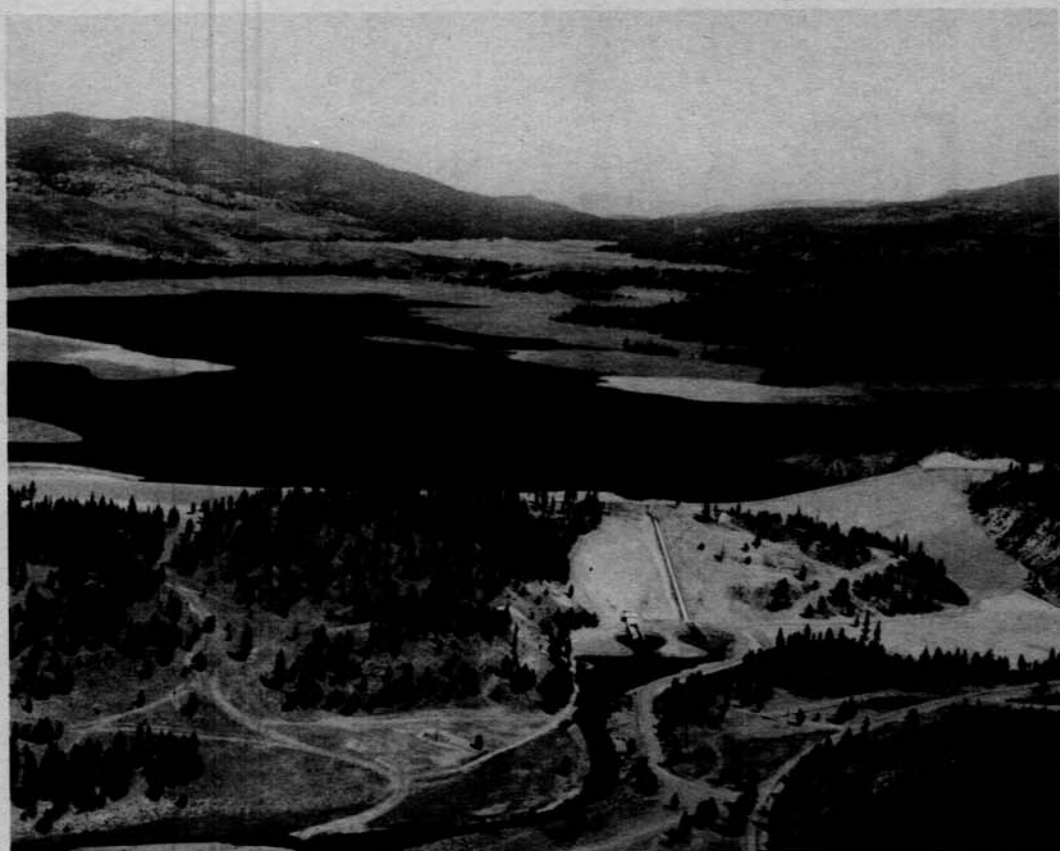
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 154

December 1990



IN THIS ISSUE

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

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

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

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Cover photograph:

Stampede Dam, Washoe Project, California, is the spotlight of this issue. Visible from left to right are the dike, outlet works, spillway, and the dam.

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WHEEL-MOUNTED AND ROLLER-MOUNTED GATES MAINTENANCE TIPS

by Bill Bouley[1]

Wheel-mounted gates, also referred to as fixed-wheel gates, consist of a structural steel leaf on which wheels are mounted to support the hydraulic load. Roller-mounted gates are similar to wheel-mounted gates but the hydraulic load is supported by a roller train system or a series of roller trains instead of wheels. These gates are generally installed as guard gates in high head locations such as penstocks or outlet conduits. The three applications for wheel- or roller-mounted gates are surface type, generally used for spillways; face type, installed on the upstream face of a dam; and tunnel type, installed in midconduit. Wheel- and roller-mounted gates have similar leaf designs which could benefit from the following discussion.

Because of the configuration of the surface type wheel- or roller-mounted gates, the upper portion of the structural members is usually exposed to the elements. Wave action, air- and water-borne debris, and ultraviolet rays of the sun attack the protective coating on the gate. On the top structural member, accumulations of precipitation could create corrosion problems. Debris collecting in the structural members can plug the drain holes resulting in rusting from rain or snow collection.

The Salt River Project in Arizona has numerous wheel- and roller-mounted gates on storage dams throughout its project area. To protect the top of the gates from ultraviolet rays, splash shields have been installed atop the gates. The splash shields consist of corrugated metal placed at an incline to prevent reservoir wave action from depositing water and debris that may lead to corrosion. Corrugated fiberglass panels may be a better choice for splash shields as they are lighter and cause less of an increase to the overall load on the hoist equipment.

The surface and tunnel type gates can benefit from wire mesh screens attached to the structural members on the downstream side of the gate leaves. Screens tack welded on the gate leaves at Bonny Dam in eastern Colorado prevent bird nests and other debris from collecting in the leaf webs. Prior to considering any of the modifications described above, an evaluation of increased loading to the hoist equipment should be performed.

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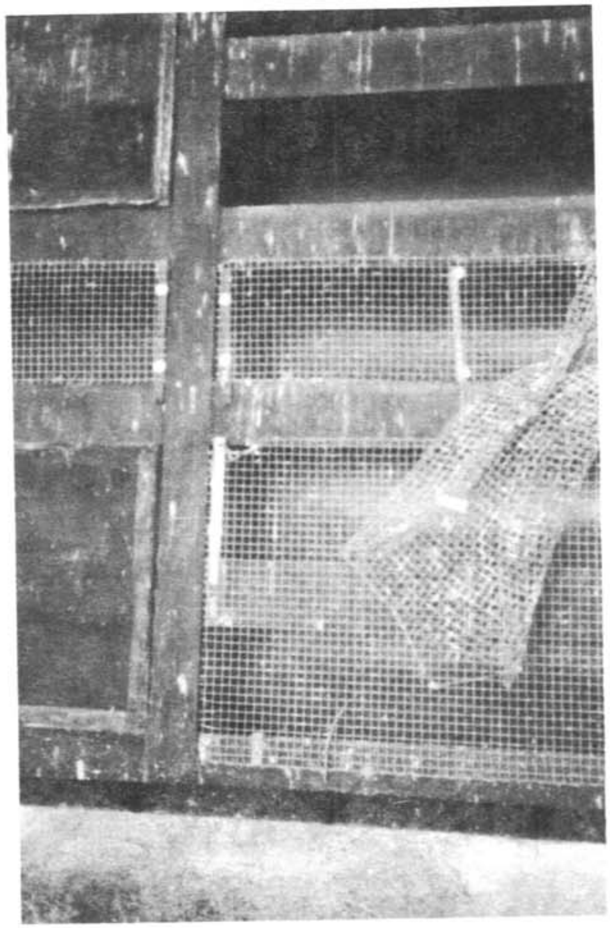
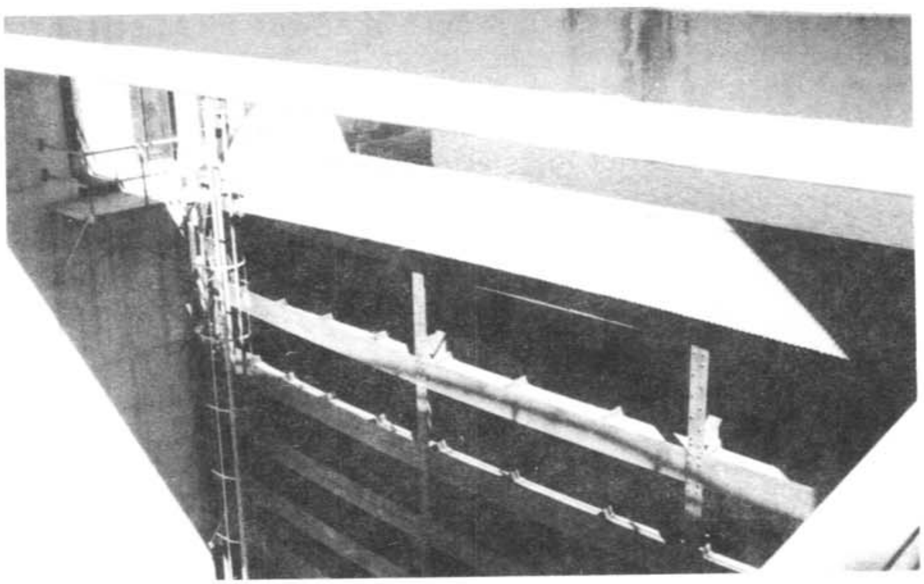
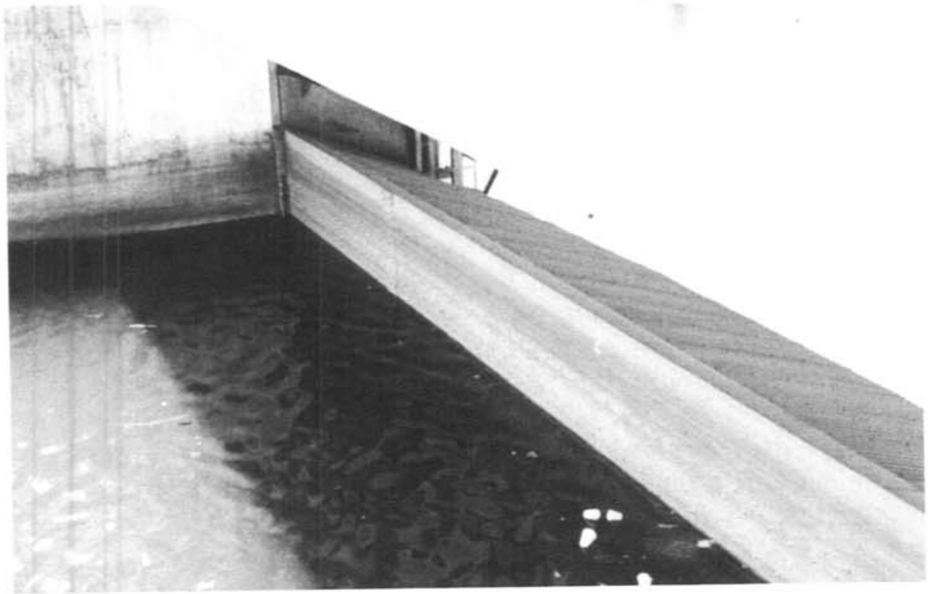
[1] Bill Bouley is a Civil Engineer, Facilities Engineering Branch, Denver Office, Bureau of Reclamation.



Photograph 1. - Wire mesh screens attached to the downstream side of the gate at Bonny Dam. 5/88



Photograph 2. - Splash shield atop the gates at Mormon Flat Dam. 4/90



Photograph 3. - Splash shield atop gate as viewed from upstream side at Mormon Flat Dam. 4/90

WHAT YOU SHOULD KNOW ABOUT VALVES[1]

Ages before the first valve was manufactured, Nature was using valves of all kinds to control countless biological processes in plants and people. They have been used in the making of mankind, machines, and music.

For example, valves are utilized in human veins and those of innumerable other living creatures to regulate the processes of life itself, as any heart surgeon or cardiac patient can tell you. This is because, among other things, they can temporarily close a passage or orifice, or permit movement of fluid in one direction only. When heart valves fail, they need to be repaired or we sicken and die.

A totally different type of valve is used for protection by the clam or oyster, to open and close its shell. Even a string bean has a valve of sorts that is called by that name. The natural examples are endless.

A manufactured valve, on the other hand, can be any of numerous mechanical devices by which the flow of liquid, gas, or loose material in bulk may be started, stopped, or regulated by a movable part that opens, shuts, or partially obstructs one or more ports or passageways. The movable part of such a device is also called a valve.

Without valves, we would have had no Big Band era. That's because a valve is used in a brass instrument to quickly channel air flow through an added length of tube, in order to change the fundamental tone by some definite interval. (For all these varied definitions, incidentally, our thanks go to Webster's Ninth New Collegiate Dictionary.)

Whether the inventor of the first mechanical valve took any of Nature's varied and ingenious examples as a guide, we will never know. What we can say with certainty is that valves are a vital part of modern agricultural and landscape irrigation, just as they are fundamental to many other industries.

According to Larry Schneider, field engineer for Bermad Control Valves of Anaheim, California, "Understanding the purpose and limitations of the equipment used in a water treatment system makes any operator's job easier and more effective." In discussing the purposes and limits of pressure-reducing valves, he tells exactly what they can do — and, just as importantly, what they can't:

Pressure-reducing valves reduce pressure.–They do not maintain, sustain, obtain, or retain pressure; they simply reduce it. A pressure-reducing valve will reduce highly fluctuating upstream pressures to a steady downstream pressure.

