Best Practice Catalog

Draft Tube Gates

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1.0 Scope and Purpose

This best practice for draft tube gates addresses the technology, condition assessment, operations, and maintenance best practices for the gates and associated operating equipment with the objective to maximize performance and reliability of plant generating system.

The primary purpose of the draft tube gate is to protect the interior powerstation equipment of the hydropower plant including the turbine by providing a barrier and blocking water flow during maintenance and dewatering activities. Most draft tube gates fall under the category of "bulkhead gates or stop logs" that are normally lifted vertically into place and installed under no flow conditions for maintenance. They typically spend a vast majority of their lifecycle in storage rather than service. The gates may be sectioned or un-sectioned with the sectioned subassemblies lifted into place individually and stacked vertically. Although different materials have been used historically, draft tube gates are primarily made from carbon steel and therefore will be the primary focus for this best practice.

1.1 Hydropower Taxonomy Position

Hydropower Facility → Water Conveyance → Draft Tube Gates

1.1.1 Components

The components of the draft tube gate system are those features that directly or indirectly contribute to the effectiveness of the maintenance and dewatering operations. The system is made up of the draft tube gates itself along with the gate operating equipment.

<u>Draft Tube Gate:</u> Also referred to as stop logs or bulkhead gates, these assemblies are used to block water so that construction, maintenance, or repair work can be accomplished in a dry environment. These gates are stored in a secure storage yard, positioned by a crane, and dropped into slots on the pier, which is sometimes integrated with the dam, to form a wall against the water.

<u>Draft Tube Gate Seals:</u> Gate seals function to close off the open gap between the edge of a movable gate and a fixed sealing surface so as to prevent any water from passing through the interface. The seals are typically rubber material, and formed from a flat strip of rubber, or shaped by a molding or extrusion process.

<u>Draft Tube Gate Hoists:</u> Hoists are mechanical (electrically or manually driven), hydraulic (oil or water), or pneumatically operated machines used to raise and lower in place heavy water control features such as gates and stop logs. A lifting beam attaching the gate to the hoist is commonly a key component of the hoist system for draft tube gates.

<u>Draft Tube Gate Bearing Structure:</u> Openings are formed in reinforced concrete walls with dedicated piers at the edge of the openings to hold the draft tube gates in place. Slots are configured in the concrete piers to match the size and geometry of the edges of the gate to allow for a tight fit.

1.2 Summary of Best Practices

1.2.1 Performance/Efficiency & Capability - Oriented Best Practices

- Monitor leakage and functionality of the draft tube gates and include findings in the plant's unit performance records. The plant should routinely monitor and maintain a record of unit performance at the Current Performance Level (CPL).

1.2.2 Reliability/Operations & Maintenance - Oriented Best Practices

- Develop a routine inspection and maintenance plan.
- Routinely inspect draft tube gates, seals, hoists, and bearing structure components for degradation.
- Trend draft tube gates, seals, hoists and bearing structure components for degradation and adjust life expectancy accordingly to ensure that the system has the appropriate degree of functional reliability.
- Routinely inspect and maintain draft tube gate operating hoist and lift equipment.
- Maintain documentation of Installed Performance Level (IPL) and update when modification to equipment is made (e.g. gate seal replacement/repair, concrete piers/slots upgrade).
- Include industry knowledge for modern draft tube gate system components and maintenance practices to plant engineering standards.

1.3 Best Practice Cross-References

- Civil – Penstocks and Tunnels
- Civil – Leakage and Releases
- Civil – Trash Racks and Intakes
- Civil – Flumes and Open Channels

2.0 Technology Design Summary

2.1 Material and Design Technology Evolution

Figure 1: Norris Dam – Anderson/Campbell County, TN

A wide variety of draft tube gate designs have been used at hydropower plants over the course of the last century. Popular designs implemented include slide gates, roller gates, and stoplogs (wood or steel). As mentioned previously, the most commonly used gate is constructed of carbon steel members and plate. These steel gates have the advantage of being relatively inexpensive to construct and can be positioned using standard lifting equipment.

The Norris hydro plant had been in operation for nearly 60 years without dewatering equipment for the draft tubes. But modernization of the plant could not be accomplished without dewatering. Shown in Figure 1 is the initial installation of one of the new draft tube gates supported by the overhead traveling gantry crane connected by the lifting beam. The overhead gantry and crane rail girder is shown in Figure 2 while undergoing load testing. Other system components included in the design but not shown are the dewatering pumps, draft tube gate guides, and seal bearing plates.

