Hoover Dam Cylinder Gate: Bulkhead Gate Sealant Alternatives

Science and Technology Program
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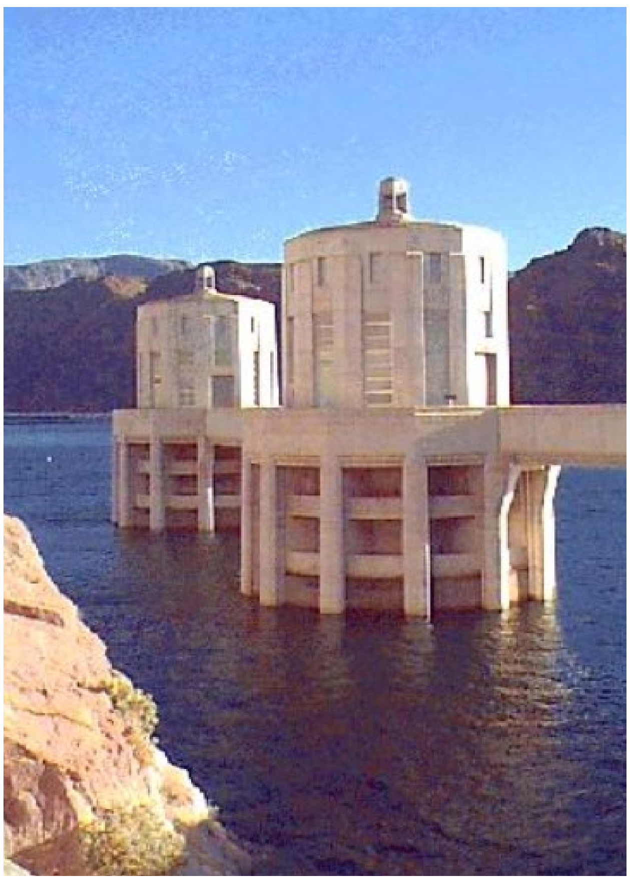

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14. ABSTRACT Sealing the intake towers at Hoover Dam is a very labor-intensive operation. The goal of this study is to survey hydroelectric facilities to review their process of sealing their intake systems. All facilities had rubber on their seals. Approximately half of the facilities only needed to use the bulkheads with rubber seals. Debris sealants were used at other facilities when the bulkheads with rubber seals were not sufficient. Grand Coulee Dam is the only other facility that used a submersible device to deploy debris sealant, which is like Hoover Dam's device. A small number of facilities use preformed flexible gaskets to enhance their bulkheads. The conclusion is that there are no readily available solutions to Hoover Dam's intake tower sealing issues and an engineered solution specific to the needs of the intake tower is warranted.			
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sealing methods: Grand Coulee Dam, Folsom Dam, Hungry Horse Dam, Nimbus Dam, Trinity Dam, Parker Dam, New Melones Dam, Glen Canyon Dam, Davis Dam, Friant Dam and Seminoe Dam. The following Army Corp of Engineers hydroelectric facilities offered information on their intake system sealing methods: Saint Joseph Dam, Dworshak Dam, Gavins Point Dam, Oahe Dam, Garrison Dam, Big Bend Dam, Garthright Dam, Libby Dam and Wolf Creek Dam.

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Peer Review

Bureau of Reclamation
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Acronyms and Abbreviations

CEATI	Centre for Energy Advancement through Technological Innovation
Feet	Ft
Hoover	Hoover Dam
Reclamation	Bureau of Reclamation

Contents

Executive Summary

Sealing the intake towers at Hoover Dam is a labor-intensive process. The cylinder gates and bulkhead gates are not sufficient in sealing the intake towers and additional sealants must be used to minimize leakage. Hoover Dam uses a 1:1 mixture of bentonite and stag manure that is filled into a cannister, submerged to the elevation of the bulkhead gates and released. There are 24 total bulkhead gates, 12 at the upper intake elevation and 12 at the lower intake elevation. Each bulkhead gate requires, on average, three successful deployments of the sealant to reduce leakage to an acceptable level. The approximate time to deploy the sealant to an upper and lower bulkhead gate is 15 and 30 minutes respectively. The process requires a team of at least four hydroelectric mechanics and has taken up to 720 labor-hours to complete.