They cannot produce pressure.–A pressure-reducing valve is not able to produce pressure within a system. For example, if the pressure upstream of a reducing valve were to fall to near or below the adjustment point, the valve would have no pressure left to reduce. Pressures both upstream and downstream of the valve will fall. A pressure producer, such as a pump, must be activated to once again build up pressure.

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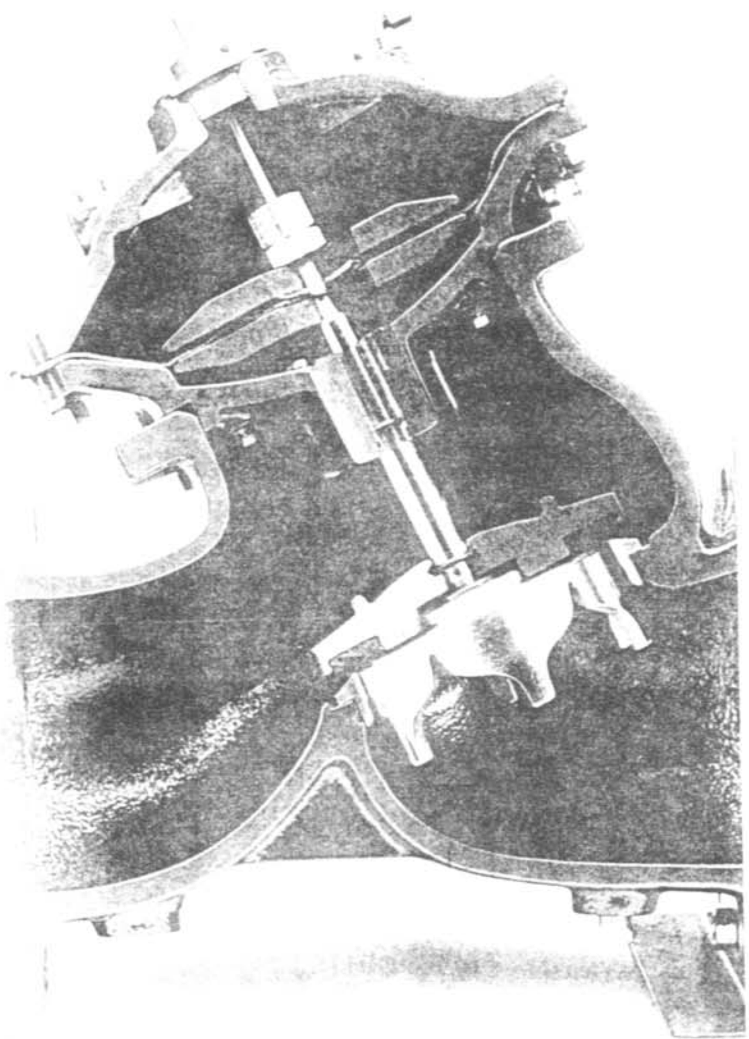
[1] Reprinted with permission from the Associate Editor, Irrigation Journal, March 1990 issue.



Cut-a-way view of a basic diaphragm activated control valve with V-Port throttling plug.

These valves do not regulate gallons per minute of flow.–While reducing valves will continually reduce pressure, they do not control the rate of waterflow. At high flow demands, the valve will be near full open. At low flow demands, it will be near closed. In both instances, a steady downstream pressure will be maintained. It may be surprising how far a valve will close in order to regulate a desired pressure.

Pressure-reducing valves can be fooled!–Reducing valves sense downstream pressure through a pipe or copper tube connected to the downside of the valve. Sometimes this reading can be incorrect.

One situation that will "fool" the valve is a sudden and immediate steep slope downstream of that valve, combined with a big demand. The suction effect of the rapidly cascading water can give a false signal as to the true pressure. This may cause the valve to malfunction and be forced to constantly hunt for the control point.

Pressure-reducing valves cannot react to elevation changes that occur after the valve.–Within any system, the pressure after a large downhill drop may build back to its original reading, due to static head. The effect at the end of the run may seem to indicate that the valve is not doing its job. However, these valves can only control pressure at the valve centerline, and higher or lower elevations after the valve must be considered.

Pressure-reducing valves can be trapped.–They cannot react instantly to sudden changes in a system. For example, in a dead-end system such as a sprinkler field, the sprinklers are turned on one by one and the pressure-reducing valve opens wider and wider. At each step, the valve is accurately controlling pressure.

If flow demand is great enough, the valve may be full open. However, if all sprinklers were closed rapidly at the same time, the pressure-reducing valve would still be wide open. Maximum pump discharge pressure would instantly be recorded throughout the entire pipe system, because the valve cannot react fast enough to close. The valve is trapped in a wide-open position and cannot reduce the pressure until the excess pressure is bled out of the pipe.

Pressure-reducing valves may not seal forever.–Normally, reducing valves close as flow demand decreases. Eventually, if flow stops altogether, the valve will close and seal, preventing any pressure buildup downstream.

Unfortunately, objects such as scale, dirt, rust, and calcium, or lime deposits can prevent the valve from closing completely. Consequently, a leak from a small sand particle can allow full upstream pressure to be transmitted to the downstream side.

Reducing valves modulate.–Switches are often installed on them to light lights, sound alarms, or start pumps. For example, as the valve opens wider, a switch may turn on a second pump, or as demand decreases a switch may turn off chlorinators.

However, pressure-reducing valves are always adjusting and readjusting to take care of fluctuations in demand or pressure. Under certain conditions, the valve-controlled switch may cause a pump to turn on and off several times per second. To prevent this, lockouts or time delays must be designed into the switch circuit that uses a valve to control a system component.

Pressure-reducing valves need pressure to operate.–They rely on pressure in the pipeline for power to actuate the valve. If water cannot get to the actuator for control, the valve will not have the pressure required to operate and will not function.

These valves are designed for average reaction times.–After a pressure change has occurred, it will take time for the valve to sense the change and react. If changes are more frequent, more sudden, or faster than the valve's reaction time, reduced accuracy, excessive stroking, or greater amplitude of stroke may occur.

Reducing valves are designed for average conditions, and it may be necessary to readjust for more rapid changes. This can be done using a speed-control valve to smooth out the valve's operation.

Pressure-reducing valves require a minimum differential pressure to actuate.–Most of them rely on some flow and some minimum pressure to operate. A valve with a pressure of 55 lb/in^2 upstream, set to control 52 lb/in^2 downstream, may take a long time to react. In this example, the 3 lb/in^2 differential must overcome the stiffness of an actuator and the frictional loss of items in the control piping.

Reducing valves are often oversized.–Water-system designers tend to overdesign a system when determining equipment size. Larger-than-needed pumps are often chosen, and pipe friction tends to be less than expected, especially if old pipes are replaced with new plastic pipe. The result is excess pump flow.

Reducing valves may be expected to compensate for this excess flow and get the system back to design conditions. Sometimes valves are so oversized and demand is so small that the reducing valve is nearly closed most of the time. Cyclic bounce, or chatter, can result, because flows are beyond the valve's capabilities.

Schneider also offers what he calls "a dozen things you should know about pump control valves." Once again, some of his statements may surprise you. For instance:

Pump control valves do not control pumps!–Motors, switches, relays, and drives control the pumps. Control valves merely open and close and give an indication of stroke position. The position signal is wired into the pump electrical circuit and acted upon by the pump controls.

Other names are also used to describe this function, such as "pump electric check valve." The purpose of the valve is to close while the pump is running. Once closed, the position switch on the valve stops the pump. Reverse flow is prevented, without the noise and shock often found when fluid drives a check valve closed.

Stopping a pump can be serious business.–A typical system consists of a pump and a check valve. Sooner or later, if enough systems are installed and the conditions are right, a pump stoppage will cause water hammer. The surge has even been known to shear pumps off their bases.

Check valves of all sizes, shapes, and types have been used to prevent surges, as well as to prevent backflow of water. All of these devices are designed to combat the flowing water conditions after the pump has already stopped. In other words, check valves directly attack the problem. Pump control valves prevent the problem from happening in the first place.

There are many types of pump control valves.–In theory, any valve can be made into a pump control valve. Butterfly valves, plug valves, and ball valves have all been used.

Globe valves are commonly accepted as the practical "way to go." The reason for this is that globe valves work directly off the pressure already in the pipe. Diaphragm area is about twice the area of the pipeline. Closing force is two times the force to open. The valve is self-contained, and in essence picks itself up by its own bootstraps. External air, oil, or electricity are not required.

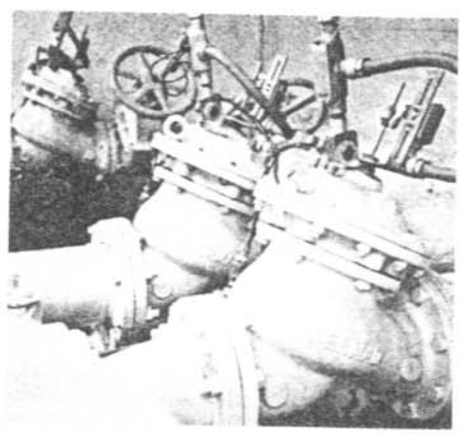
Pump control valves are more than simple check valves.–There are wafer check valves, swing checks, center guided checks, tilted disc checks, ball checks, and folding disc checks.

Many customers are tempted to use the pump control valve without the electrical hardware, as a simple center-guided check valve. This can be done, but a check valve is still a check valve. If the closing speed is too fast, loud noise and banging from water hammer may result. If the closing speed is too slow, there will be reverse flow which could spin the pump backwards.

It may not be possible to find a happy medium. The customer is stuck with the limitations of a check valve. Adding a limit switch and a solenoid valve will create a true pump control valve.

Pump control valves can do other worthwhile control jobs.–The advantage of "self-contained" globe-style control valves is that many special features have been designed for the valve. By adding a control pilot to the control piping, the customer can create a pressure-reducing valve which will maintain a steady downstream pressure in the system.

Pressure-sustaining pilots will not allow the valve to open unless a preset upstream pressure is obtained. An altitude pilot will stop the pump after a tank is full. Speed-control valves will allow slow filling of an empty system or slow, almost unnoticeable cutting off of the water supply. All of this is also accomplished by using the pressure already in the line for control purposes. External power is not required.



Three booster pump control valves controlling three separate pumps.

Pumps can also be problems on starting.–Deep-well pumps have been known to cause severe water hammer upon starting. A typical system is to relieve the air column somewhere between the valve and the pump. When the air-release valve slams closed and the pump control valve is not yet open, a shock can be created.

An air-releasing-pressure relief control valve can be used instead. This valve will not slam closed when water gets to it. Instead, the water passes right through the valve to vent. The gradual buildup of pressure in the control piping and the diaphragm closes the valve as slowly as desired. If excess pressure is ever sensed by the relief pilot, the valve will reopen to vent.

Pump control valves still protect a pump upon power failure.–When power fails, these valves are demoted back to being fancy check valves. Fast closing is necessary to prevent backflow. Manufacturers have devised many ingenious methods to speed up closure. Some use a splined shaft or a lifting disc. Some use a power-failure solenoid which allows closing water through a bigger-diameter power-failure loop at a faster rate.

Double-chamber diaphragm actuator designs do not require special features. They do not rely on solenoid condition or control piping capacity. Closing is with the pressure decay in the pipeline. Reverse flows are prevented and they are silent closing.

Power failure on some pump control situations may require special attention.–Analyzing the surges created by power failure is a business that can stump the experts. Most pump installations are simple, but some can be very complex.

Simply put, when a pump stops on power failure, the water momentum continues to carry it forward. The forward momentum sort of stretches the water and creates a low-pressure zone wave. The collapse also creates a wave.

Wave amplitudes traveling through the pipe can combine and cause very high pressures. A wave traveling a 4,000 ft/s and creating a pressure increase of 50 lb/in^2 for every foot/second of flow-velocity loss would not surprise an expert. In these instances, customers install special valves that can actually anticipate a surge wave. They also use quick open-slow closing relief valves.

Pump control valves can prevent pump starvation.–A pilot can be installed on the valve to monitor pump suction. If pressure gets too low, the valve starts to throttle. This prevents the pump from running out of water or starving.

Quite often pumps on tanks are started and stopped repeatedly by switches if levels get too low. A suction pilot does the same thing hydraulically by throttling. The pump can keep on running with the proper NPSH (net positive suction head).

Pump control valves can hold a pump's flow constant.–Still another trick which can be done with a pilot is to use a pilot that monitors both suction and discharge pressure. This is a differential pressure pilot. It will throttle the pump control valve to hold a preset differential.

By looking at a pump flow curve, it can be seen that holding a fixed differential pressure indirectly holds a constant flow rate. The flow is very steady, regardless of pressure fluctuations.

These valves can be a wizard's delight.–Complete electronic packages are available to make a pump control valve as sophisticated as can be dreamed. A computer in the valve control box can tell the pump to stop if pressure is not obtained in one minute.

