RECLAMATION
Managing Water in the West

Water Operation and Maintenance Bulletin

No. 238

In This Issue . . .

U.S. Department of the Interior
Bureau of Reclamation

June 2015

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

The *Water Operation and Maintenance Bulletin* and subject index may be accessed on the Internet at: **www.usbr.gov/assetmanagement**.

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

For further information about the
Water Operation and Maintenance Bulletin, contact:

Ben Claggett, Managing Editor
Bureau of Reclamation
Technical Service Center (86-68260)
PO Box 25007, Denver, CO 80225-0007
Email: bclaggett@usbr.gov

***Cover photograph*:** Completed installation of new stiffeners, coating of exterior adjacent pipe shell, and installation of life line poles on the Unit P2 discharge tube at Grand Coulee Dam.

Water Operation and Maintenance Bulletin

No. 238 – June 2015

CONTENTS

Page

Available on the Internet at:
www.usbr.gov/assetmanagement

CEDAR BLUFF DAM OUTLET WORKS LEAKING TUNNEL REPAIR

by: Matthew Klein, Ph.D., Bureau of Reclamation, Technical Service Center, Concrete, Geotechnical, and Structural Laboratory

Recently, staff from the Concrete, Geotechnical, and Structural Laboratory (CGSL) from the Technical Service Center (TSC) in Denver performed repairs to leaks in the downstream conduit at Cedar Bluff Dam. The dam is located about 40 miles from Hays, Kansas, on the Smoky Hill River south of Interstate 70 on the K-147 State Highway. The 525-foot-long, 10-foot-diameter concrete conduit downstream of the gate chamber was leaking and causing maintenance issues for the 5-foot 6-inch steel outlet pipe.

The crack was over the outlet pipe access hatch about 500 feet upstream of the control house (figure 1) and was actively leaking and contributing to excessive corrosion on the hatch, limiting its use. The CGSL recommended using chemical grouting to seal the crack over the hatch.

Figure 1.—Crack location over outlet pipe access hatch.

The crack at Cedar Bluff was likely due to shrinkage stress concentrations at construction joints. Several cracks were observed at regular intervals and were oriented radially. There were no other issues, such as settlement, defective concrete mixtures, freezing/thawing cycles, or chemical attack, observed with the cracking. While the shrinkage can continue indefinitely, the rate slows, so the repair needs to be able to respond to potential continued movements.

The chemical grouting solution chosen to keep the crack sealed even with future movements was a flexible hydrophobic polyurethane grout. The grout is a moisture-activated polyurethane resin that is a hydrophobic grout; it can withstand repeated wet/dry cycles and does not shrink in the absence of water. Unlike typical hydrophobic grouts, this particular grout has the ability to remain flexible and stay watertight if the crack moves.

The actual location of the crack was obscured by heavy deposits of rust and calcium carbonate, which had to be removed before repairs could begin. Since the objective was to prevent water from dripping on the pipe, the targeted crack repair was in the crown from springline to springline. The crack measured about 15 feet in length and varied from 0.01 to 0.06 inch wide.

Design drawings indicated that the concrete tunnel wall thickness was 2 feet 6 inches. Grouting is performed to intersect the crack at the midway point in the concrete thickness to force grout inside and outside of the tunnel. Eighteen-inch-long injection holes were drilled about 12 inches from the crack at a 45-degree angle to intercept the crack at about 12 inches deep (figure 2). Since the clearance between the pipe and wall was limited on the backside of the pipe, the injection holes were started with shorter bits, and the longer bits were switched out when depth permitted.

A total of 23 holes were drilled along the crack. The holes were staggered and located about 6 inches apart. Once the holes were drilled, concrete dust was cleaned out using air pressure. Plastic hammer-in packers were placed in the holes and Zerk fittings attached to the packers. Water was used to test and prime the injection holes and to test for connectivity between the holes and the crack. During the water connectivity test, water was observed draining through the crack from all ports, indicating good connectivity.