The objective of this study was to find other deployment methods and sealant materials being used at other hydroelectric facilities to gain insight on improving the sealing process of Hoover Dam's bulkhead gates. Facilities were contacted and interviews were arranged with knowledgeable personnel on their intake systems. The primary methods of sealing were discussed, if additional sealant needed to be used, and if a mechanism was created specifically to deploy the sealant.

Findings revealed that all facilities contacted use bulkheads with rubber seals; Hoover's seals are metal. Many facilities do not need to use additional sealants. Furthermore, most of the facilities that use additional sealants do not use a submersible device for deployment. Instead, these facilities deploy the sealant on the water's surface above the intake system and let the material sink to the gate

elevation. Grand Coulee Dam is the only surveyed facility that uses a submersible cannister similar to Hoover's.

The Center for Energy Advancement through Technological Innovation (CEATI) surveyed their members about the sealant materials used at their facilities. Hoover has tried many of the "dump and drift" sealants listed by CEATI; however, Hoover preferred the bentonite and stag manure mixture because it provided a sufficient seal with the least deployments when compared to other sealants. Davis Dam and Parker Dam use preformed flexible gasket strips to augment their bulkhead's sealing capabilities if necessary. An engineered solution specific to Hoover's needs are necessary to lessen the level of effort to seal its intake towers.

Introduction

Hoover has four intake towers which convey lake water to a respective penstock. Each intake tower is 395 ft tall, measured from the concrete base, located at the bedrock, to the top of the tower. At the top of each intake tower is the Operating House, which houses all the mechanical components that operate the cylinder gates and a 20-ton overhead crane that rotates on a circular track. Each tower has two intake elevations; the upper gates are located at elevation 1,045 ft and the lower gates are at elevation 925 ft. These elevations are with respect to sea level. Each intake elevation has 12 intake openings that are spaced equally around the circumference of the tower.

The cylinder gates seal the intake tower in an emergency. These gates are lowered behind the intakes to stop water flow or raised to allow water to enter the penstock. The upper cylinder gate weighs 150,000 pounds and the lower cylinder gate weighs 240,000 pounds. The Driving Unit in the Operating House drives a gearing mechanism that rotates the drive shafts to operate a gear driven hoist, which raises or lowers the stems connected to the cylinder gates.

Bulkhead gates are hydraulic engineering control elements that are placed in front of the intakes to stop the flow of water into the penstock. The bulkhead gates used at Hoover are nine-ton portable cast steel gates with metal seating surfaces. There are 24 bulkhead gates, one for each opening. These bulkhead gates are lowered into position through the Operating House floor with the 20-ton overhead crane. The downstream face of a bulkhead gate can be seen in Figure 1.

Figure 1 Downstream face of a Hoover Dam bulkhead gate.

The cylinder gates and bulkhead gates are used in tandem to seal the intakes. After the initial shutdown of the penstock, the cylinder gates are closed in a balanced head condition and the 24 bulkhead gates are seated around the intake openings. The cylinder gates are then raised, which creates differential pressure to seal the bulkhead gates against the intake openings. The hydrostatic force bearing on each upper and lower bulkhead gate is 65 tons and 400 tons, respectively.

Ideally, the bulkhead gates would sufficiently seal the intakes to safely stop all water flow into the tower. However, Hoover experiences significant leak-by that must be mitigated to safely accomplish work in the penstock. Mitigation is achieved with the use of debris-based sealants and a submersible delivery cannister as shown in Figure 2. The cannister is loaded with 500 pounds of sealant, lowered to the leaking intake, and the sealant is released by triggering a trapdoor mechanism located at the bottom of the cannister.

Figure 2 Hoover Dam's sealant deployment device.

The water penetrating the sealing surfaces carries the sealant into the crevices where it swells and improves the seal at the seating surfaces. The process is repeated until the leakage is acceptably minimized. Figure 3 shows the inside of the intake tower before the sealant has been deployed. Note the significant amount of water entering the tower. Figure 4 shows minimal water flow into the intake tower after the sealant was successfully deployed.