There is automatic shutdown on failure of any component and "valve did not open" or "valve did not close" warnings. Packages have power-failure lights, low-pressure alarms, and automatic dialing. Time delays can be changed and reprogrammed right on the job site, all of this with colored lights, LED's, buzzers, and blinkers.

The Cla-Val Company Irrigation Division of Newport Beach, California, points out that the need for control is vital to all automatic water pumping systems. The people at Cla-Val warn that the hydraulic "shock waves" created by the starting and stopping of system pumps can be potentially harmful to the system unless proper control is available.

They say that the following elements are essential to a pump control valve system: Control of surges, water hammer, pump "backspin," pressure reversals, pump suction pressure, and pump discharge pressure. The type of control required will depend on system design and the conditions involved.

The means for providing the required control are varied. They run from the simple check valve, which controls reverse flow only, to the highly engineered system which provides complete, smooth, automatic operation, both on pump "start" and pump "stop."

Clayton Automatic Valves are available for all of these functions. The company says their valves offer "the flexibility to meet the 'custom-built' changing demands of today's automated irrigation systems." The firm specializes in surge-control, pressure-control, filter-flush, and remote-control valves, among others, and has valves designed for center pivot systems.

Mark Hewitt, northwest sales manager for Netafim Irrigation, Inc., whose main office is in Valley Stream, New York, concludes our survey with a report on a new diaphragm valve. While unique in its construction and mode of operation, it is nevertheless typical of the innovations that valve manufacturers everywhere are constantly putting into their products, in order to better serve the irrigation market.

"In recent years," says Hewitt, "advances in material technology have enabled the construction of an entirely new type of valve, with remarkably simple operation and extremely low pressure losses. This valve is characterized by a 'straight through' water passage."

Like most automatic valves, he observes, it uses hydraulic pressure operating on an internal device to open and close the valve. "However," he reveals, "what makes this valve unique is that water is applied directly to the surfaces of a single diaphragm to control the opening and closing of the valve. In essence, the diaphragm is the only working component of the valve! The uniquely constructed diaphragm is what makes this possible."

The pressure losses through this type of valve are much improved over traditional pattern valves, Hewitt asserts. In many situations it is possible to install a diaphragm valve of smaller size than would have been necessary had a different type of valve been installed, and not sacrifice hydraulic efficiency, he declares.

"A second key advantage of these valves is their service ability," Hewitt notes. "The only internal parts to these valves are a diaphragm and a spring, and these parts can be serviced without removing the valve from the service line."

In addition to their simple automatic operation, says Hewitt, the Dorot line of hydraulic valves can perform a variety of water- and pressure-control functions, including pressure regulation, pressure relief, and flow metering.

"These advantages of simplicity, performance, and ease of maintenance make the diaphragm valve the valve of choice for the ever-changing agricultural, landscape, and industrial marketplaces," Hewitt concludes.

Not only is there a valve for every application, there is a wide choice for each use. We hope this brief survey helps you understand valves better.

THE COFFERDAM SYSTEM OF CONSTRUCTING A TURNOUT[1]

by Eric Erickson[2]

Water is delivered to our customers in various ways. If the amount is fairly modest, the delivery can be made by a pump up over the side of the canal. Most deliveries, however, are made at a special outlet called a turnout constructed through the aqueduct lining. These have openings which reach pretty well down to the bottom of the aqueduct. The openings are protected by racks and constitute a part of the original design of the canal lining. As such, they were made during initial construction when no water was in the aqueduct. Now, with the canal full and water being delivered, constructing such a turnout would mean stopping deliveries, draining the water and cutting through the concrete liner. This would be plainly difficult if not impossible to do. We did not anticipate the need for it. But, in San Luis Field Division, just such a need arose.

The Pinoche Water District is a long-time customer. Their three turnouts were original construction. They are entitled to more water, in our new association with the Delta-Mendota Canal. Since this canal is much lower than the California Aqueduct, the new entitlement water would have to be pumped up to storage by our pumps. This would add to the cost of the water. The ideal answer, of course, was to construct a turnout for them right in the California Aqueduct so there would be no lift required. That would open all the problems mentioned previously. Yet, they now have a new aqueduct turnout and our water deliveries were never interrupted. This is how it was done.

Obviously, the thing to do was build a turnout. But how, without stopping waterflow? Design and engineering personnel from Stoddard and Associates, Los Banos, California, came up with a specially tailored cofferdam to enclose the entire working area so that water delivery could continue on one side and new construction go forward on the other. That meant that the cofferdam had to fit the configuration of the aqueduct lining all the way down to the lowest point of construction. The fit would have to be perfect to eliminate possibility of water leakage. This was done. In fact, the cofferdam (which rested on a rubber gasket against the lining) fit so well that the only leaking was around some of the bolts used in the cofferdam itself. Fabrication was done in a shop, and the cofferdam was then trucked to the turnout site. A power crane lifted it and positioned it properly. For added weight, to assure a good seal, 18 concrete blocks (10 by 6 feet) were placed around the top edge of the cofferdam. The cofferdam arms were also secured by a number of 24-inch bolts into the lining. With everything in place, the lining was then cut out in the configuration of the future turnouts and earth removed to the correct level. Forms were constructed and concrete poured to create the turnout opening and delivery lines.

When all the new construction was completed, the control gates, controls, and trashracks were installed. Earth was then packed and graded around the new turnout. The final step consisted of removing the protective cofferdam. The resulting turnout looks just like the ones constructed in the beginning of the project.

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[1] Reprinted with permission from the Information Officer, Office of Public Information and Communications, California Department of Water Resources, Sacramento, California, from Technical Bulletin No. 81, January/February/March 1990 issue.

[2] Eric Erickson is in the Technical Information Development Section, California Department of Water Resources, PO Box 942836, Sacramento, California 95814 [telephone (916) 445-1141].

This is all easier to tell than it ever was to do. There were difficulties. Merely handling the cofferdam was a king-sized chore. The arms are 32 feet from side-to-side; the face is 30 feet wide; it is 9 feet high. The aqueduct was drawn down a little. This made it necessary for some customers to get their water from temporary pumps that lifted over their normal turnout location. This was about the only operational change, and it did not interrupt delivery.

Much of the activity surrounding construction of the new turnout was recorded in the following pictures - included here for illustration.

For additional details, you may write or telephone the author of this article.

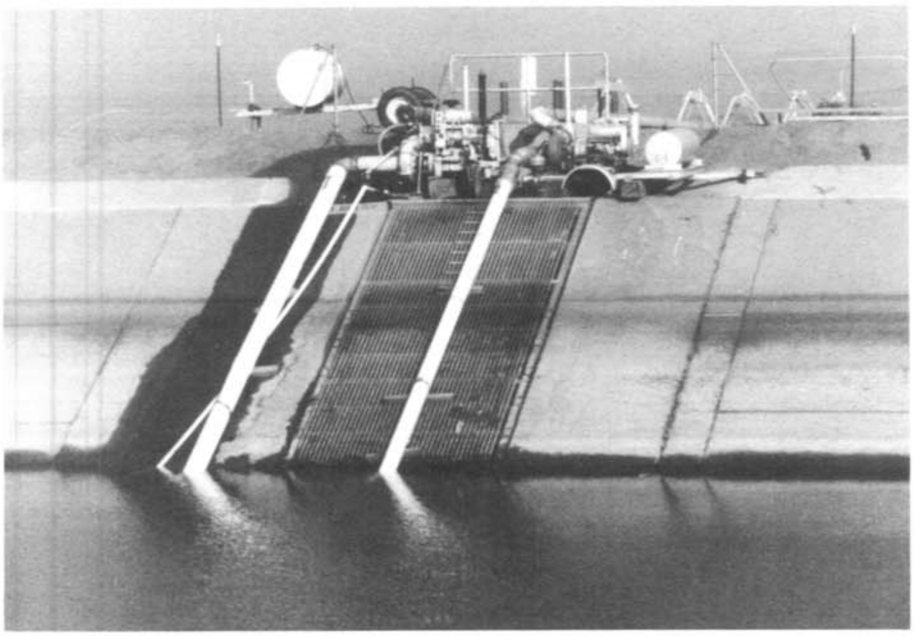

Figure 1. – Customer siphon pumps taking water from the drawn-down aqueduct during turnout construction.

Figure 2. - The cofferdam.

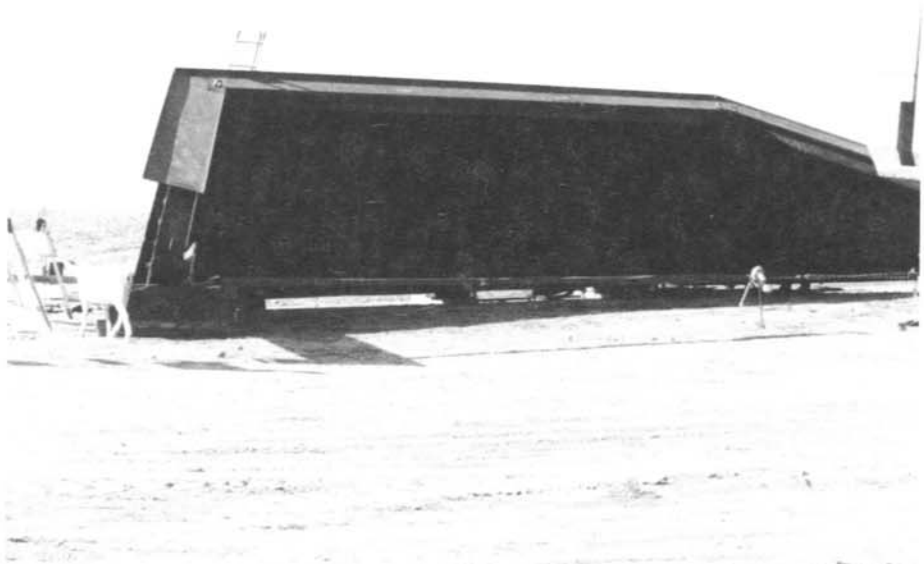

Figure 3. - The cofferdam.

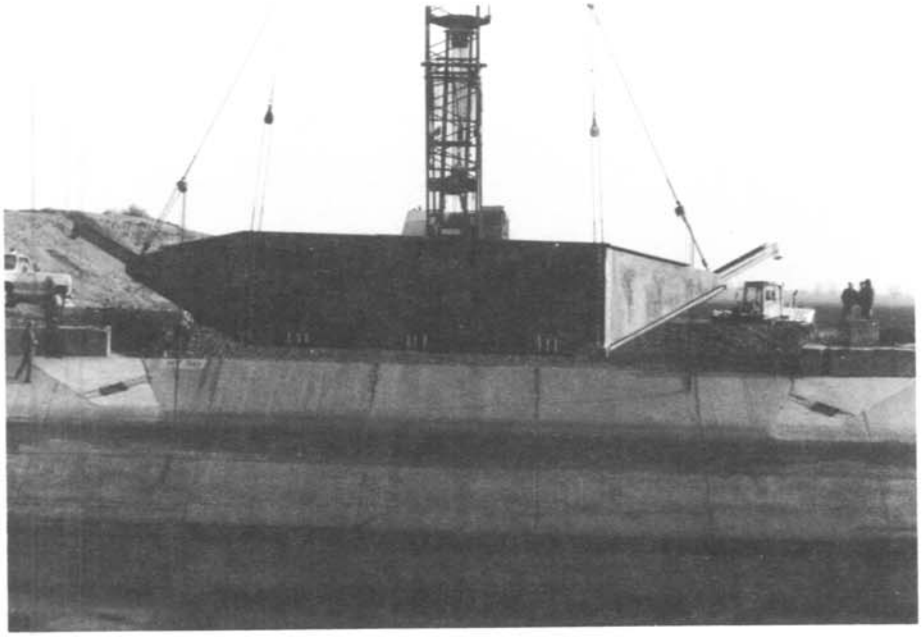

Figure 4. - Lowering the cofferdam.

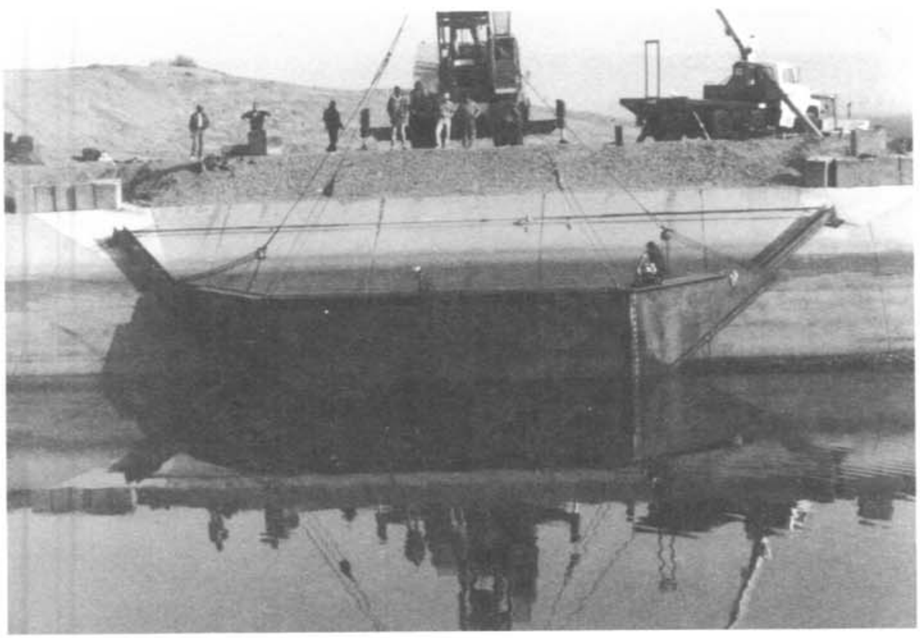

Figure 5. - Lowering the cofferdam.