The grout was catalyzed and injected using an airless paint sprayer fitted with a Zerk connection port and a check valve and ball valve to control flow. In this case, the catalyst was dosed at the maximum allowed since the moisture in the crack was minimal. This allowed for a quick set time, which was verified with a cup test. A cup test consists of adding the catalyzed grout to water, mixing, and observing the time to set.

The injection assembly is kept on a port using pressures of about 50 to 100 pounds per square inch until the grout begins seeping from the crack opening. Then the assembly is moved to the next port until all ports are injected. In places where water is still seeping, the assembly is reattached, and additional

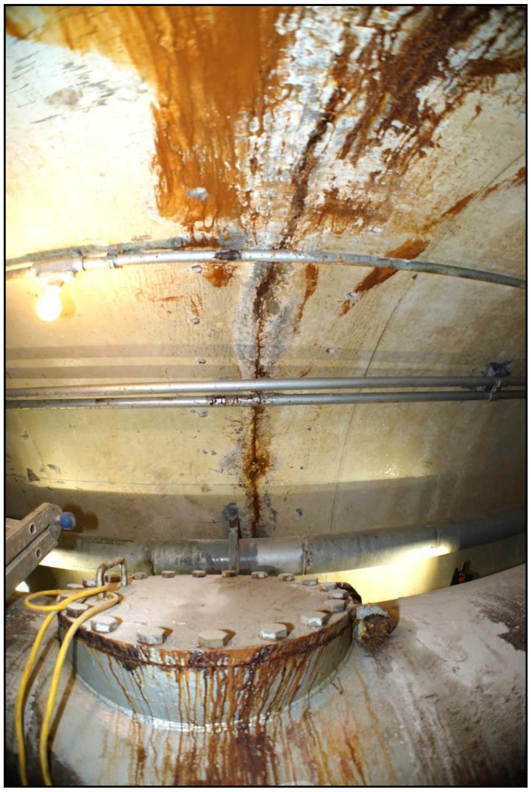

Figure 2.—Repair procedure showing drilled holes (the cover is coated with concrete dust).

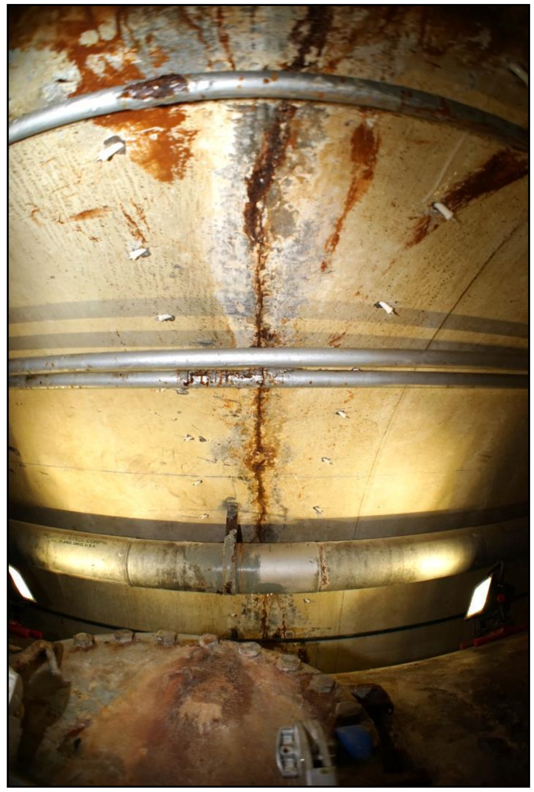

Figure 3.—Repair procedure showing ports.

grout is injected to adhere to the previously cured grout. The process is repeated until water is no longer seeping from the crack. In this case, 2.5 gallons of grout was injected along about 15 feet for an injection density of about 0.2 gallon per foot.

Grout strength is initially low and increases as it cures. When a crack is sealed, water pressure begins to build, and the rate of the water pressure often exceeds the grout strength, resulting in blowouts. When this happens, the best procedure is to inject in small portions, allowing the grout to adhere to itself and cure before adding additional grout. This allows the strength to develop and resist the water pressure, eventually sealing the crack.

