

Consultant vendors have varied backgrounds focusing on inventory, purchasing, engineering, accounting, or maintenance. Each type of background will produce a different type of package. And each package will be stronger in the consultant's background and weaker in the other areas.

System integrators have existed for several years. These companies have expertise in all the maintenance areas. However, system integrators are usually more expensive than other vendors.

7. *Narrow the vendor list.–*

After a brief evaluation of vendors, the project team should be able to narrow its selection to three to five vendors. At this level, enough information should be available to represent a good cross section of vendors, but not too many to be able to do an indepth evaluation. Once the vendor list is established, each vendor should be sent the requirements for the system identified in step 4. Several forms may be necessary including a check sheet, a request for quotation, or a request for proposal.

A check sheet can be used when looking for a small system. It lists all requirements (step 4) and includes space for the vendor to check off whether he can or cannot meet this need. This form is generally used in single site purchases, particularly in the PC environment.

A request for quotation is a larger document. It details, in writing, the needs for a maintenance management system. It presents the requirements and adds details to clarify them, so the vendor has a better understanding of what is needed. The vendor, in turn, responds by stating which of his products meet these needs, and provides the relative price of the software. This form is used for multiple site purchases of PC-based systems, PC LANS and minicomputers.

A request for proposal is the most detailed of the three documents and requires considerable effort from the company and the vendor. This document provides an overview of the organization, its present status, and the goals and objectives for the project. It must give the vendor a scope to measure his product against. The vendor, in turn, will provide a document showing how he plans on meeting the requirements and how his product will fit into the organization. This project is lengthy. It may take weeks for an organization to put together and weeks for a response from the vendor. It should only be used when dealing with a few selected vendors.

8. *Conduct site visits and additional evaluations.*-

Visit a site where a vendor's system is in operation. For smaller purchases, ask the vendor to provide a list of 10 references having a similar size organization or in the same industry to contact about using the proposed system. If this is not possible, ask for an organization that conducts business in the same manner as your company. It will not be necessary to call all 10 sites, but 10 possibilities prevents the vendor from controlling exactly which site will be called. In fairness to the vendor, however, ask referrals specific questions, express any concerns, and ask for solutions to any common problems. Do not waste the contact's time with idle talk. In some cases, there is a direct charge to the vendor for time spent talking to prospects. Good business conduct and practices should be used at all times.

Site visits are a must for larger purchase. These involve an actual visit to one or more sites where the proposed system is in use. One or two locations is sufficient for the largest contracts. The same rules apply as for smaller purchases—a similar industry, similar size organization, or a similar method of doing business. Site visits can take considerable time and effort, so make sure there is a fixed agenda with specified time periods for question and answers. Each member of the project team should try to spend some time with his counterpart at the site to maximize the benefits of the visit.

Additional evaluations are made from a final presentation by the vendor to your project team and management representatives, if appropriate. Look for the vendor's strength. Can the vendor meet your company's needs? Does the presentation include a live demonstration of the product, a hardware proposal, and a method to implement the plan?

Ask questions. Involve all the skills and talents of project team members to assure accuracy and a good evaluation.

The software demonstration is an important part of the presentation. Have the vendor explain the information flow through the system. Ask specific questions. When a requirement is covered, have the presenter show how the system accomplishes the task. Look at the number of keystrokes involved. How much information must be memorized to get what is needed from the system? Proper analysis during the presentation can deter problems later on in the process.

9. *Select the vendor.*-

After the final presentation, the project team will meet to compare notes, highlighting the pluses and minuses of each vendor from the perspective of each part of the team. This input should lead to vendor selection. Project team discussions should take place less than a week after the final presentation. All vendor presentations should be made within the same week to maintain continuity.

After the vendor is selected, ask for help to tie up any loose ends. If help is needed to sell the system to any part of the organization, set up a presentation and let the vendor present his case studies including how the system has helped other similar organizations.

10. *Implement the system.*–

System implementation will require data collection and verification, hardware installation, software installation, user training, and system startup.

The data collection and verification phase includes the design for all numbering schemes, such as those required for equipment and inventory. Numbering schemes must fit in the vendor's fields. Many times organizations have developed 15 digit equipment numbers and the vendor's systems only allowed 10. Once equipment and inventory are identified, all required data for each item must be gathered and verified. For a rough estimate, good data gathering will average from 1/2 to 1 hour per item. A time estimate can assist in estimating the size of the data gathering effort.