Figure 2: Norris Dam – Anderson/Campbell County, TN

Difficulties have been experienced while lifting draft tube gates with a height to width aspect ratio of less than 1.0 from a central lift point. Gates of this configuration have an increased potential to tilt and bind in the gate slots while lifting. Providing two lift points one at each end of the gate or using a lifting frame assembly can alleviate this issue. The lifting assembly above includes a lifting beam, crane hook, hook lift points on the gate, and a gate dogging device for supporting the gate when not being utilized.

2.2 State of the Art Technology

The primary technological advances for draft tube gates are in the areas of the seals and corrosion protection of the steel. Seal geometry and means of attachment to the gate can be selected so that the seal is not susceptible to being rolled over due to the velocity of the water past the seal, or due to wedging of debris between the seal and the sealing surface. The double stem top seal, shown in Figure 3, is highly desirable due to its geometrical stability and ability to resist rolling over due to water velocity past the seal. Concrete and steel surfaces must be smooth, burr and rust free to prevent wear and damage to the seals. For steel sealing surfaces, a stainless steel overlay or cladding can be utilized to provide the seal with an unpitted and rust free sliding surface. An important advancement in draft tube gate design and fabrication in the past 40 years has been the use of rubber gate seals with a J-bulb or music note shape (See Figure 4). This advanced seal design allows for movement by using adjustable mounting attachments.

Figure 3: Solid Double Stem Seal

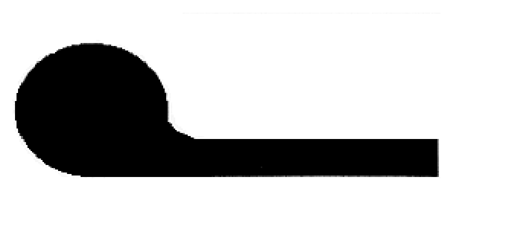

Figure 4: Solid J-Bulb Seal

3.0 Operation and Maintenance Practices

3.1 Condition Assessment

Conditions and problems associated with a draft tube gate, its guides, rails and seal plates, and crane can only be properly assessed if the various components are readily accessible. The draft tube gate assemblies spend most of their life cycle in storage rather than in service. The following are primary issues to be concerned with during a condition assessment of the draft tube gate assembly:

- Anomalies in gate slots in concrete piers
- Condition of seals, crane and lifting components, and electrical parts
- Debris jamming gates
- Corroded, bent, and damaged structural gate members and gate components

These common problem areas for draft tube gates can be assessed by a series of visual inspections to determine structural integrity, life expectancy, and necessary improvements. Prior to an assessment all maintenance records, previous inspection reports, and design drawings should be collected and reviewed. Each component should have a known physical condition and age from these supporting documents. This should assist in identifying existing problem areas as well as previous repairs.

These assessments will primarily be performed by visual examination and physical measurements for gates that are normally stored out of their slots and are readily accessible. For gates that are normally stored underwater in confined slots and are not visually accessible, it is necessary to temporarily pull the gates out of the slots so that they can be thoroughly inspected. Gate guides are normally underwater and will need to be inspected by a combination of divers and Remote Operated Vehicle (ROV) equipment. The determining factors of which underwater inspection method to utilize will depend greatly on the plant specific dewatering capabilities and required data collection. When a visual inspection is all that is required an ROV will typically be the most practical option. For this the ROV should be equipped with a lighting system and high quality video with an engineer present to direct the underwater observations and note areas of concern for either immediate closer viewing or for future inspection using a diver [3]. A disadvantage of the use of an ROV may be its limitation in turbid water due to poor visibility [4]. Diver disadvantages include regulations that restrict the allowable depths and durations of dives, the number of repeat dives in a given period, and limitations in cold climates [5]. Other difficulties encountered when using divers is the plant must shutdown the unit being inspected as well as the adjacent units.

The alkali chemical reactions caused by the chemistry between the water and some specific high alkali aggregates in the concrete can result in aggregate growth leading to concrete expansion. This occurrence is commonly known as Alkali-Aggregate Reaction (AAR). AAR can cause the gate to bind due to the reduction of gate opening and misalignment of the original opening with the gate geometry. Another cause of gate slot irregularities are local deterioration and spalling of the concrete that can lead to the pier slots geometry being out of tolerance with the gate. Exact measurements using calibrated instruments are an essential part of evaluating the concrete slots during the visual inspection. Therefore, gate slots and concrete piers that form the openings require access by divers to perform a thorough condition assessment. When using a diver, this person should be equipped with lighting, voice communication, and an audio/video camera. Communication should be arranged so that the engineer supervising the inspection can view and be in direct contact with the diver. This ensures all required measurements and information are obtained.