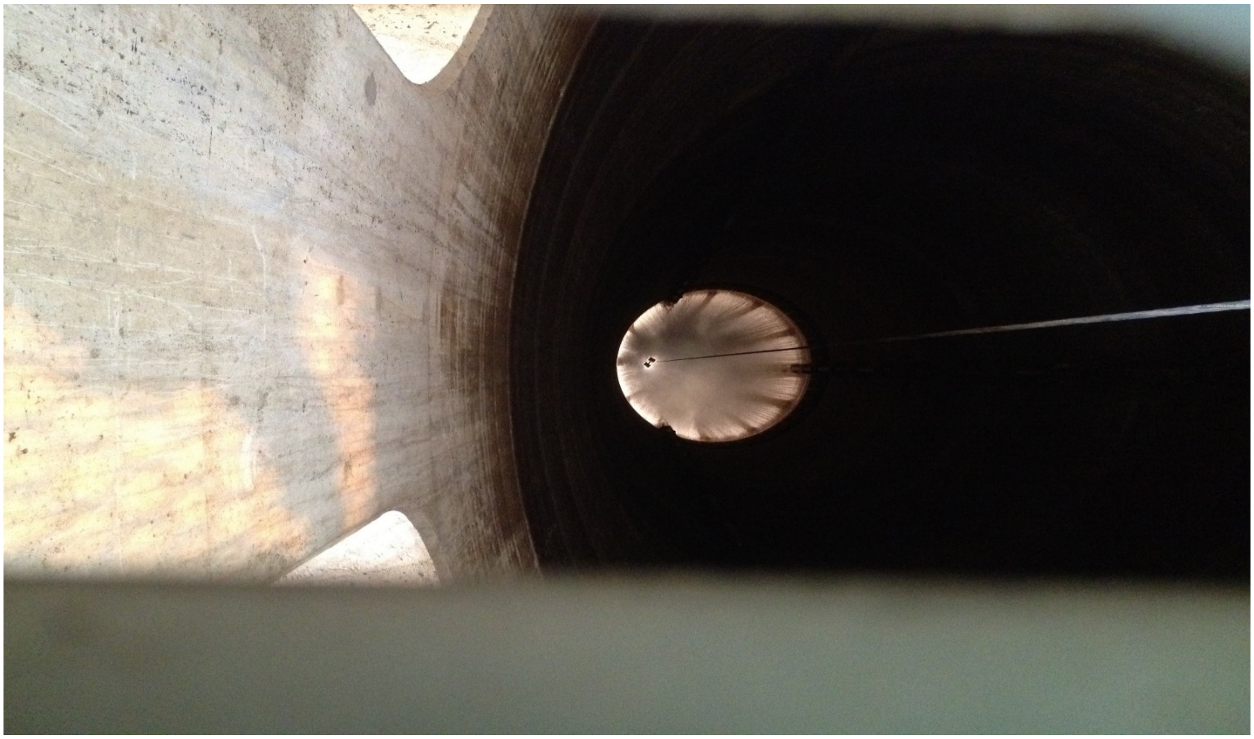

Figure 3 Flow entering the intake tower before sealant is applied.

