Flatiron Powerplant Unit 2 Butterfly Valve Cavitation Resistant Coating Field Trial

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Technical Memorandum No. 8540-2023-34

Big Thompson Project, Colorado
Missouri Basin Region

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14. ABSTRACT

Flatiron Powerplant butterfly valves experience cavitation since the seats were replaced with stainless steel in 2010. Different linings have been used to reduce cavitation damage on the downstream side of the butterfly valves, with minimal success. Laboratory testing identified two commercial polyurethane elastomers that may provide better cavitation resistance than prior linings used in draft tubes for cavitation resistance. The two lining materials were selected for field trials on a Flatiron Powerplant Unit 2 butterfly valve as a cavitation repair material for filling the entire cavitation pit, i.e., without stainless steel weld repair. The butterfly valve has a moderate cavitation environment with an approximate pressure drop of 500 pounds per square inch.

15. SUBJECT TERMS

Butterfly valve, moderate cavitation, polyurethane elastomer, field trial, cavitation resistant materials

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prepared by

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Cover photograph: Area on interior of penstock showing the test coating fully applied.

Peer Review

Bureau of Reclamation
Technical Service Center
Materials and Corrosion Laboratory Group

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Contents

Executive Summary

Hydroelectric powerplants must conduct cavitation repairs every few years to slow cavitation damage on components subjected to high flow conditions that contain a pressure drop, such as the downstream side of butterfly valves and turbine runners. Through recent laboratory testing, the Technical Service Center (TSC) has identified two polyurethane elastomers (materials with rubber-like properties) which demonstrate superior cavitation resistance compared to other lining materials tested. The laboratory test data indicate these two lining materials, PE1 and PE2, may provide protection in moderate or severe cavitating environments that is comparable to stainless steel weld overlays, the traditional approach to providing cavitation resistance in high flow areas.

In February 2023, TSC applied field trials of PE1 and PE2 to Nathaniel Washington Powerplant Unit G21 turbine runner [1]. TSC needed a separate field trial to evaluate these materials for use as fillers to repair cavitation pits. The Unit 2 butterfly valve at Flatiron Powerplant was chosen for the trial. The downstream side of the valve body exhibited 3/8-inch-deep cavitation pits, resulting from the 500-pound-per-square-inch pressure drop caused by water seeping around the seats when the valves are in the closed position. Trial repairs were conducted on March 28, 2023.

The cavitation areas of the butterfly valve body were power tool cleaned to bare metal, per SSPC-SP11, using angle grinders, needle guns, and a bristle blaster [2]. An adhesive was applied directly to bare metal and allowed to cure. PE1 and PE2 were applied in accordance with the product datasheets. Each elastomer was applied to approximately 3 linear feet within the cavitation damage zone. PE1 filled the entire 3/8-inch-deep pit without sagging. PE2 sagged and dripped out of the deep pits, requiring a second coat. The field trial commenced on April 11, 2023, when the penstock was watered up with the valve in the closed position. Flatiron power plant is not scheduled for an outage until March 2025, and the cavitation repair trial will be evaluated during this outage.

1. Background

Hydroelectric powerplants must conduct cavitation repairs every few years to slow cavitation damage on components subjected to high flow conditions, such as the downstream side of butterfly valves or turbine runners. The Research and Development Office’s Science and Technology Program funded project number 20024, Field Repairable Materials and Techniques for Cavitation Damage, a laboratory research effort which evaluated 24 commercial lining materials for cavitation resistance [3]. The tests subjected the candidate materials to high-velocity impinging water conditions, and compared the results to type 316 stainless steel, ASTM A36 mild steel, and type 308/309 stainless steel welds overlaid on mild steel, which is the traditional approach for providing cavitation resistance to components in the field. Two polyurethane elastomers (materials with rubber-like properties) showed excellent cavitation resistance in the laboratory testing, performing comparably to 308/309 stainless steel weld overlays. The other 22 lining materials exhibited damage within eight hours of the lab testing conditions. Some of those materials have been used in draft tubes with mild cavitating environments and have shown satisfactory performance. These cavitation resistant coatings failed around 8 hours under laboratory testing. The top two performing polyurethane elastomers, PE1 and PE2, failed around 150 hours in laboratory testing and might perform well in more aggressive or moderate cavitation environments. Table 1 provides typical observations for the varying severity of cavitation intensity. Field trials are necessary to determine if these materials can provide improved cavitation prevention to traditional mitigation methods. One goal of this study is to increase the service life or maintenance cycles of cavitation repairs, which could reduce facility maintenance costs.