Seals become damaged mainly due to excessive wear and environmentally caused deterioration (debris/flow past the seal). Also, over time the seal material will oxidize and become brittle making the seals more susceptible to damage. The visual inspection should carefully check for any debris trapped between the seal and the sealing surface. Seals can also be damaged by rolling over during gate lifting. The condition of the seal should be carefully documented, being sure to note any cracks, chips, or disfigurement.

The crane condition assessment should include the crane and all of the associated components. A mobile gantry crane typically utilizes a lifting beam to raise and lower the sectioned or un-sectioned draft tube gates into the gate slots. Common problems associated with the lifting beam include floating debris blocking the gate's lift lugs and malfunction of the lifting beam sheaves or lift lug engagement device. If applicable, moving parts should be properly lubricated, gearbox oil is free of contaminants/moisture, gears and bearings do not have excessive wear, and hoist ropes have no broken strands or deformation. When examining the rope it is important to evaluate the entire length especially the underside that contacts the drum or sheaves. Typically visual inspection of the rope is sufficient, however if the integrity or serviceability is in question for a critical application a non-destructive test method called magnetic flux leakage (MFL) is available. This MFL testing may be performed for further evaluation or the rope simply be replaced based on the associated cost and feasibility. The gearbox inspection should confirm that all items are properly lubricated and that water has not contaminated any oil reservoirs. Operate the mechanism at full operation cycle and all operating speeds. Abnormal sounds and vibrations coming from the gearbox may be indications of internal problems. If abnormal sounds or vibrations are observed, further internal inspection should be performed. [2]

Bent and damaged gate members could cause twisting of the gate, resulting in the gate not being lifted smoothly. The assessment should visually inspect for warped flanges of wide-flange and channel steel members, misaligned or partially loose exterior plates, loose bolts or rivets, other localized defects such as weld cracks and gouges, and signs of structural overstress (i.e., excessive deflections). Note the functionality of all gate components such as wheels and rollers and verify that they are properly lubricated.

Protective coatings are essential in ensuring the longevity of draft tube gates and preventing corrosion; therefore, condition assessments should include coating inspection. Some evidence of coating failure can include discoloration, peeling or flaking, blistering, voids, cracking, and fading. The Society for Protective Coatings (SSPC) has established guidelines and certification for protective coating inspections. It is recommended that these guidelines by consulted prior to condition assessment. Ideally, the coating inspection should be performed by a SSPC certified contractor/inspector.

The carbon steel used for construction of these gates will frequently corrode due to the aggressive environment experienced during storage or submerged conditions. This corrosion can range from minor surface rust to significant cross-section loss. The minor surface rust can cause an abrasive and uneven sealing surface leading to degradation of the seals and leakage.

3.2 Operations

The draft tube gate functions during plant maintenance and dewatering activities, and is typically stored in a site yard during plant operations. Therefore, draft tube gates are not subjected to operational conditions. Problems associated with their functionality during these maintenance and dewatering periods will be discussed in detail in the following section on Maintenance.

3.3 Maintenance

Opportunities to improve draft tube gate performance involves properly diagnosing any of the common problems noted above in the Condition Assessment section, determining the apparent or root cause, and applying the most appropriate cost effective repair. It is imperative that the required maintenance be performed on the gates and the associated equipment. Consistently, performing the recommended maintenance on the appropriate schedule will extend the life of the component and help avoid unnecessary costs encountered due to emergency repairs and lost revenue during extended outages.

Problems with concrete openings not allowing the gates to be inserted properly are often due to the expansive nature of the concrete and any long term deterioration that reduces the clear opening leading to gate binding. There are a few methods for alleviating this condition including cutting back or trimming the concrete slots so as to enlarge the opening, trimming the edges of the gates to restore proper clearance, and fabricating a new gate that allows for some width adjustments. If concrete spalling is causing sealing difficulties because of significant surface roughness and pitting, an epoxy concrete or cementitious repair mortar may be used to restore the damaged surface.

Inadequate maintenance of seals and hoisting mechanisms can lead to several problems such as seal damage/rolling, unequal hoisting chain length and loading, and motor overload. When a gate is being lifted, seals can roll over and wedge the gate between the sealing surfaces, thereby damaging the seal and increasing the lifting loads to be overcome by the hoist. The corrective action involves replacing the gate seals and redesigning the means used to attach the seal to the gate, or using reconfigured seal geometry. Most seals at today's hydropower plants are made of rubber and can become worn or damaged over extended time periods of use. Worn or damaged seals can cause excessive leakage which results not only in loss of water, but can also lead to erosion of the concrete surfaces. Replacing the seals with the current bulb type, which are adjustable, provides more allowance for movement in the seal and provides capability to resist water pressures from either side. If excessive seal to guide friction is causing problems, this can be mitigated by providing fluorocarbon cladding to the seal bulb. J-bulb seals work best when allowed to deflect rather than compressing the bulb against the sealing surface.