Hardware installation involves setting up the computer system. If the platform is a minicomputer or mainframe, it is usually done by MIS or systems personnel. Hardware for a PC-based system can be installed by the end users. Proper protection for the computer must be provided at this point. Without proper protection (surge suppressors and uninterruptible power supplies, for example) the PC will damage or lose data necessitating data recovery efforts, which can be time consuming and ineffective. Proper hardware setup is extremely important.

Software installation is a matter of installing the system on the hardware. For a PC-based system, floppy disks provided by the vendor need to be loaded. If the system uses a minicomputer or mainframe, software installation is usually performed by the company's MIS or systems personnel.

The software vendor's technical personnel should be onsite when loading and starting minicomputers and mainframe systems for the first time to assure smooth startup.

Training software users is often the most overlooked part of the project. **It is critical to the success of the system for the right people to get the proper amount of training.** Heavy system users are planners, store clerks, and maintenance clerks. These groups will be required to interact almost continuously with the system. Casual users may need information from the system, or input information to the system on a less frequent basis. Supervisors, managers, or production supervisors might fit into the casual-user category.

This point cannot be overstated: Lack of good user training has contributed to the failure of, or the lack of use, of many computerized maintenance management systems. The vendor's reputation, as well as the reputation of those who helped select the system are affected when computerization fails or remains dormant.

When the data are loaded and current, and when users are knowledgeable about the system operation, it is time to put the maintenance system on-line.

This procedure can be done in steps depending on the size of the installation. Some companies like to bring certain departments or areas on-line first; others begin with certain craft groups. Smaller plants may choose to run parallel systems for a short time. Some sites start different parts of the software at phased intervals. Or they may begin by scheduling preventive maintenance, then issuing inventory items, followed by work orders. One important point—use the vendor's suggested method for starting up. Experienced vendors know the problems that can occur and can offer suggestions to avoid them.

11. *Monitor the system operation.–*

Watch data going into the system to assure accuracy. Observe users during operation to identify weaknesses. Look over all output from the system to assure that data are consistent and accurate. This step is especially important in the first few months of operation.

12. *Evaluate the results.–*

After the system has been in operation for 9 to 12 months, evaluate the results. By using the benchmarks prepared in step 1, benefits, improvements, and cost savings can be measured. This procedure will benefit the project team, the organization, and the vendor. In most cases, cost savings will be substantial. This step is essential in retaining the necessary management support to maintain good system operation. If management support is lost for any reason, the system will gradually fade into disuse. Lack of management support is a major reason why some systems work well for a year or two and then seem to have problems.

Good communication about the bottom line benefits holds management support, which keeps the entire maintenance organization, including the software system, operating at its peak.

Computerizing maintenance management should not be a confusing or frightening experience. By involving a project team, following a standardized plan of action, and using these steps, maintenance management can be computerized. Software, however, does not make things happen. It is only a tool for successful maintenance management.

COLORADO STATE WELLHEAD PROTECTION PROGRAMS

by Judy Hamilton[1]

Amendments to the Federal SDWA (Safe Drinking Water Act) in 1986 established a wellhead protection program. This is designed to protect public drinking water wells and wellfields from contamination and requires the states to develop programs to establish and manage areas of protection. The Wellhead Protection Program has three separate and distinct phases: (1) development of the State's program, (2) submittal of the State's program and approval/disapproval by EPA (Environmental Protection Agency), and (3) implementation of approved programs. A number of states have already developed programs, and many more are in the process of developing them. In the 17 Western States, programs are in various stages. Kansas, Texas, Oklahoma, Arizona, and New Mexico have approved programs. North and South Dakotas, Nebraska, Colorado, and Utah have submitted proposed programs to the EPA, and approval is anticipated in FY 1992. Wyoming and Montana will be developing programs this year; and Oregon, Washington, and Idaho are also in the process of developing programs. Nevada and California are not yet developing State programs, but there is strong local interest in wellhead protection plans.

The design of the Wellhead Protection Program is based on EPA's recognition of the need to meet the goals stated in the SDWA, while taking into account the diversity of hydrogeologic settings and sources of contamination, maximizing State creativity and flexibility in design and implementation of the programs, and recognizing State and local privacy in matters of land use and water allocation.