The repair was allowed to cure overnight, and when the repair team arrived the next morning, the crack was completely dry. The next step was to remove the hammer-in packers from the ports. The Zerk fittings were removed; then, a slide hammer fitted with a threaded end was used to remove the packer. The grout holes were then filled with a stiff non-shrink cementitious grout (dry pack) (figure 4), which was mixed in small amounts so that it didn't set up before it was able to be used.

Figure 4.—Finished repair showing grouted injection holes.

This project was a textbook demonstration of successful grouting. The project was completed within 1-1/2 days, including setup and cleanup.

GRAND COULEE DAM – JOHN W. KEYS III PUMP-GENERATING PLANT UNIT P2 DISCHARGE TUBE STIFFENER REPLACEMENT

by: David Tordonato, Ph.D., P.E., Bureau of Reclamation, Materials and Corrosion Laboratory, Technical Service Center

Management Summary

The purpose of this report is to document activities related to P2 discharge pipe rehabilitation work at Grand Coulee Dam, John W. Keys III Pump-Generating Plant. Cracking of 5B-H pipe stiffener welds and leakage at that stiffener location have been observed for a long time during operation of the pipe. The record of other crack repairs at the P2 discharge pipe is included in Technical Memorandum (TM) No. GRC-8110-2013-1 [1].

Stiffener 5B-H at the P2 discharge pipe was replaced, and the pipe shell was repaired by the Grand Coulee Dam in-house team between October 14, 2014, and January 20, 2015. The rehabilitation work was performed per the Technical Service Center (TSC) recommendation included in TM No. GRC-8110-2014-1 [2] and P2 discharge pipe modification drawing 222-D-60000. The TSC provided consultation to the field team during the stiffener repair work. As-built drawing 5B-H (222-D-60016) for the 5B-H stiffener replacement was created.

Background

The H-type stiffeners on discharge pipes P1–P6 have created maintenance challenges with varying frequency and severity depending on the unit. The executive summary issued by the TSC [1] describes these issues and the TSC's activities in greater detail. During a site visit in July 2014, it was reported by field personnel that stiffener 5B-H had begun to leak. In the 1970s and early 1980s, a stiffener replacement program was in place, and most of the H-type stiffeners on the P1 discharge pipe were replaced with plate-type stiffeners. Some stiffeners on the P2 discharge pipe were also replaced, but 13 H-stiffeners remained. All H-type stiffeners originally installed on discharge pipes P3–P6 remain in place.

In recent years, cracked stiffener welds and pipe leaks on the discharge pipes have been weld repaired. A correction to the approach was suggested by the TSC: avoid re-welding the problematic stiffeners (that actually masks any cracks in the pipe shell covered by the H-stiffener flange) and instead replace the H-stiffeners with plate-type stiffeners [2]. It was decided to start the process with modification of the 5B-H stiffener in which significant leakage was noted. Work on P2 discharge pipe was planned to begin immediately following the conclusion of the 2014 irrigation season.

Rehabilitation Chronology

The TSC prepared a stiffener replacement procedure, which included proposed dimensions of a new plate-type stiffener, the welding procedure, and drawing 222-D-60000, which were transmitted to Grand Coulee on September 26, 2014. Originally, a single 1-inch-thick plate-type stiffener 9 inches in height and consisting of six segments was specified. The design assumed sound conditions of the pipe shell under the existing H-stiffener flange.

Repairs

Replacement of the 5B-H stiffener began on October 14, 2014, shortly after the conclusion of the irrigation season. The crew at Grand Coulee began by removing the existing H-stiffener. Once the stiffener was removed, it was discovered that there was significant undercutting in the pipe shell along the fillet welds that held the stiffener in place (figures 1 and 2). The undercutting needed to be ground down and then weld repaired. The crew discovered a 7-inch crack near the pipe crown during the process of grinding out the undercutting. The crack became larger during grinding from the outside of the pipe. The crack was ground away and completely re-welded for a full repair. The repair of the crack required 1 root pass and 5 cover passes to complete and was subsequently ground flush and penetrant tested.