Motor overload results from a non-uniform torque transfer into the hoist's gearbox. Overload causes include motor undersizing, additional frictional or resisting gate loads, drive shaft misalignment, and deterioration of the motor windings. Solutions include replacing the motor, diagnosing the workings of the hoist machinery and replacing any defective parts such as drive shafts, reduction gears, bearings and drive train. If the problem cannot be shown to be directly related to the condition of the hoist, assess the gate to determine the cause of the additional loads that the hoist must lift.

Other issues to look for at regular maintenance periods include debris that is jamming gates and deformed/damaged gate structural members. Debris can readily get stuck between the gate and support piers or guides, causing binding of the gate. A common solution is to modify the gate to prevent debris from becoming wedged between the gate and gate supports. Modifications may include extending plates from the upstream side of the gate to reduce the width of the gap between the gate and the support piers or guides.

The expected lifespan of chains and lifting hardware is highly variable but can also be as low as 15 years particularly for portions that are exposed to fluctuating wet and dry cycles such as near the waterline. Gate rubber seal and paint service lives are approximately 20 to 25 years. For the steel parts (plates, structural shapes, bolts, welds, etc.) used for the draft tube gate assembly, 75 years is a reasonable service life when the proper attention is given to the initial surface coating/protection and regularly scheduled preventative maintenance. Often after 75 years of service, the area of the gate most in need of major repair or replacement is around the perimeter of the gate adjacent to the gate seals.

Bent and damaged gate structural members (i.e., steel wide flange and channel shapes) can lead to warping of the gate, resulting in the gate not being lifted smoothly. The only viable solution is to inspect the gate regularly, and remove and replace the damaged members as necessary. If welds between steel members and plates look visually flawed, ultrasonic testing can be performed to determine if the weld needs to be reconstructed.

The damage caused by minor corrosion can be limited with minor preventative maintenance such as coatings. If significant section loss is present due to corrosion, complete or partial replacement may be justified for gate members and its associated components.

4.0 Metrics, Monitoring and Analysis

4.1 Measures of Performance, Condition, and Reliability

For draft tube gates the measure for performance will be a direct result of its functionality. The purpose of these gates is to protect and keep water away from the required portions of the hydropower plant during dewatered maintenance and repairs. It is important that these gates function properly not necessarily for efficiency but for safety since failure can have dire consequences. Leakage of these gates can be tolerated as long as safety and equipment protection are not compromised. The leakage around the gate seals should be in the order of 0.01 gallons/minute per foot of wetted perimeter for rubber seals. For metal on metal seals the allowable rate of leakage is 0.1 gallons/minute per foot of wetted perimeter. [1]

4.2 Data Analysis

Leakage of these gates can be tolerated as long as equipment protection and safety are not compromised. Relatively small amounts of leakage can be tolerated and handled by pumping water out of areas maintenance will be performed. However, if pumping becomes excessive the cost of new seals, repair of gate guide seal mating surfaces, or other corrective actions may be justified.

4.3 Integrated Improvements

The field test results for leakage should be included when updating the plant's unit performance records. These records shall be made available to all involved personnel and distributed accordingly for upcoming inspections.

5.0 Information Sources:

Baseline Knowledge:

1. American Society of Civil Engineers, Civil Works for Hydroelectric Facilities: *Guidelines for Life Extension and Upgrade*, 2007.

2. US Army Corps of Engineers, *Hydro Plant Risk Assessment Guide*, Appendices E9 and E11, September 2006.

3. HCI Publication Paper No. 072, Aging Plants – Time for a Physical: Conducting a Comprehensive Condition Assessment and the Issues Identified, HydroVision 2008.

4. Bureau of Reclamation, McStraw, Bill, *Inspection of Steel Penstocks and Pressure Conduits,* Facilities Instructions, Standards, and Techniques, Volume 2-8, September 1996.

5. US Army Corps of Engineers, *Evaluation and Repair of Concrete Structures,* Engineering and Design, EM 1110-2-2002, 30 June 1995.

6. *Hydro Life Extension Modernization Guides: Volume 1 – Overall Process,* EPRI, Palo Alto, CA: 1999. TR-112350-V1.

It should be noted by the user that this document is intended only as a guide. Statements are of a general nature and therefore do not take into account special situations that can differ significantly from those discussed in this document.

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