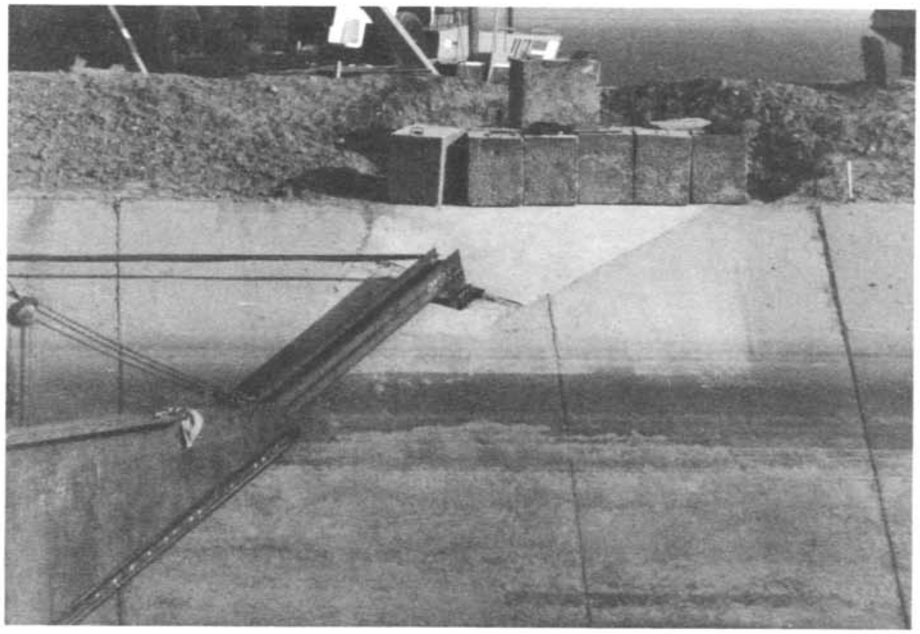

Figure 6. - Bolting the cofferdam arm in place (concrete weights on canal bank).

Figure 7. - Cofferdam in place (note concrete weights).

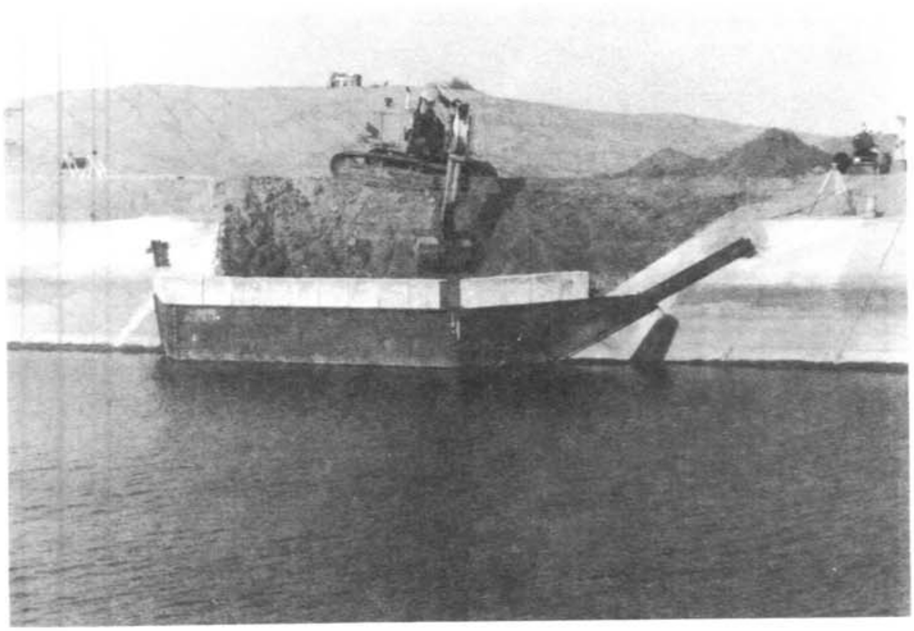

Figure 8. - Lining cut, and excavation underway.

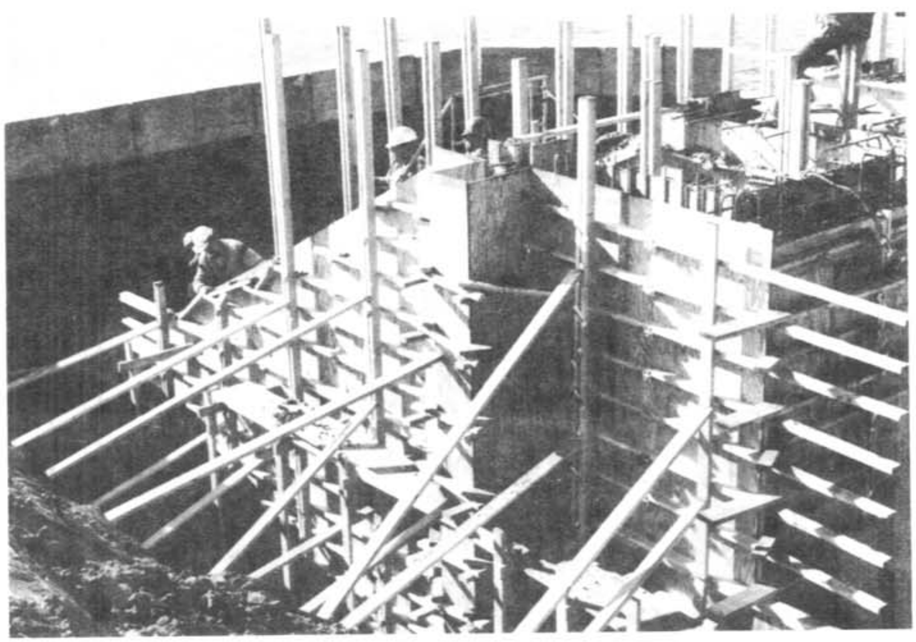

Figure 9. - Forms being constructed behind cofferdam.

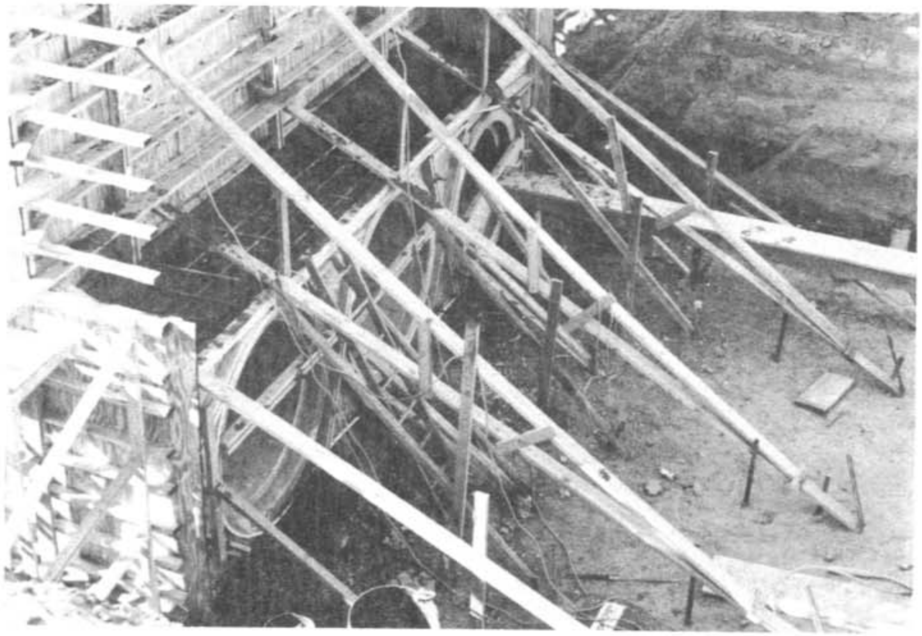

Figure 10. - Forms in place around discharge pipes.

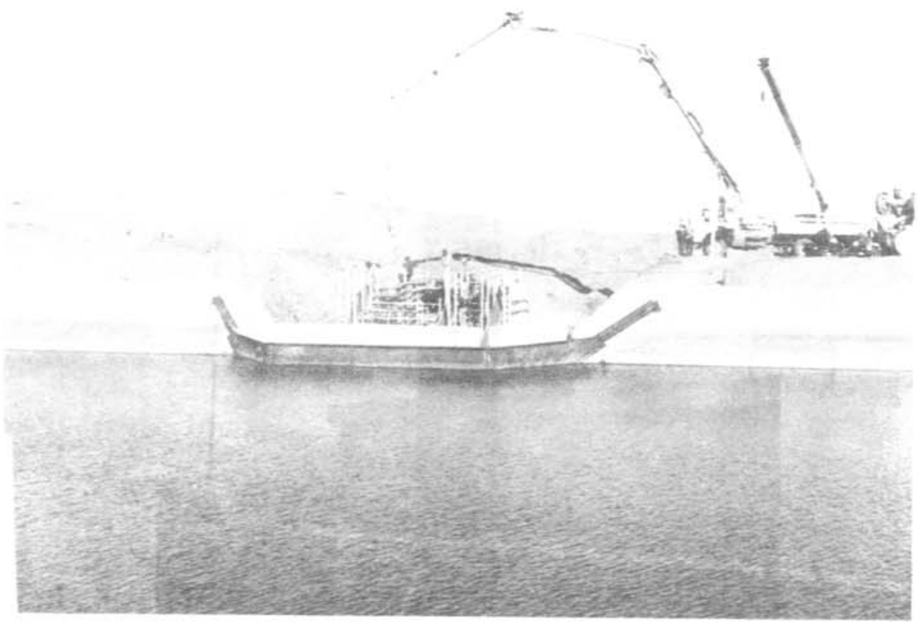

Figure 11. - Pumping concrete into the forms.

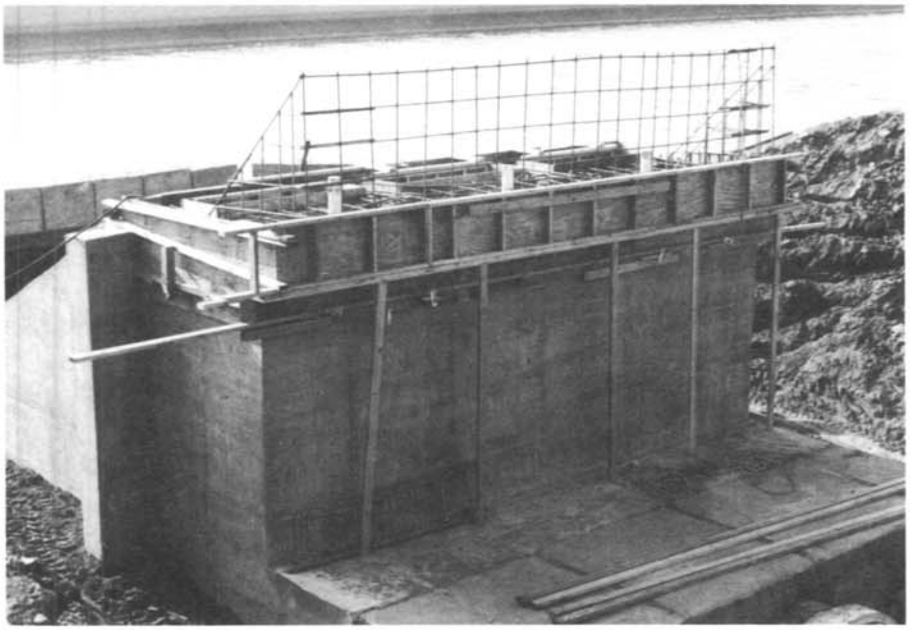

Figure 12. - Forms removed from the turnout structure.