Table 1.—Cavitation severity levels defined for this research based on the damage level observed in traditional polymer coatings, mild steel, Type 308/309, and 316-series stainless steels after 200 hours of laboratory testing or an estimated 10,000-hour exposure in the field.

Cavitation Level	Traditional Polymer Coatings	Mild Steel	Type 308/309 Stainless Steel	Type 316 Stainless Steel
Mild	Volume loss and some complete removal	Light frosting/ minor metal loss	No damage	No Damage
Moderate	Complete removal	Moderate metal loss	Light frosting	No Damage
Severe	Complete Removal	Severe metal loss	Moderate metal loss	Light frosting
Extreme	Complete Removal	Severe metal loss	Severe metal loss	Moderate metal loss

2. Field Trial Details

PE1 and PE2 were applied to the Nathaniel Washington Powerplant Unit G21 turbine runner in February 2023 as the first field trial of cavitation resistant coatings with total applications of 20–50-mil dry film thickness [1]. A separate field trial was needed to evaluate the lining materials as fillers to repair cavitation pits with applications exceeding 3/8-inches (375-mil) dry film thickness. Researchers selected the Unit 2 butterfly valve at Flatiron Powerplant for the second trial location. Trial repairs were applied on March 28, 2023 and the trial commenced when operations resumed on April 11, 2023.

2.1 Surface Preparation

The downstream side of the valve body, shown in Figure 1–Figure 2, exhibited 3/8-inch-deep cavitation pits, resulting from the 500-pound-per-square-inch (psi) pressure drop caused by water seeping around the seats when the valves are in the closed position. On the morning of March 28, 2023, the area was cleaned with needle guns and a bristle blaster to prepare the cavitated areas of the butterfly valve body to bare metal conditions per SSPC-SP11, as shown in Figure 3–Figure 5 [2].

2.2 Adhesive Application

Following surface preparation, Flatiron Powerplant staff brush-applied a thin coat of clear adhesive to all cavitation areas. Surface temperature was measured and recorded at 49 degrees Fahrenheit following the adhesive application, prior to the elastomer applications. No epoxy primer was used in this application and the adhesive was applied direct to metal. The adhesive was worked into the cavitation pits to evenly coat the cavitation pitted surfaces.

2.3 Application of Polyurethane Elastomer 1

PE1 was mixed for three minutes and applied to its test area between the 8 o’clock and 11 o’clock positions, and across the trunnion at the 9 o’clock position. The lining was worked into the surface profile and cavitation pits with a thin initial layer using brushes. The lining was applied in layers until all pits were filled. A trowel was used to periodically smooth any sags until the viscosity held the elastomer in place and no further sags formed. Figures 6–7 show the PE1 test area after the final application.

2.4 Application of Polyurethane Elastomer 2

PE2 was mixed for three minutes and applied to its test area between the 11 o’clock and 1 o’clock positions and between the 7 o’clock and 8 o'clock positions. The lining was worked into the surface profile and cavitation pits with a thin initial layer using brushes. The lining was applied in layers until all pits were filled. A trowel was used to periodically smooth any sags, but sags continued to form, as the viscosity of this coating was lower than PE1 and it never increased to a point where it would stay entirely in place. Figures 8–10 show the test area after application of the first coat. A second coat was applied on March 29, 2023. Once the second coat had cured, remaining drips and sags were ground smooth with an angle grinder. Figure 11 shows the competed field trial cavitation repair area.

3. Discussion

The field trial at Flatiron repaired cavitation pits up to 3/8-inch deep with two unique polyurethane elastomers, PE1 and PE2, instead of using the traditional 308/309 stainless steel weld repair technique.

The field trial will determine the effectiveness of polyurethane elastomer linings in a moderate cavitating environment. If successful, these linings could be used as repair material alternatives to 308/309 stainless steel weld overlays in moderate cavitation environments with comparable or improved performance. These materials could provide powerplants greater flexibility in maintenance and operation decisions.

4. Conclusions

- The Flatiron Powerplant field trial is a complementary trial to the Nathaniel Washington powerplant field trial [1]. The Flatiron Powerplant test will determine if two polyurethane elastomer lining materials, PE1 and PE2, are suitable for bulk cavitation repairs to fill pits up to 3/8-inch thick. The same lining materials are being tested at Nathaniel Washington as 20–50 mil (dry film thickness) linings, applied after cavitation pits had been repaired with 308/309 stainless steel weld overlays.
- Two polyurethane elastomer lining materials were successfully applied to the downstream side of the butterfly seat on Unit 2. Instead of using a stainless steel weld overlay to make the repairs, the lining materials were used to fill cavitation pits.
- Polyurethane elastomer field trials will determine the effectiveness of these lining materials in moderate cavitating environments.