In addition, the leakage through the crack at the pipe crown had created a large area of crevice corrosion in the 7/16-inch-thick pipe shell under the stiffener flange, near the pipe invert, approximately 3 feet long by 6 inches at the widest (figure 3). The metal losses and pits up to 1/8 inch in depth necessitated repairs. Two options were considered: (1) cut-out the compromised portion of the pipe shell and replace with new 1/2-inch-thick steel plate or (2) arc gouge the corrosion and repair the cavity using a weld procedure similar to cavitation repairs. The latter option was chosen, and a carbon arc was used to remove the existing corrosion (figure 4). The approach did not require welder access to the inside of the pipe. The average depth of gouging was 1/8 inch, with several spots going up to 3/16 inch.

Figure 1.—Undercutting in pipe shell observed along H-stiffener fillet weld after stiffener removal.

Figure 2.—Undercutting observed on weld under flange after H-stiffener removal.

Figure 3.—Corrosion pitting 1/8 inch in depth under the H-stiffener flange.

Figure 4.—Corrosion area under stiffener flange after arc gouging.

Arc gouging was followed by grinding and penetrant testing for additional surface defects. Welding required significant time and approximately 30 pounds of weld rod to completely fill the area.

Stiffener Replacement

The original plan was to replace the 5B-H stiffener with a single 1-inch-thick plate stiffener 9 inches in height. However, once the original stiffener had been removed, field staff noted that the pipe appeared to be deformed in the area where the H-stiffener had been installed. The field team described the pipe at that location as "appearing like a balloon with a rubberband around it." Figures 5 and 6 illustrate the pipe deformation that was observed. In other words, the pipe in the areas upstream and downstream had bulged out. In addition, portions of the pipe from 20 to 45 degrees from the top on either side appeared to be deformed, creating fit-up issues for the new stiffeners. The decision was made to provide two similar plate stiffeners to create a pair of stiffeners (14–16 inches apart) on either side of the affected area. The welded overlay used to repair the corroded pipe shell near the invert also factored into the decision to provide two new stiffeners.

Welding of New Plate Stiffeners

Although the new stiffeners were located away from the pipe shell deformed area where the old H-stiffener had been installed, some pipe out of round was noted when it was time to begin tacking the new segments to the pipe. The first approach was to field fit the machined stiffener segments to the existing pipe by adjusting the inside diameter of the stiffener segment to match the pipe curvature. This was initially done for two segments but ultimately proved to be time consuming for the remaining stiffener segments. Also, field fitting the bottom segments on each stiffener created an offset with the adjacent stiffener segments (figure 7). This offset required cutting and feathering to smooth the transition. Instead, a clamp was tack welded to the pipe and to each new stiffener segment. The clamp was then adjusted to reduce the gap between the pipe and the stiffener segment.

Once welding was complete, the new stiffeners and exterior of the adjacent pipe shell were coated, and life line poles were installed (figure 8). No inspection or repair of potential damage to the paint on the inside of the pipe shell at the stiffener repair areas was performed.

The final configuration is documented in as-built drawing 222-D-60016.

Figure 5.—It was noted that the pipe in the area of removed stiffener had bulged out both upstream and downstream in a manner analogous to a rubberband around a balloon.

Figure 6.—Pipe deformation is evident near previous stiffener location.

Figure 7.—The first two segments were field fit and required cut and feathering to achieve a smooth transition between segments.