To aid States in developing their plans and also to inform the public about the general requirements of the plans, EPA has several publications available (see References). A bibliography, which is updated every few months, is also available. Publications can be obtained from the EPA, and addresses of their Regional offices are listed at the end of this article.

The EPA requires each wellhead protection plan to have a minimum of seven elements:

1. Definition of roles and duties of State and local agencies
2. Delineation of wellhead protection areas
3. Contaminant source inventory
4. Identification and evaluation of management approaches
5. Development of contingency plans
6. Location criteria for new wells
7. Provision for public participation

The program developed by the State of Colorado illustrates the process of development of a wellhead protection program. Protection of ground water is of great importance in the State, since 60 of Colorado's 63 counties use ground water as a drinking water source, and 29 counties rely solely on ground water for drinking. Under the direction of the Colorado Department of Health, the State has developed a WHPP (Wellhead Protection Plan) which will serve as a model from which local wellhead protection plans

[1] Judy Hamilton is a Geologist, Bureau of Reclamation, Ground Water Branch, Denver, Colorado.

can be developed. The WHPP includes the definition of WHPA (Wellhead Protection Areas) which will be established around each well or wellfield.

A volunteer citizen advisory group was established last August to provide input from municipalities; ground-water professionals; water suppliers; Federal, State, and local agencies; and the general public. They met monthly to assist the Health Department in developing the plan. In contrast to a number of other States, the plan they developed is voluntary and non-regulatory. The plan is now being reviewed and will be submitted shortly to the EPA for their review.

Basic provisions of the Colorado plan to meet the required elements are described below.

1. Numerous agencies in Colorado are concerned with ground-water supply and protection. On the State level, the Departments of Health, Natural Resources, Labor and Employment, and Agriculture each have certain responsibilities concerning ground water. Municipal and county governments have some control over potential contamination through their land use and zoning regulatory powers. As many municipal governments are water suppliers, they have a special reason to protect the ground water. Local health departments regulate many activities which affect ground-water quality. In addition, there are a number of privately owned water companies and associations which will need to develop plans for protection of their supplies.

2. Criteria have been established by the Advisory Committee to evaluate protection areas for both confined and unconfined aquifers. These provide a minimum acceptable area based on radius from the well, but allow for more precise delineation using various ground-water models.

3. The list of potential contaminant sources has been compiled. The contaminant source inventory for the local well suppliers will be the responsibility of either the well supplier or the municipality. In Colorado, the principal contributors to ground-water contamination are organic and inorganic chemicals traced to waste disposal, mineral extraction and processing, urbanization, and agriculture. The WHPP provides a list of information that needs to be included in this inventory. The list will be reviewed and updated annually.

4. Management approaches developed by the advisory group include regulatory, non-regulatory, and improvements in existing programs. The regulatory procedures include zoning and land use restrictions, agricultural regulation, and agricultural controls such as the conservation reserve program. Non-regulatory methods include land acquisition, environmental easements, monitoring program, technical assistance, and intergovernmental agreements or contracts.

The size of the wellhead protection area is a management decision which should be based on the time needed to find an alternative water supply in the event of actual or threatened contamination of the WHPA. The advisory group has recommended 5 years of time of travel as the minimum acceptable in delineating the WHPA.

5. Contingency plans include plans for emergency response, long-term actions, new source development, and remediation.

6. For locating new wells, the minimum recommended time of travel is 10 years; however, shorter time periods may be acceptable provided the contingency plan has the ability to respond to problems within the shorter period. If more funds are available for studies, the recommended delineation area for new wells is one using analytical modeling, while the optimum methods would combine this with hydrogeologic mapping.

7. Public participation includes notification of target groups identified as having an interest in, or would be affected by, wellhead protection measures. Pilot projects are being proposed.

More information on Colorado's Wellhead Protection Plan can be obtained from Kathleen Reilly of the Colorado Department of Health [telephone (303) 331-4573] or the author of this article [telephone (303) 236-8069]. Information on Wellhead Protection Plans in other States can be obtained from the EPA. Their publication on Wellhead Protection Programs lists the ground-water protection contacts in each State.

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