<u>Recommendations for Flatiron Power Plant:</u>

- Record the total run time of Unit 2 and the time the butterfly valve was in the closed position, which causes cavitation.
- Conduct inspections when there are outages and document the appearance of the test areas. Provide detailed photos to the TSC project lead, Allen Skaja (askaja@usbr.gov).

5. References

[1] Skaja, A., Interim Report ST 2023-20024-02 “Grand Coulee Dam G21 Turbine Runner Cavitation Resistant Coating Field Trial” Bureau of Reclamation, Denver CO, 2023.

[2] SSPC-SP11, "Powertool Cleaning to Bare Metal," SSPC, Pittsburgh, 2020.

[3] Skaja, A., Henderson, C., “Investigation of Polymeric Elastomers for Cavitation and Erosion Resistance,” 2023 AMPP Conference, Denver CO, March 20, 2023.

6. Figures

Figure 1.—Condition of the cavitation damage downstream of the butterfly seat (left side of stainless steel seal) prior to surface preparation.

Figure 2.—Condition of the cavitation damage downstream of the butterfly seat prior to surface preparation.

Figure 3.—Power tool cleaning to metal of the cavitation damage downstream of the butterfly seat. The blue tape is protecting the stainless steel seat. The 3/8-inch-deep cavitation damage is to the left of the tape.

Figure 4.—Powertool cleaning to metal of the cavitation damage downstream of the butterfly seat. The blue tape is protecting the stainless steel seat. The 3/8-inch-deep cavitation damage is to the left of the tape.

Figure 5.—Cavitation damage downstream of the butterfly seat shown after power tool cleaning exposed pits up to 3/8 inches deep.


Figure 6.—PE1 is shown applied between the 9 o’clock and 11 o’clock positions.


Figure 7.—PE1 is shown applied between the 8 o'clock and 9 o'clock positions.

Figure 8.—PE2 is shown applied between the 11 o'clock and 1 o'clock positions.

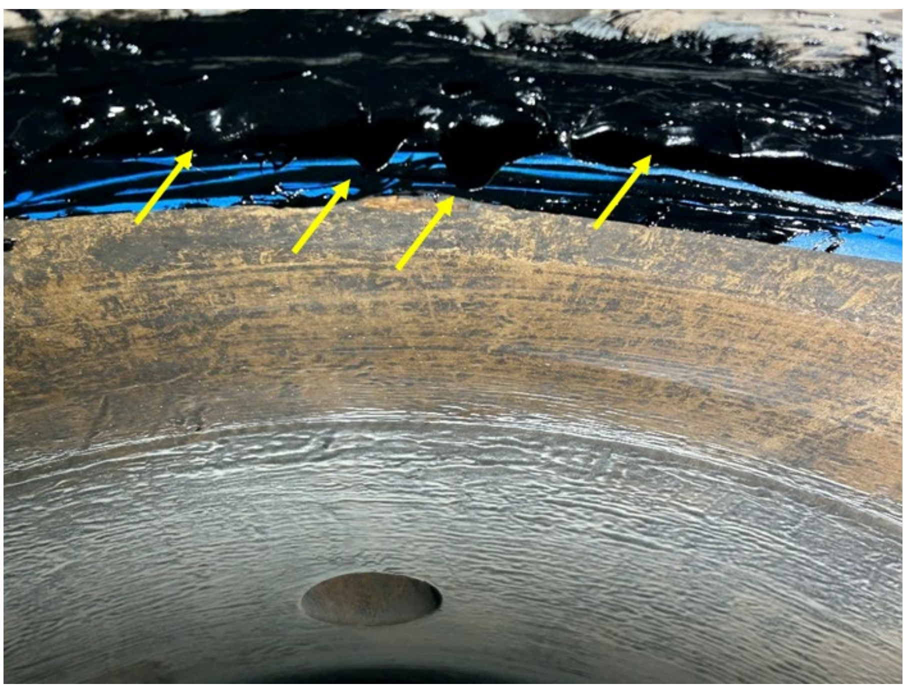

Figure 9.—PE2 is shown applied between the 11 o'clock and 1 o'clock positions. The lower viscosity resulted in sags and drips, noted with arrows.

Figure 10.—PE2 is shown applied between the 7 o’clock and 8 o’clock positions.

Figure 11.—Test area is shown prior to recommissioning Unit 2 penstocks. Drips and sags had been smoothed, but a few areas still needed to be sanded down to allow for proper operation of the butterfly valve.