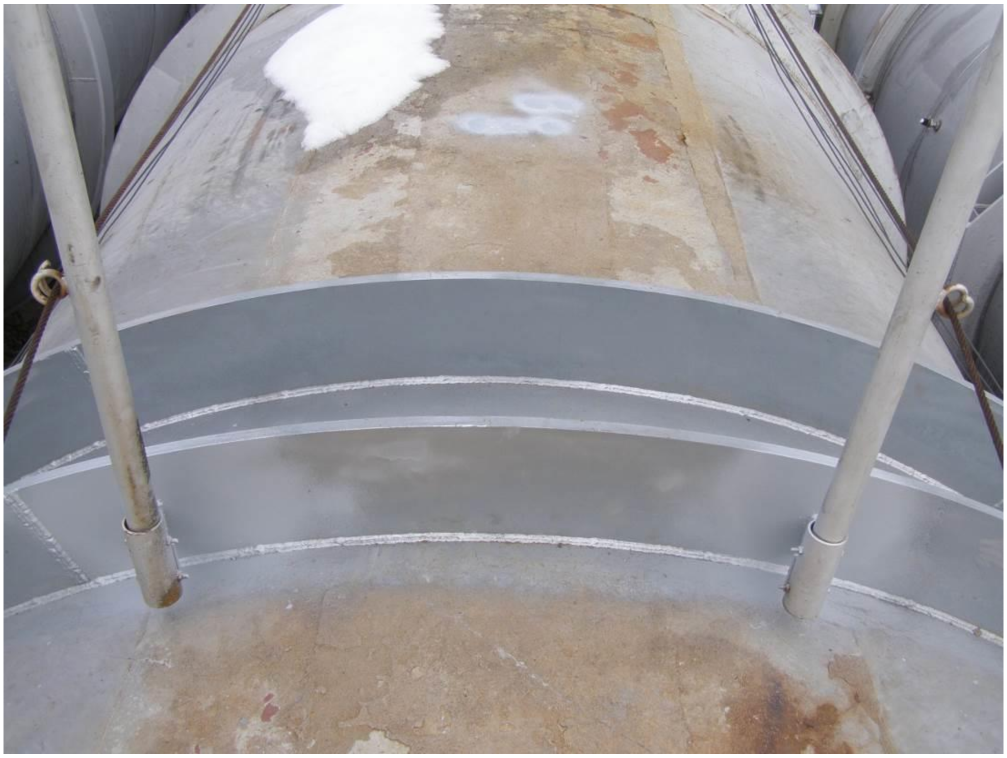

Figure 8.—Completed installation.

Table 1.—Summary of stiffener replacement activities

Dates	Phase	Milestone/issue
9/26/2014	Design	Draft design drawing transmitted
10/6/2014	Design	Feedback on drawing received
10/8/2014	Design	Revised drawing transmitted
10/14/2014	Stiffener removal	Stiffener removal
10/21/2014	Pipe repairs	Grinding flush to the surface reveals significant undercut
10/22/2014	Pipe repairs	Grinding to remove the undercut reveals a crack near top dead center that appears to have initiated from the inside diameter of the pipe
10/22/2014	Pipe repairs	Pipe deformation was noted in the area where the stiffener had been placed
10/23/2014	Pipe repairs	Crack repair – Grind out, penetrant testing, weld fill with six passes
10/29/2014	Pipe repairs	Extreme crevice corrosion discovered at the bottom of the pipe
11/4/2014	Pipe repairs	Corrosion pitting air-arc gouged and ground
11/6/2014	New stiffener installation	New stiffener arrangement recommended: 2 stiffeners 14 inches apart and 2 inches from the weld repair overlay
11/10/2014	New stiffener installation	New stiffener placement locations are finalized
11/21/2014	Pipe repairs	Undercut repairs are substantially complete (grinding remains)
12/5/2014	New stiffener installation	Begin tacking new stiffener sections into place
1/13/2014	New stiffener installation	Welding of stiffeners is complete
1/16/2015	New stiffener installation	Handrail poles welded
1/16/2015	New stiffener installation	New stiffeners are painted
1/20/2015	New stiffener installation	Completion

Discussion

Replacement of stiffener 5B-H ended up taking longer and costing more than was initially anticipated. The main factors impacting the cost and time of service were:

- *Cracks in the pipe shell* – The crack discovered in the pipe shell after the H-stiffener was removed required repairs. Prediction of the crack location and its size was a difficult task with the H-stiffener in place. Consequently, the extent of the work to repair the cracks in the pipe shell was difficult to estimate without removal of the H-stiffener.