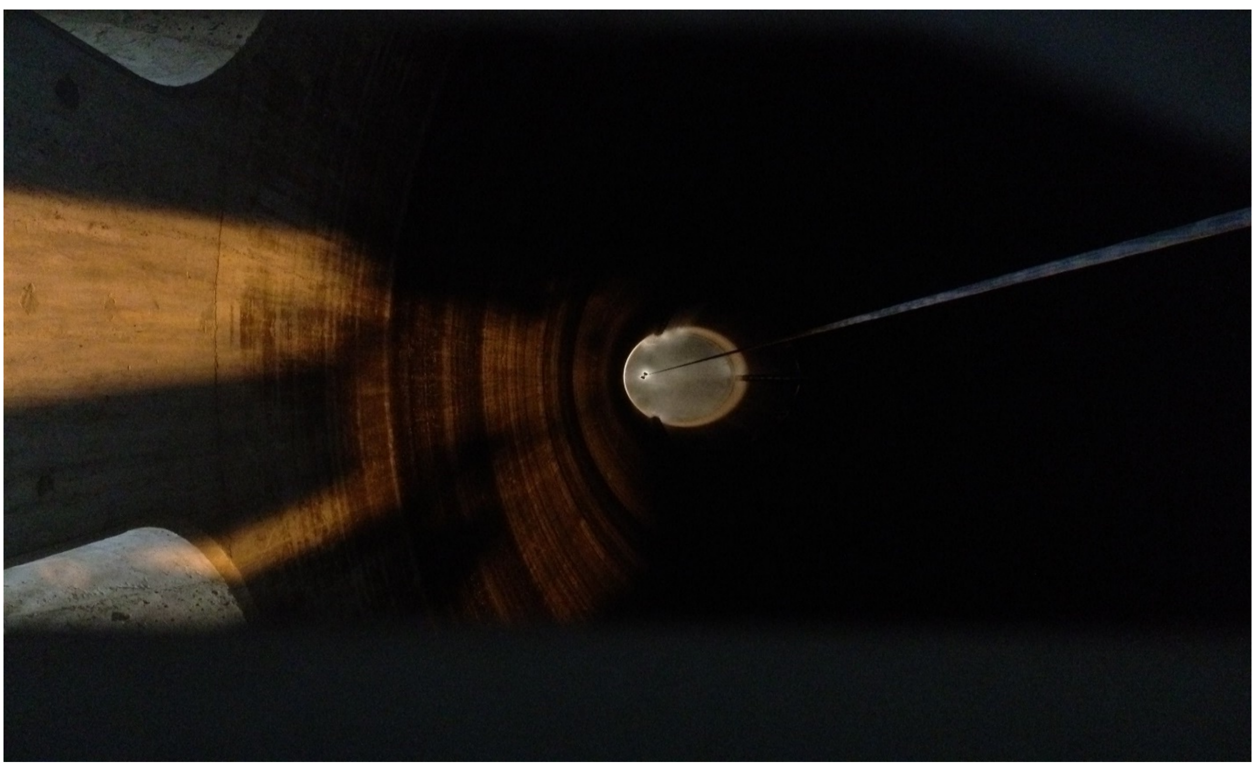

Figure 4 Flow entering the intake tower after sealant is applied.

This is a time-consuming process due to the trivial accuracy when delivering the sealant to the leaking location. On average, each bulkhead gate requires three successful sealant releases to achieve an adequate seal. However, it is not uncommon for the sealant to become lodged in the delivery device resulting in an unsuccessful attempt and losing sealant material. Maintenance personnel have commented that most of the time consumed while sealing the gates is spent lowering and raising the device to the intake elevations. They estimated 15 minutes to reach the upper gates and 30 minutes to reach the lower gates. Historically, this process has taken up to 720 labor-hours to complete with a team of four hydroelectric mechanics.

Hoover has tested several materials, such as wood products, Hydro-Lite, cinders, and pure manure, to minimize the time expended in achieving an acceptable seal. However, the method that creates an acceptable seal is a 1:1 mixture of bentonite and manure. The objective of this study was to find other methods of sealing the intake towers that are less labor-intensive and less time consuming. Different methods might include using a different delivery mechanism, different sealing materials, or an industry accepted method that is unknown to Hoover. Designing a system specific to sealing Hoover Dam's intake tower was not within the scope of the project.

Methods

Information for this study was collected from 20 hydro-electric facilities throughout the country. The Bureau's Technical Service Center (TSC) was also contacted for information. Discussions with plant managers, plant mechanics, and TSC's Hydraulic Equipment Group included accepted sealant materials and alternatives, secondary sealant materials, and sealant delivery methods. Discussions and interviews were conducted via telephone and emails.

Results

Thirteen of the facilities contacted utilize rubber seals that are located on the perimeter of the downstream face of the bulkhead and do not require application of additional sealants. The most common type of seals used at these facilities were J-seals. The facilities stated that the seals degrade over time but are replaceable. Rocks, wood, or other foreign debris can become wedged between the sealing surfaces and obstruct a proper seal, but when this occurs the debris is cleared by raising and lowering the gate.