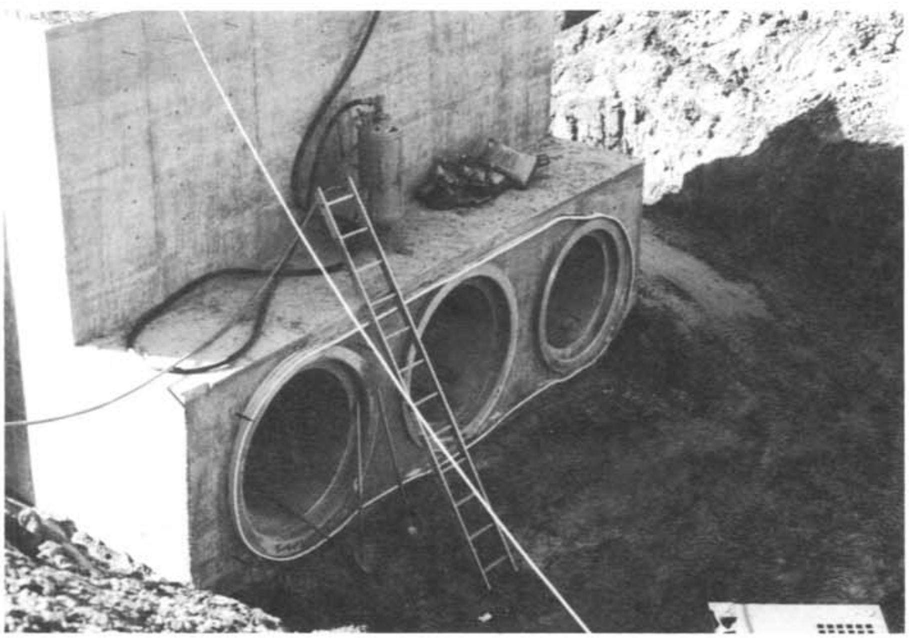

Figure 13. - Forms removed from the turnout structure.

Figure 14. - Earth being graded in around turnout.

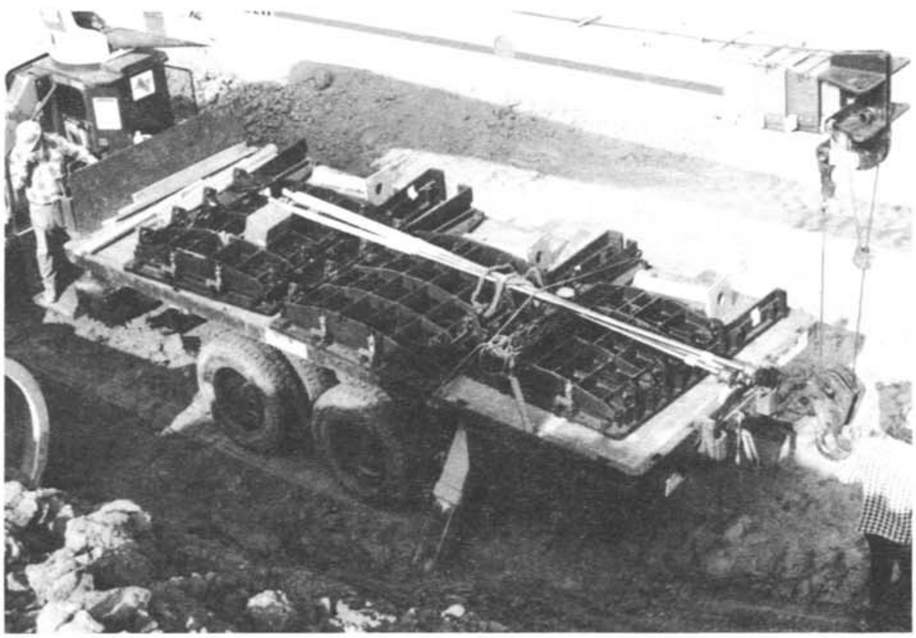

Figure 15. - Turnout control gates delivered.

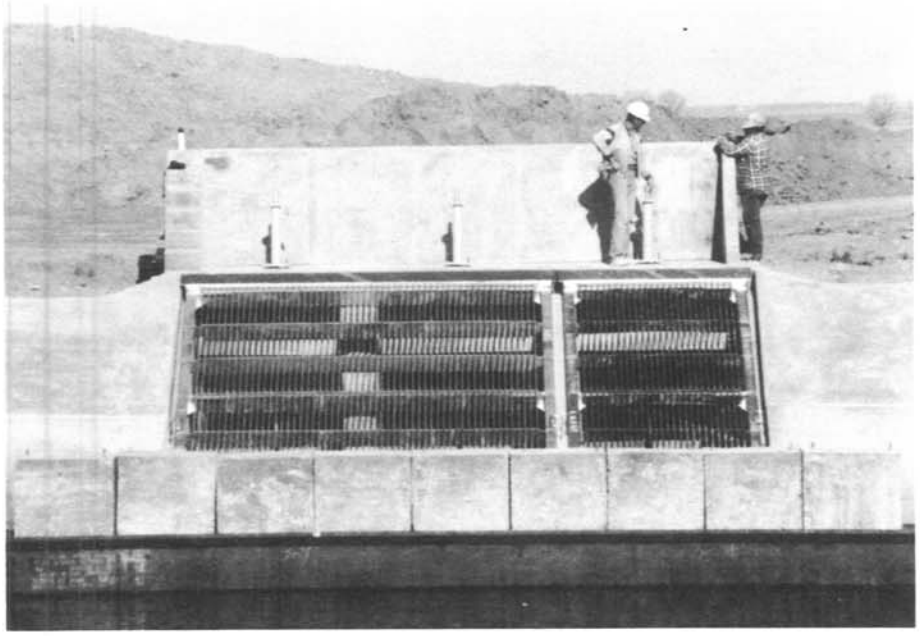

Figure 16. – Trashracks in place.

Figure 17. – View of trashracks and gratings.

Figure 18. - Preparing to remove the cofferdam.

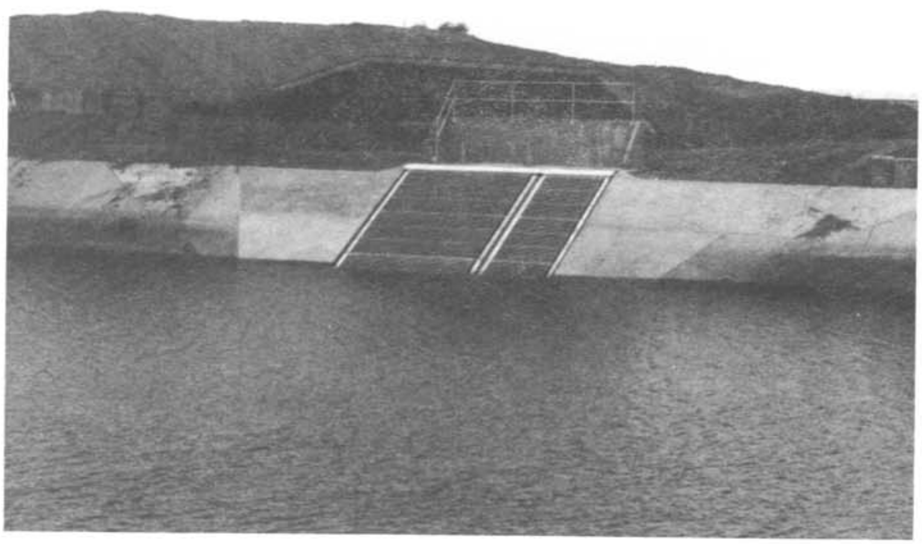

Figure 19. - View of completed turnout.

A NEW EAR PLUG AT DELTA[1]

by Melvina Rhoades[2]

Industrial noise of all kinds is a recognized hazard. In our industry, we may not get the serious assault to hearing that they get in a foundry or heavy-duty machine shop. But, the rotating machinery and gas-operated breakers in our plants can produce noise levels that qualify as hazardous, particularly over a period of time. This is a condition that was recognized long ago. Our workers have always been provided with ear plugs or muffs, depending upon the situation and their preference. At best, these devices are tolerable. They hardly qualify as comfortable. The Delta Field Division now has an ear plug that just might alter this condition.

The ideal ear protector is one where the wearer's ability to hear at ordinary levels is not diminished, but high-noise levels or sudden noises are screened out. Comfort is also a factor. That sounds like a tall order — a hard-to-get item. It is, and it isn't. The new ear plug involves a certain amount of employee cooperation and effort to produce, but the results then meet ideal standards. The safety coordinator at Delta spent extra time convincing everyone that the plug was the answer. Now, the device is selling itself.

The new ear plug has to be molded to fit the individual ear canals of each using employee. This process takes about 20 minutes, and a good deal of cooperation from the person being fitted. But the ear plug that results is a perfect fit after that and can be carried and used safely. This new ear plug is not a moldable, disposable type. That kind of plug works well enough; however, if the hands of the user are dirty with oil or other substances, the plug could be contaminated. The new one is carried and put in place by the wearer. Each plug has a color-coded tab to identify right and left. This tab is held when installing the plug so no contamination is possible.

A supervisor's approval, and 20 minutes or so of the employee's time, is all that is needed at Delta to get the new ear plug. It is as complete an answer to the problem as possible at the present time.

[1] Reprinted with permission from the Information Officer, Office of Public Information and Communications, California Department of Water Resources, Sacramento, California, from Technical Bulletin No. 81, January/February/March 1990 issue.
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STRIDES IN NONDESTRUCTIVE TESTING[1]

by Larry D. Olson, Cliff Wright, and Kenneth H. Stokoe II[2]

Early nondestructive tests with stress waves involved evaluating stones by striking them and listening to the ringing sound with the human ear. Stress wave methods have come a long way since then and applications are increasing in the civil engineering field. Some recent applications provided data on the density of a massive landslide, the integrity of drilled shaft foundations, support conditions beneath a concrete slab, and concrete conditions of a thin-arch dam. The investigations were conducted for quality assurance, forensic and rehabilitation purposes, and provided important information that would have been uneconomical or impractical to obtain with destructive tests.

The term "stress wave" encompasses a broad group of waves that cause physical distortion to the media in which they travel. Examples of naturally occurring stress waves are sound waves in air, pressure waves in water, and seismic compression, shear and surface waves in the earth. In solids, such as earthen materials, compression waves travel fastest, with the velocity of shear and surface waves decreasing in that order. The absolute velocity of any type of wave depends on the stiffness or modulus of the material; the stiffer the material, the greater the velocity.

Mechanically generated stress waves involve one of four measurement approaches: (1) frequency, or spectral, analysis of surface wave propagation; (2) direct measurement of stress wave velocities; (3) measurement of stress wave echoes; and (4) resonant, or modal vibration, measurements. The case histories illustrate each.

No Borings

A new seismic method, spectral analysis of surface waves (SASW) determines shear modulus profiles at soil sites and Young's modulus profiles at pavement sites. The method, developed at the University of Texas at Austin, evolved from the steady-state Rayleigh wave technique introduced in the 1950's. It is based on the field measurement of surface wave velocity as a function of wavelength, and subsequent theoretical modeling determines the shear wave velocity profile. SASW can determine shear stiffness profiles for layered pavement and soil systems nonintrusively — without drilling borings — because both the source and receivers are placed on the exposed material surface.

The method's nonintrusive characteristics were used to estimate the global density of a massive landslide in the Valtellina valley of northern Italy in 1987. The landslide filled the valley with a total slide mass of 42 million cubic yards, from a height of 4,200 feet. Engineers had to make a qualitative estimate of the landslide debris density. The debris was a heterogeneous mix of silt, sand, cobbles, and boulders that could not be tested using standard geotechnical tests. It would have been difficult, and possibly

[1] Reprinted with permission from Civil Engineering, a monthly publication of ASCE (American Society of Civil Engineers), May 1990 issue.

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dangerous, to advance boreholes or penetration devices in the mass. The heterogeneity from clay to boulder sizes of the material was another obstacle to conventional tests.

Engineers from ISMES, Bergamo, Italy, working with Stokoe, used the SASW method to determine shear wave velocity profiles and were able to infer, on a global scale, the debris density for geotechnical engineering analyses. They used the method at five sites across the landslide mass. Surface waves were generated by applying a dynamic vertical force to the ground surface — either by dropping weights or driving a bulldozer back and forth. The engineers monitored surface wave propagation using two receivers set in line with the source. The source-receiver spacings were increased progressively to determine the shear wave velocity profile to greater depths.

In the field, the receivers measure particle motions created by the source in the time domain. A dynamic signal analyzer transforms these into the frequency domain. This produces the resulting linear spectra of the two signals. Through further processing with the signal analyzer, the key data, the phase of the cross power spectrum and the coherence function (signal-to-noise measurement) are produced for each source-receiver spacing. These data make up the dispersion curve (surface wave velocity vs. wavelength) from all the source-receiver spacings.