- *Extensive corrosion of the pipe shell under the H-stiffener flange* – The extent of corrosion of the pipe shell under the H-stiffener flange was difficult to estimate with the H-stiffer in place. Since the performed work on the 5B-H stiffener was the first of such kind in the recent years, the need to remove and repair undercutting as well as repair of the pipe shell was unexpected as was the extent of the pitted area on the underside of the pipe. Both required significant time to repair prior to moving forward with installation of the new stiffener.

- *Second plate stiffener* – The need for a second stiffener required additional time for fabrication, surface preparation, welding, and finishing.

- *Local deformation of the pipe shell at the stiffener locations* – If additional H-stiffeners are to be replaced, there is now a strategy for dealing with the out-of-round pipe using half clamps. It should be noted that this technique will create additional residual stresses in the pipe and weld material, potentially reducing the fatigue life to some extent. In this replacement, it was the most expedient method for construction.

- *Winter conditions* – Low ambient temperature resulted in the delay of the repair work.

Another item for consideration is the corrosion repairs performed near the pipe invert. These repairs proved to be fairly time consuming, and it may be more practical to cut and replace the damaged area in the future. However, this would require access to the inside of the pipe as well as compliance with confined space safety requirements.

An alternative to replacement of each H-stiffener and other required reinforcement of the existing discharge pipe is replacement of the aboveground portions of some of the pumping unit discharge pipes. The new discharge pipes could be designed in accordance with modern water conveyance design standards with extended operation life. Given the field costs of existing discharge pipe repairs, associated costs with hazardous material removal, stiffener replacement, re-lining and recoating, and limited service life of repaired pipes, the replacement option may end up being competitive from a cost standpoint in a long-term perspective.

Lessons Learned

1. Corrosion under the existing stiffener flanges can be substantial, requiring time-consuming repairs or field patching.

2. The existing fillet welds of the H-stiffener contain undercutting, which is visible after the stiffener is removed. The undercutting can act as a crack nucleation site or, in the case of stiffener 5B-H, can be a point of localized wall thinning where a propagating crack will first breach.

3. The existing pipe was permanently deformed underneath the H-stiffener, and it was out of round in sections immediately upstream and downstream from the stiffener. This could be similar for all H-stiffeners on discharge pipe P2 and other pumping units and can create issues for new stiffener segments being fitted to old pipe. Tacking and using a half clamp to reduce the gap is one way to overcome curvature mismatches, but it can also create additional stresses in the pipe and weld.

Recommendations

The structural modification plan previously recommended may end up being more expensive than the option of exposed pipe replacement. It is recommended that an appraisal-level cost analysis be performed for the discharge pipe replacement alternative.

References:

[1] *John Keys III (Grand Coulee Dam) Pump-Generating Plant, Structural Analysis of P2 Discharge Pipe Report*, GRC-8110-2013-1, December 9, 2013.

[2] *John Keys III (Grand Coulee Dam) Pump-Generating Plant, P2 Discharge Pipe Modifications – Appraisal Level Design*, GRC-8110-2014-1, June 2014.

[3] *John Keys III (Grand Coulee Dam) Pump-Generating Plant Discharge Tube Inspection Report*, prepared by Jerzy Salamon and Dave Tordonato, July 28, 2014.

[4] *John Keys III (Grand Coulee Dam) Pump-Generating Plant Executive Summary of the Planning Work on Discharge Pipes*, GRC-8110-2014-2, prepared by Dave Tordonato, August 18, 2014.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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

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

Prospective articles should be submitted to Ben Claggett, Technical Service Center, email: bclaggett@usbr.gov

Regional Bureau of Reclamation contacts are listed below:

Scott Boelman, Great Plains Region, email: sboelman@usbr.gov

Paul Caruso, Mid-Pacific Region, email: pcaruso@usbr.gov

James Dean, Pacific Northwest Region, email: jdean@usbr.gov

Scott Foster, Lower Colorado Region, email: sfoster@usbr.gov

Clyde Thomas, Upper Colorado Region, email: cthomas@usbr.gov