Dan Campbell, who authored "Hydraulic Units Excessive Gate Leakage Measurement, Prevention Methods, and Materials", breaks sealant types into two groups, "dump and drift" and "diver applied". "Dump and drift" type are debris-sealants which are typically applied on the surface of the water and the mixture sinks to the intake level. This type of sealant requires coarser materials to seal larger leaks. CEATI stated that the diver applied sealants ranked poorly for ease of use (Campbell, 2012). Table 1 is a list of sealants reported by CEATI members.

Table 1 Sealants Listed by CEATI

	Dump & Drift		Diver Applied
1	Cinders	1	Oakum
2	Wood Products	2	Beet Pulp
3	Hydro-Lite	3	Rags
4	Bentonite	4	Sandbags
5	Granite Dust	5	Expanded Polystyrene
		6	Plastic Sheet/ Tarp
		7	Weeds

Debris-sealants are used by approximately 40 percent of the facilities interviewed. None of the facilities use diver applied methods, Hydro-Lite, or granite dust. Grand Coulee Dam's approach is slightly different than the typical "dump and drift"; where a cannister is deployed below the intake elevation and releases sawdust that floats upwards into the leaks. While Coulee's material choice is

different, the overall method closely resembles Hoover's method. Their canister also uses a trapdoor for material release and the process is repeated until the leak rate is considered acceptable by on-site personnel. Grand Coulee's personnel describe the activity as time consuming and arduous.

Preformed flexible plastic strips have been used to augment the sealing capabilities of the bulkheads at Parker Dam and Davis Dam when the rubber seals are insufficient. The specific gaskets used are "RN101-RAM-NEK Preformed Flexible Gasket", which is modified bitumen based. These strips can be applied on the perimeter of the sealing surface if the bulkhead is observed to be leaking after initial placement. The strips are applied iteratively until the leakage is acceptable. Personnel at these facilities stated that this method of sealing is more time-efficient and easier to apply than the "dump and drift" methods.

Discussion

Factors that could be contributing to the excessive leakage at Hoover are:

- The metal seals on the bulkhead gates or the intake seating surfaces may be deformed, corroded, or otherwise compromised
- Water flowing through the small crevices may be eroding the sealing surfaces

While the bulkheads can be easily inspected, the intake seats are only accessible via diver or submersible Remote Operated Vehicle (ROV). The conditions of the sealing and seating surfaces should be examined.

A softer seal material would better accommodate any surface imperfections on the seat. Many facilities get an adequate seal only using rubber seals on their bulkheads. The use of preformed flexible gaskets was not listed by CEATI but does offer an alternative method of sealing for facilities. However, the concern with using rubber seals or flexible gaskets at Hoover is that the bulkhead guide slots slope outward rather than being vertical. This slope would introduce friction

between the gasket and the surface of guide slot, which could shear the gasket off while the bulkhead is being lowered. Friction reducing materials, such as Teflon, could mitigate this concern and should be considered for long-term solutions.

When the rubber seals are not adequate, "dump and drift" methods are primarily used. However, facilities which use a deployment device are rare. Grand Coulee was the only facility which used a submerged cannister similar to Hoover's. Consequently, other deployment methods or devices were not discovered.

Lake elevation may also affect the effectiveness of the seal. The lower lake elevations reduce the pressure on the surface of the bulkheads, which decreases the compression between the seal and the seat. If the bulkheads were designed to operate at or above a specific elevation, leaks may occur regardless of the seal and seat condition.

Leakage measurements would allow Hoover to quantify the effectiveness of the seals before applying additional sealant. Pump monitoring, float switches or flow meters downstream of the gates can be used to quantify leakages from year to year (Campbell, 2012). This data can be used to identify trends pertaining to seal or seat degradation and the effects of lake elevations on water flow after the bulkheads have been seated.

The research into sealing methods has revealed that an "off the shelf, ready-to-go" solution for Hoover's bulkhead gates is not available and requires an engineered solution. If rubber seals or flexible gaskets were to be implemented, a design to minimize friction on the seal surface while raising and lowering the bulkhead gate would need to be developed. The next step in developing a long-term solution is to determine the root cause of the leaks, which should include an inspection of the bulkhead gates and intake seating surfaces. Further studies should also attempt to correlate lake levels to the leakage rates observed at the sealing areas.

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