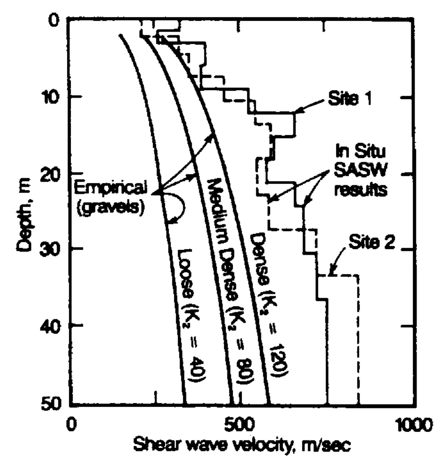
Next, a theoretical dispersion curve is calculated from an assumed profile of shear wave velocities and layer thicknesses. The assumed shear wave profile is adjusted until a good match is achieved between the theoretical and measured field dispersion curves. Research and project experience show the final theoretical shear wave profile represents actual field conditions accurately.

The resulting shear wave velocity profiles for two of the five landslide test sites are shown in Figure 1. The SASW measurements were effective to depths of more than 150 feet without drilling borings. The engineers compared SASW measured values of shear wave velocity with values calculated using empirical relationships for gravels. Qualitative loose, medium and dense gravel curves are also presented on the shear wave velocity profile of the figure, which shows that the debris at these two locations is dense. Similar results were found at the other locations. The SASW method provided data that were essentially impossible to obtain conventionally.

Deep Foundation Integrity

In North America, nondestructive testing (NDT) of deep foundations has largely been high-strain, dynamic pile testing to predict the capacities of pile foundations. Low-strain integrity testing of deep foundations has been performed here, but on a much smaller scale than in Europe. However, interest is growing.

FIGURE 1.
LANDSLIDE DATA



Spectral analysis stress wave data for the Valtellina, Italy landslide mass. Shear wave velocity vs. depth profile shows landslide density.

Low-strain NDT conducted from the surface relies on reflections of stress wave energy from flaws to indicate internal conditions of deep foundations. There are two primary low-strain stress wave techniques for evaluating the integrity and length of deep foundations from the foundation head: seismic echo (SE) and impulse response (IR). Both can locate defects in deep foundations, such as soil intrusions, voids, and breaks. Test equipment includes an impulse hammer, accelerometer and geophone receivers, and a dynamic signal analyzer. The signal analyzer processes and displays the hammer and receiver outputs.

Both the SE and IR tests involve hitting the foundation head with the hammer to generate a compression wave that travels down the foundation. The wave energy is reflected off the bottom of a sound foundation or irregularities in the concrete and travels back up the foundation to the surface where the receivers monitor the echoes. The wave travel velocity indicates the concrete quality and is used to predict reflector depths. The wave amplitude attenuates with distance through soil-foundation damping of the wave energy, and some energy is transmitted into the bearing materials at the foundation toe, according to acoustic impedance relationships. More concrete-like bearing materials reflect less energy. Conversely, softer bearing materials reflect more energy at the soil-foundation interface.

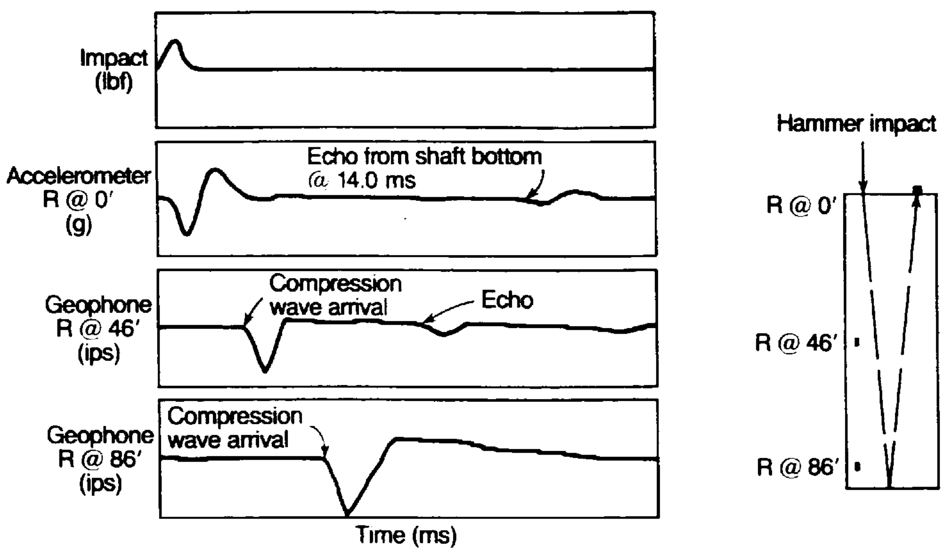
The two surface methods were used on a drilled shaft foundation for a microwave communication tower for which the New Jersey Transit Authority specified quality assurance with NDT. Three 5-foot-diameter concrete shafts, 92-92.5 feet long, were installed for the Kearny, New Jersey, tower by Coastal Caisson Drill Company, Inc., Clearwater, Florida. The firm used a slurry drilling method and the shafts were bottomed in shale bedrock.

Seismic Echo Test

The impulse hammer blow to the top of a shaft is shown in Figure 2, along with an example SE record. The compression wave travels down and back up a drilled shaft, monitored by a surface accelerometer receiver and two geophone receivers embedded on the shaft reinforcing cage. The top trace in the figure is from the impulse hammer blow, the second trace from an accelerometer on the shaft head. The third is from a geophone embedded at 46 feet, the fourth from a geophone at 86 feet.

FIGURE 2.

SEISMIC ECHO TEST



Seismic echo integrity test for a drilled shaft foundation.

Direct compression wave arrivals through the shaft concrete to the embedded geophones give direct compression wave velocities by dividing the geophone depths by the arrival times. The reflected wave energy or "echo" arrival at the surface is indicated by an increase in vibration amplitude for the accelerometer at a time of 14.0 msec. Using a direct velocity of 13,400 ft/sec, the reflector depth is then calculated as 94 feet. This compares favorably with the actual drill-log shaft length of 92 feet. The test result indicates the reflection is from the shaft bottom and the shaft is sound; there are no earlier reflections suggesting an irregularity.

Impulse Response Test

Like the SE test, the IR test consists of striking the foundation head, then recording the vibration response to determine the arrival of the reflected compression wave energy. However, analyses of the IR test results are in the frequency domain (modal techniques) to identify reflector depths rather than the time domain as for the SE tests. Because of its rod-like shape, elastic theory indicates that a deep foundation has a consistent change in frequency between resonant peaks that is a function of the reflector depth and compression wave velocity as follows: $\Delta f = V_c / (2 \times D)$. Thus, in the IR test, an echo is indicated by the average change in frequency between multiple frequency peaks and reflector depth is calculated.

An impulse hammer measures the impact force and a geophone typically records the vibrations of the foundation head. The dynamic signal analyzer processes time domain data with fast Fourier transform algorithms to produce a mobility plot of the foundation's vibration response as a function of frequency. Mobility is the vibration response of the foundation top in inches per second normalized to the impulse hammer blow in pounds force.

This example shows an average change in frequency of 71 Hz between the resonant frequency peaks. Using V = 13,400 ft/sec and the equation we have shown, this then corresponds to a reflector depth of 94 feet. Other frequency peaks with a wider frequency spacing would indicate a shallower reflector, but there are none. The estimated IR reflector depth agrees with the SE reflector depth and compares favorably to the actual shaft length of 92 feet.

The IR test also measures the low-strain dynamic stiffness (force-deflection) at the foundation head, which is indicative of soil-foundation interaction conditions. Dynamic stiffness can be correlated with the static stiffness measured at low loads with a load test. This stiffness is typically one to two times the static stiffness for deep foundations. The dynamic stiffness for the tested shaft was 13,300 kips/in. Dynamic stiffness is most sensitive to upper portions of a foundation. Comparatively lower dynamic stiffnesses are measured for foundations with defects, such as soil inclusions, breaks, and necking. Dynamic stiffnesses should be compared only for similar-sized deep foundations in similar soils and do not indicate the foundation capacity.

Slab and Pavements

The impulse response (IR) method for integrity testing of deep foundations was first adapted for subgrade support evaluation of concrete slabs and pavements by an English-French research and consulting group, Testconsult/CEBPT. The method can identify comparatively good, questionable, and void/poor support conditions of slabs. The technique has been applied to concrete pavements, spillways, conduits, and tunnels as well as slabs on grade.

Frequently, loss of subgrade support occurs due to water damage. This happened in a 25,000-ft^2 warehouse after the rupture of a high-pressure water main for a fire sprinkler system. Water pressure contained by the foundation's slab and walls reached 120 lb/in^2, floating the slab and lifting it up to 18 inches. Because of the heavy loads on the slab, it settled back down once the water pressure was turned off. However, concern over support conditions for the 6-inch-thick slab-on-grade floor resulted in slab IR tests on an 8-foot grid throughout the warehouse (see figure 3).

Results showed 13 percent of the area was underlain by void to poor support conditions. Subsequent probe holes showed excellent correlation between actual subgrade support conditions and IR test results, and slab grouting repairs were made for void/poor areas. Void and poor support conditions are characterized by lower dynamic stiffnesses and more irregular mobility compared with good support areas.

The IR method has applications for evaluating grouting repairs, for vibration-sensitive clean-room areas in electronic manufacturing, concrete pavement and airport runways, spillway slabs, and tunnel linings. IR is sensitive to very thin voids and will define the areal extent of a void on a grid basis. However, to determine void depth, one must use destructive coring or drilling either in conjunction with IR tests or during slab grouting.

Integrity Evaluation

There are two main stress wave techniques used to evaluate structural integrity: ultrasonic pulse velocity (a direct measurement technique); and impact echo (a reflection technique). Both are primarily used on concrete, but the basic techniques can also be useful in nondestructive evaluation of wood, masonry, and other materials. The ultrasonic pulse velocity method is well documented in technical literature and there is an ASTM Standard for concrete applications.

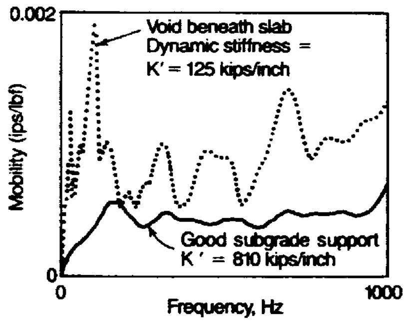
Impact echo (IE) is a sonic echo test for detecting flaws and measuring thicknesses of structural concrete members. During the past decade, the National Institute of Standards and Technology (NIST) has funded research and development of the method, which shows that echoes or reflections in comparatively thin concrete members are more clearly identified in the frequency domain than the time domain.

IE was used to evaluate conditions at Humphrey's Dam, a single-curvature thin-arch dam built in southwest Colorado from 1923-24. The dam has a crest length of 185 feet, a structural height of 85 feet, and thickness ranging from 3.5-16 feet. The reservoir was filled before the upstream face of the dam was waterproofed as originally planned and seepage subsequently occurred, accelerating freeze-thaw damage to the concrete. ECI, a dam engineering consultant in Englewood, Colorado, conducted an engineering investigation of the dam for rehabilitation purposes, working as subcontractors for Olson Wright, Inc. The study included direct measurement of compression and shear wave velocities, seismic echo tests from the dam crest, and impact echo tests from the downstream face. The test equipment used on Humphrey's Dam included various impulse hammers, accelerometer receivers, and a dynamic signal analyzer. Rappelling techniques were used from the dam crest to provide access to the downstream face for IE tests along east, center, and west test lines.

Test records for areas of sound (solid trace) and flawed (dotted trace) concrete are plots of vibration displacement per unit force or flexibility (see figure 4). The solid line of the lower trace shows a dominant frequency peak, $\int$, at a frequency of 1,720 Hz. This peak is termed the thickness frequency peak because it was produced by reflections from the opposite, upstream face of the dam and corresponds to the 3.5-foot thickness, T, of the dam at the location tested. Knowing $\int$ and T, the velocity of the compression wave, V_c, can be calculated as: $V_c = 2 \times T \times \int = 12{,}000$ ft/sec, reasonable for good quality concrete.

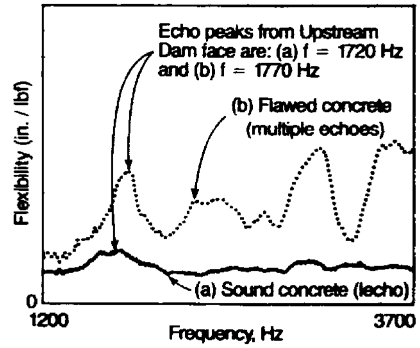
The IE test record for a flawed concrete area with the same 3.5-foot thickness is the dotted trace in the same figure. The multiple frequency peaks are a marked contrast

FIGURE 3.
SLAB ON GRADE RESULTS



Results for an impulse response test for a subgrade support evaluation.

FIGURE 4.
THIN-ARCH DAM RESULTS



Impact echo test results for evaluation of a thin-arch dam in Colorado.

to the single peak for the area of sound concrete. The lowest frequency peak at 1,770 Hz is the thickness frequency peak, which corresponds to a compression wave velocity of 12,400 ft/sec, according to the aforementioned equation. Higher frequency peaks correspond to internal tangential cracking flaws. The IE test results indicate the cracks are in partial contact since an echo was identified from the upstream face with a reasonable concrete velocity. Tests in thicker sections of the dam indicated some areas where cracking was more severe and no echo was obtained from the upstream face. All the wave energy would be reflected from a wide-open crack with an air-filled gap.

The test results correlated well with the results of tests on three cores from the downstream face of the dam. The cores revealed multiple cracks in the concrete tangential to the downstream dam face. The IE results were used to design repairs and estimate costs. The dam repairs were completed in early 1989. Concrete removal confirmed that the IE tests accurately indicated actual conditions.

IE tests have been conducted from one surface on concrete structures, such as bridges, buildings, parking garage decks, dams, and tunnels. Concrete flaws such as void, honeycomb, cracking, and delamination are detected. Concrete member thicknesses can be estimated and fire and frost damage to concrete can be evaluated. The method can also be used for quality-assurance purposes of concrete placement and prediction of early age strength if it is correlated with destructive test results.

We believe stress wave methods for civil engineering purposes will continue to grow as emphasis increases on infrastructure maintenance and rehabilitation. The advantages of NDT are many. Among them are: economy and the ability to investigate large areas and obtain data in situ with undisturbed conditions; definition of the limits and nature of defects; and, little or no testing damage.

METRICS: 1 ft = 0.3 m 1 in. = 0.25 m 1 lb = 0.45 kg
1 yd = 0.9 m 1 ft² = 0.09 m²

RADIO HYDROMET NETWORK ON THE PALMETTO BEND PROJECT

Early Warning System and Delivery System Monitor

by Bill Bouley, James Roach, and Charles Reckaway[1]

As part of the original project authorization, Public Law 90-562, a combination rainfall and streamflow data collection system was to be provided by the Bureau of Reclamation to the operating agency, the Lavaca-Navidad River Authority (L-NRA). On October 16, 1981, a cooperative agreement was signed among the Bureau of Reclamation, U.S. Geological Survey (USGS), National Weather Service (NWS), and the L-NRA. L-NRA procured the system, USGS installed the additional river stage instruments, and NWS provided the technical assistance in site selection for reporting and subsequently assists with data analysis and forecasts.

The Palmetto Bend Project receives its water supply from the Navidad River watershed located near the Gulf of Mexico in southeast Texas. The drainage basin is 1,402 mi^2 in area. Rainfall averages from 35 inches per year on the western edge of the basin to 40 inches per year on the eastern edge. Since frost-free days average between 260 and 300 days per year, the majority of this rainfall runs off the watershed. Average annual discharge averages from a minimum of 13,000 acre-feet to a maximum of 1,038,000 acre-feet. With these extremes for the watershed, it is not unusual for Palmetto Bend Dam to release Lake Texana's volume of about 170,000 acre-feet at least three times a year due to floods. Being near the Gulf of Mexico, runoff predictions gain special importance when hurricane season begins, especially considering there are no storage allocations for flood control in the reservoir.

Fourteen stations were installed to provide an early warning system and for normal project operations. Battery-powered radios at each station transmit data to a central minicomputer at the River Authority office complex. In the northern part of the watershed, sites are used to monitor rainfall data only. Precipitation stations transmit each 0.04 inch of rain, and stream gauges transmit each 0.05-foot change in stream stage. There are six stream/rainfall gauges in the system which provide data to the L-NRA allowing releases to be made up to 2 days before the arrival of flood waters into the reservoir. Alarms sound at the office complex if programmed parameters are exceeded at selected stations.

The computer program for the system enables operators to obtain discharges in cubic feet per second or total volume in acre-feet for any given period of time, and adjusts for a variation in reservoir elevation within seconds. At the spillway for Palmetto Bend Dam, radial gate positions for each gate are monitored in the control room and at the L-NRA office. Tailwater elevation changes are sensed by a pressure transducer below the spillway. Water deliveries from the reservoir are made to Formosa Plastics via a 36-inch pipeline that terminates into a holding pond within the plastics plant. One station at the pond transmits the pond elevation, amount of water delivered, time intervals of pump operation or non-operation, as well as weather data to the minicomputer. System data can be accessed by USGS; Bureau of Reclamation; River Forecast Center, Fort

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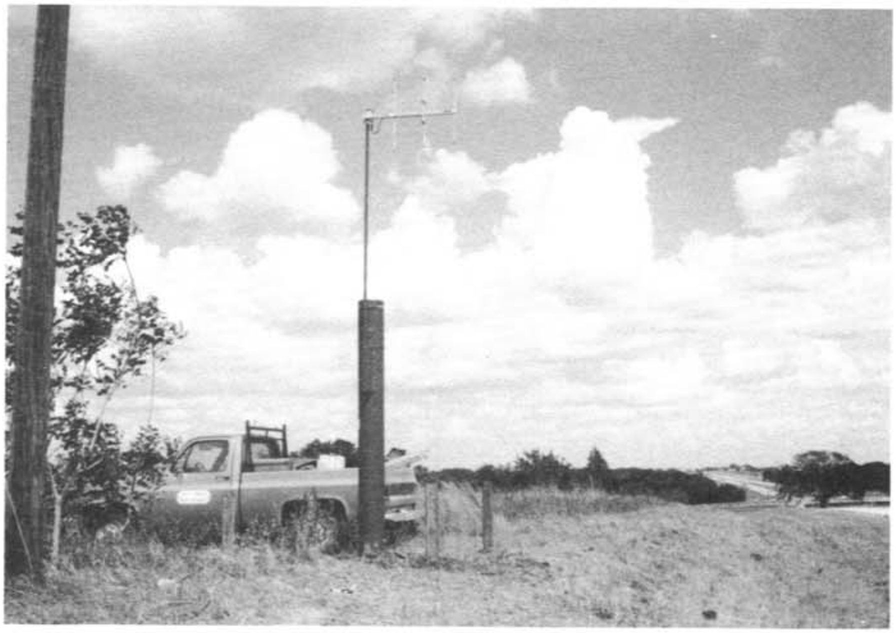
Worth, Texas; NWS, San Antonio, Texas, to assist with forecasts and operations; city of Victoria, Texas; or by other agencies or L-NRA staff home telephones equipped with a modem and computer terminal.

Batteries provide reliable power for about 1 year or approximately 20,000 transmissions. Reporting sites are serviced on 10-week intervals by River Authority staff equipped with testing equipment and spare parts. The system, called International Hydrological Services Enhanced Alert System, was installed by Sierro-Misco, Inc., in 1982 at a total cost of about $100,000. Annual maintenance expense is about $4,000 plus radio tower rental of $3,000. New stations can be added to the system for about $2,000, which includes tipping bucket, solar panel, and battery cells.

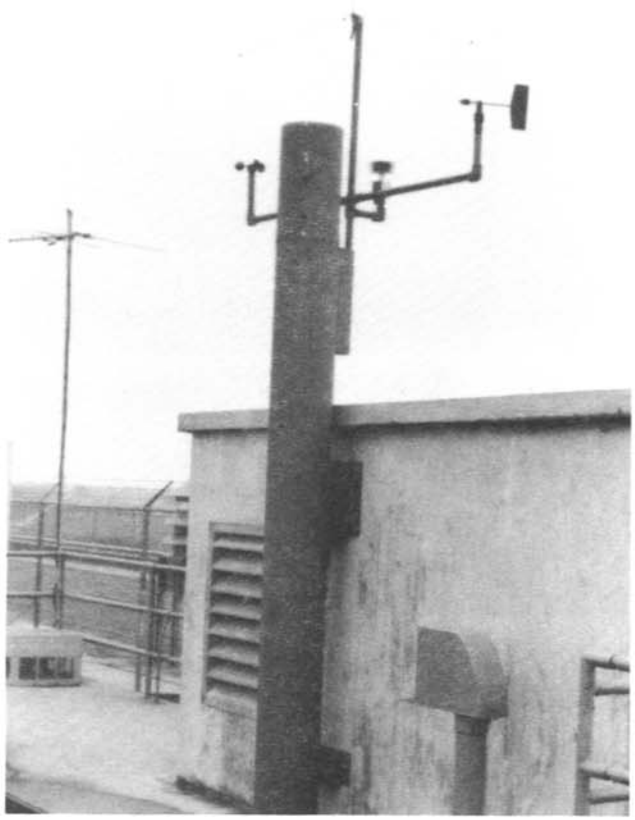
Photograph 1. – Early warning system, Site No. 3, Speaks, Texas. 8/25/82

Photograph 2. - Early warning system, Site No. 4 at Sublime, Texas. 8/26/82

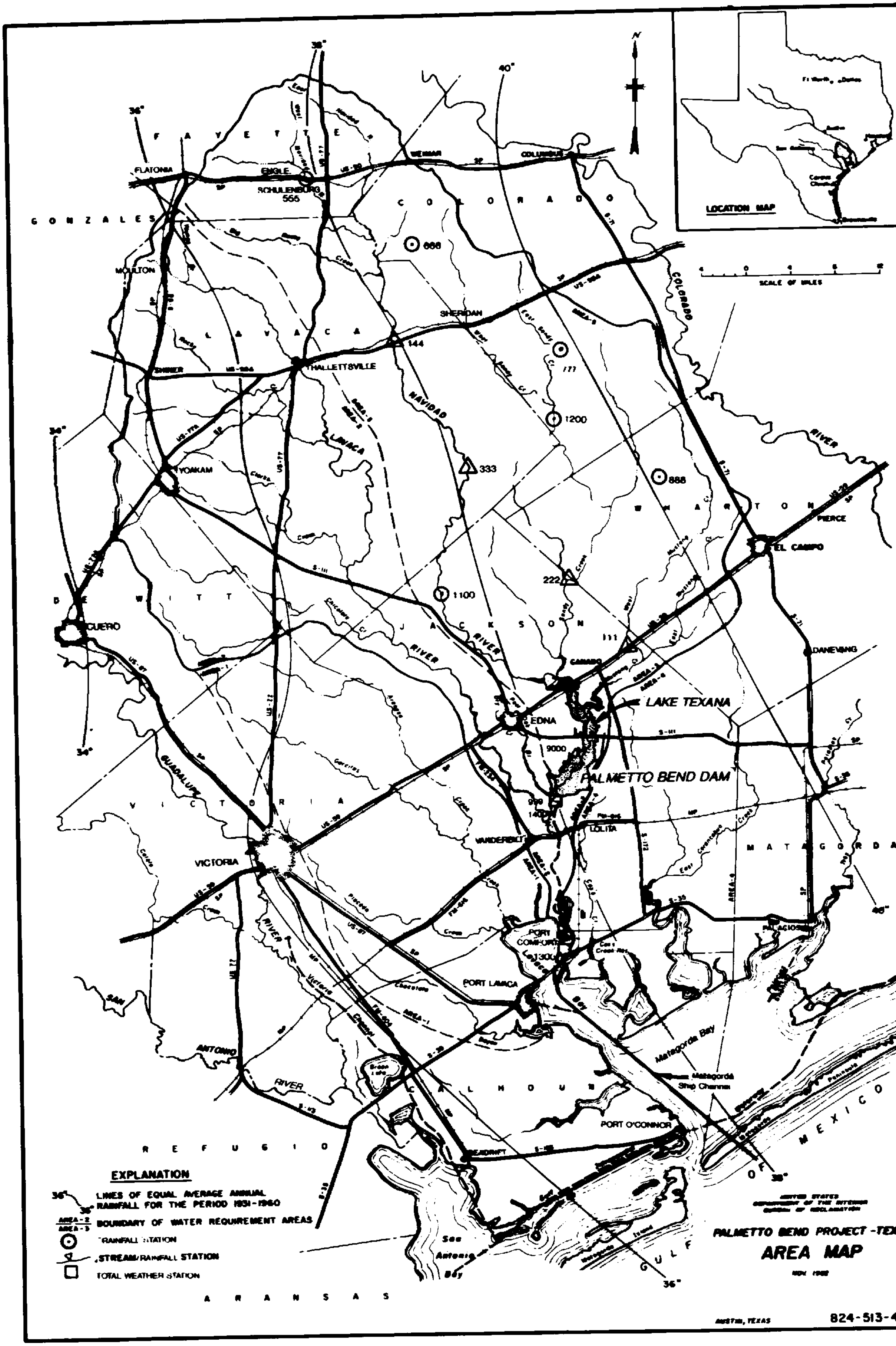
Photograph 3. - Early warning system, Site No. 6, near Weimar, Texas. 8/26/82



Photograph 4. - Early warning System, Site No. 5, in Schulenburg, Texas. 8/26/82



Photograph 5. - Early warning system, Site No. 999, Palmetto Bend. Complete weather station. 12/16/86


LOCATION MAP
SCALE OF MILES
FAYETTE
GONZALES
COLORADO
LAVACA
DE WITT
JACKSON
WHARTON
VICTORIA
MATAGORDA
CALHOUN
REFUGIO
ARANSAS
FLATONIA
SCHULENBURG
WEIMAR
COLUMBUS
MOULTON
SHINER
HALLETTSVILLE
SHERIDAN
YOAKUM
CUERO
EL CAMPO
PIERCE
DANEVANG
EDNA
GANADO
LAKE TEXANA
PALMETTO BEND DAM
VANDERBILT
LOLITA
VICTORIA
PORT LAVACA
PORT COMFORT
PALACIOS
PORT O'CONNOR
SEADRIFT
Matagorda Bay
Matagorda Ship Channel
San Antonio Bay
GULF OF MEXICO
NAVIDAD
LAVACA
GUADALUPE
SAN ANTONIO RIVER
COLORADO RIVER
EXPLANATION
LINES OF EQUAL AVERAGE ANNUAL RAINFALL FOR THE PERIOD 1931-1960
BOUNDARY OF WATER REQUIREMENT AREAS
RAINFALL STATION
STREAM/RAINFALL STATION
TOTAL WEATHER STATION
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
PALMETTO BEND PROJECT - TEXAS
AREA MAP
AUSTIN, TEXAS
824-513-452

CULVERT REPAIR AT ENID LAKE, MISSISSIPPI[1]

by Elke Briuer[2]

Until recent years, repairing in-ground pipes meant dealing with heavy equipment, adversely affecting the environment, and generally disrupting the use of the area where the pipes were located.

In a Corps of Engineers' project at Enid Lake, Mississippi, a traditional approach would have resulted in the cutting of about 40 mature trees, closing an access road to a recreational area, and having to resod major portions of the dam. To avoid these and other costly problems, project officers at the Vicksburg District contracted for in-situ repair of 37 surface-water-drainage culverts made from corrugated metal and concrete. These culverts had deteriorated during 30 to 40 years of use.

The solicitation specifications requested culvert cleaning and inspection. Also specified was culvert renovation to be performed by providing structural liners within the existing culverts. A contract was awarded and work began in September 1989.

During the cleaning and inspection phase, culverts were measured to determine the length needed for the liners. The liners were then custom made at the factory.

The material for the liners was a polyester felt, with a polyurethane coating, vacuum impregnated with a thermal-setting polyester resin catalyzed with two organic peroxide curing agents, styrene, and other additives. When cured, the molecular alignment at right angles gives the structural liner its strength.

The felt serves as the carrier for the resin. It is manufactured from 1.5 mm (1/16 inch) to 6 mm (1/4 inch) thick. Thicker liners combine several layers; i.e., a 3-mm- (1/8-inch-) thick felt inside of a 6-mm- (1/4-inch-) coated liner creates a 9-mm- (3/8-inch-) thick liner. The two liners are heat-tacked to assure proper placement. All liners go through several computerized quality control checks. If the product is for pressure application, the liner must pass through a dye bath to detect pinholes in the polyurethane coating, which are then patched.

For the Enid Lake project, the resin was factory installed, and the folded, impregnated liners were stored on ice in a refrigeration truck. Refrigeration keeps the liners in usable condition for up to 7 days. The resin is normally applied to the liners at the plant. Very large and very long liners, however, can become too heavy to truck. In that case, as has been done at Pine Flat Dam, California, liners can be resin impregnated on site.

Installation

At Enid Dam, most of the old drain pipes were buried within the embankment and parallel to the slope of the dam. Many started at the top with an 18-inch diameter changing

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to 15-inch diameter within 6 feet from the drop inlet. The liners were precut to change size at the approximate location of the narrowing pipe, favoring the transition to take place at the top of the 15-inch pipe. "Although small voids don't affect performance after curing, we prefer to fill all voids and put up with the wrinkles," said Steve A. Hastings, contractor operations manager for the Enid Lake project. In case of elbow pipes, cinch rings were factory installed at the predetermined distance. When the tube was inverted, special care was taken to feed the tube with the rings in the right direction. A string to the top allowed the crew to tighten the cinch at the location of the elbow during liner inversion.

To line the pipes within the face of the dam, a direct stop-and-go water-pressure system was used. Once half of the liner was inverted, installers kept control of the inversion speed with a rope attached to the end of the liner. PVC piping was inserted at the bottom of the culverts and sealed with a piece of wood held in place by a truck. This barrier kept the end of the liner from bursting with head pressure created by the slope. Horizontally oriented culverts required a vertical attachment that allowed for water-pressure buildup (figure 1).

Figure 1. – Installation of 46-inch-diameter structural liner in horizontally oriented culvert.

Once the liner was in place, hot water was pumped into the culvert to cure the resin. Water temperature for thermal setting of the resin must be 180 °F. Curing time at Enid Dam was approximately 8 hours per pipe up to 18-inch diameter, with 4 hours at temperature. The larger pipes (up to 48-inch diameter) had to be kept at 180 °F for at least 2 days.

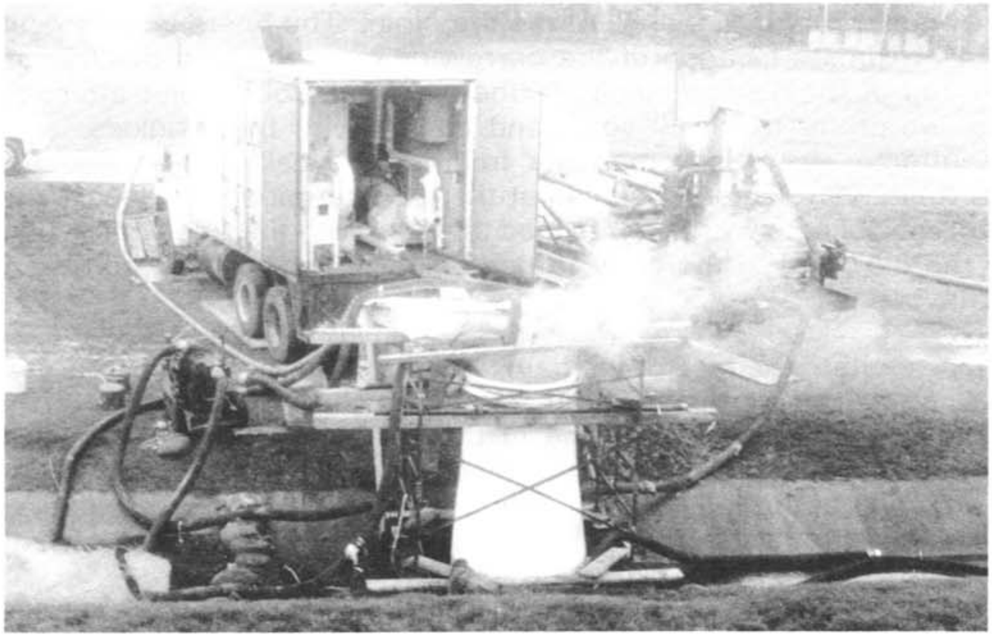

Figure 2. - Water heated to 180 °F is pumped into the liner to cure resin at Enid Lake, Mississippi.

A probe inserted between the felt and the old pipe monitored the temperature during the curing process. The probe showed what was going on outside of the liner and inside of the pipe. Some of the components in the resin, among them cobalt, are in themselves heat-generating. This heat promotes setting. "We watch the temperature gauge closely for a heat surge generated by the chemical processes. When the temperature peaks and then slowly goes back down to the water's temperature, the resin has set," said Hastings. The water was kept at 180 °F beyond the surge time to make sure cold pockets were cured. This precaution was especially important for the larger pipes, and those of corrugated metal.

A plastic, fiberglass-reinforced tube was used to preline the asphalt-coated, corrugated metal pipes, preventing contamination of the polyester by phenolic compounds (figure 3). The preliner was air installed and kept inflated with blown air during the placement of the structural liner (figure 4). The preliner served as an isolating laminate separating the two compounds until the polyester had cured.

Figure 3. - Corrugated metal culvert after cleaning, showing patchy tar coating.

Figure 4. - Air-inflated preliner is positioned in pipe while crew works on truck platform to ready liner for placement.

After several culverts were completed, a three-man crew moved in to finish the outlets. The now rigid liner was cut with a diamond saw to the angle of the original culvert, and the trimmed edges of the structural liners were sealed. Following this procedure, areas of the liner exposed to direct sunlight received a coat of UV-blocking paint (figure 5).

Figure 5. - Finished culvert outlet on bottom of downstream face of Enid Dam.

According to Hastings, this repair system can be applied to gravity culverts, high-pressure sewers, utility ducts, or any underground conduit except potable water pipes. Presently, the process is not licensed by the Environmental Protection Agency for potable water pipe repair. There are no limits imposed by materials of the old pipes. Occasionally, for example for pressure mains, an epoxy may be used in place of the polyester. This does, however, add considerably to the cost. The smallest size pipe suitable for the in-situ process is one with a 6-inch diameter. Hastings said that projects using this type of repair have involved pipes up to 108-inch diameter.

Summary

At Enid Dam, culverts ranged from 12 inches to 48 inches in diameter. Although the structural liners slightly reduce the original diameter of a pipe, the Q-factor is lowered and the capacity of the culverts will not be reduced.

With one of the Enid Dam culverts located well below the ground-water level, replacement by cut-and-fill would have included dewatering the excavated area. With the in-situ rehabilitation, no muddy water had to be discharged, an environmentally positive aspect of the repair. Normally, weather conditions have no significant impact on installation, since most of the work is underground. However, rainfall affects repair efforts of pipes that drain rainwater. During the Enid Lake project, rain from Hurricane Hugo resulted in several installation delays.

This repair system is indicated whenever high site-restoration costs are involved or when it is important not to disrupt the regular use of an area. At Enid Dam, it would have been very costly to restore the grass cover on the downstream face of the dam. Additionally, the collocated recreation areas would have been closed to the public during late summer and fall. Instead, only a water pump, several trucks, and the work crews served as indicators that a major refurbishment was going on in the area.

More information about the Enid Lake project is available from Mr. Luther Newton, Vicksburg District, (601) 631-5612.

SPOTLIGHT ON STAMPEDE DAM & RESERVOIR

Washoe Project, California

Stampede Dam and Reservoir, built and operated by the Bureau of Reclamation, are located on the Little Truckee River immediately below the mouth of Davies Creek and approximately 8 miles above the confluence of the Little Truckee and Truckee Rivers.

Access to the dam is provided by a county road from Interstate Highway 80 past Boca Dam, or by a county road from Prosser Creek Dam. During heavy snows, a snowcat vehicle capable of seating four persons is used for access to the dam. A two-seated snowmobile is also available if more rapid access is required.

Work began in early November 1966 on Stampede Dam and Reservoir, and was completed in February 1970. The dam is a zoned earthfill structure with a height of 239 feet, a crest length of 1,511 feet, and an embankment volume of 4.5 million cubic yards. The reservoir has a capacity of 226,500 acre-feet.

The crest of the dike is paved, since it is designated as a county road, and is flanked with guardrails.

The reservoir offers swimming, boating, fishing, and camping. In addition, picnicking facilities are available. Recreation facilities are administered by the Forest Service.

The powerplant is a semi-outdoor cast-in-place concrete structure housing two vertical-shaft hydraulic-turbine-driven generating units with a total installed capacity of 3.65 MW at a rated head of 183 feet. The outdoor generators are supported by the top deck of the powerplant structure. The large turbine is fully encased in concrete, while only the draft tube of the small unit is encased. The generating units must be handled by mobile crane.

The powerplant is fed by a 42-inch-diameter penstock which is attached through a reducer to the 54-inch-diameter stub from the outlet works. The powerplant is designed as a run-of-the-river plant with a 650-kW unit to produce power during low flows and a larger 3,000-kW unit that can be brought online to take advantage of large flows. Power generated at Stampede is transmitted into Sierra Pacific's power grid and is marketed by the Western Area Power Administration.

Figure 1. - Stampede Dam and Reservoir from point east-northeast of dam. Water surface will extend to tree line when filled to normal storage capacity. 7/12/70

Figure 2. - Stampede Dam and Reservoir looking upstream from left abutment. 7/1/73

Figure 3. – Stampede Dam - Deposits of sand along upstream face of dam. 5/10/90

Figure 4. – Stampede Dam - Downstream face of dam showing minor vegetative growth. 5/10/90

Figure 5. - Stampede Dam - Powerplant service yard.
5/10/90

Figure 6. - Stampede Dam - Downstream river channel.
5/10/90

U.S. GOVERNMENT PRINTING OFFICE 1990-833-436

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.

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

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

Prospective material should be submitted through your Bureau of Reclamation Regional office.