HYDRO REVIEW®

Underwater Work

Achieving Temporary Bulkheading Using ROVs

Three case studies show how remotely operated vehicles can be used to achieve isolation of gates and valves at high-head dams. In each case, the unmanned machines provided an effective method for keeping divers out of harm's way while achieving the needed repairs.

By Dave Malak

Underwater portions of dams that impound water for hydroelectric facilities present a number of challenges when it comes to operations and maintenance. Until the 1980s, when the first commercially available remotely operated vehicles started to come into use, the only options for inspecting or maintaining these parts of dams were to dewater them or to use commercial divers where safe and possible.

As time passed, underwater operations and maintenance tasks at many facilities became larger in scope because of aging infrastructure. With the significant investment required to build a new hydro plant, companies generally consider all possible avenues to extend the lifespan of existing assets. And while repairs to some of the assets are routine operations, the portions of the facility that are underwater or under pressure are often more difficult to fix. Because these underwater assets are critical to the ability to generate power, control flow, address associated environmental concerns (including fisheries and recreation), and maintain profitability, maintenance can often cause outage times or other undesired effects.

This brings into focus one of the more difficult issues some high-head dams are facing today: the approach surrounding the replacement or refurbishment of internal gates and valves.

An overview of the challenges

These gates and valves usually function as turbine shut-off mechanisms to control flow through diversion tunnels or lower outlets. Often, these gates and valves have no upstream isolation, such as another head gate or valve, which would allow for their repair. This means they are counted on as a single point of control for the flow through the dam's pressure piping. As this equipment ages, it can become stuck and lose functionality. The difficulty in replacing this equipment is that it is critical to the proper function of the dam, is under great pressure and is often difficult to access.

In the past, the only options to replace these valves or gates were to dewater the dam or take the risk of working on live pipes under pressure. While dewatering is effective in terms of allowing a specific repair to be made, it can be a lengthy and expensive process due to the outage times required and/or the requirement to build a coffer dam. In addition, dewatering places stress on the penstock, head race tunnel and pressure tunnel. Without the support of hydrostatic pressure inside the pipe and tunnel, the relative hydrostatic pressure outside the structure can increase the risk of collapsing the tunnels or penstocks. The hydrostatic pressure can be reduced over time, but it may require long outages to reduce the pressure slowly. Because of these factors, dewatering is often a method of last resort, as is working on the pipes under pressure. Working under pressure can be dangerous to both the workers involved and the facility itself.

To avoid dewatering at hydro facilities, many repairs can be accomplished by using experienced commercial dive teams equipped with the latest in underwater tooling. These teams can work effectively, particularly in lower head situations, and can perform many maintenance operations. But in terms of many of these

Dave Malak is director of marketing and senior project engineer for Hibbard Inshore LLC.

underwater gates and valves, the use of commercial dive teams can become costly and dangerous due to a combination of the high head pressure and confined nature of the location of the tunnels and pipes.

Hibbard Inshore has worked with its customers to develop a solution that addresses these issues — using ROVs to insert temporary mechanical bulkhead plugs. These plugs are built to the specific dimensions of the pressure piping; have multiple seals for redundancy and safety purposes, can be inserted into the upstream, underwater side of the piping using an ROV, can be monitored continuously throughout the project from the water surface, and can be removed at the conclusion of the project. These plugs allow a seal to be made on the upstream side of the piping that will allow just the section of piping downstream from the plug to be dewatered permitting replacement of the valve or gate. The reservoir can retain normal levels of water keeping community impact, environmental concerns and the cost of the waiting for the reservoir to refill naturally to a minimum. This is a tremendous savings in time and cost over dewatering the entire intake structure, and it can be accomplished without putting people in harm's way.

This article provides three case studies and details how an ROV solution was able to address each.

Remotely operated vehicles can be used to perform many tasks at hydroelectric facilities, including inspecting gate valve guides.

A tight squeeze

The first example is a dam in the western U.S. with more than 600 feet of head pressure and two 72-inch-diameter pressure pipes. The dam is primarily a flood control dam with a secondary purpose of generating electricity. The valves had been in service for many years and required replacement or significant service. At this dam, the pressure piping that needed to be plugged for valve replacement was about 1,700 feet into a diversion tunnel. The diversion tunnel had an intake structure on the bottom of the reservoir at about 675 feet of depth, and the intake structure had a trashrack made of concrete with steel reinforcements that could not be removed without cutting.

Based on previous bathymetric surveys taken from the surface by the project owner, it was expected that the intake would almost entirely be covered with sediment. Hibbard Inshore worked with the customer to discuss options for achieving access to this valve, including all the methods discussed above. The project owner concluded that with the confined space and concern regarding diver safety, an unmanned method of placing a plug needed to be used. Hibbard Inshore and the project owner determined a viable alternative would be to place a temporary plug using an ROV. However, before this work could proceed, the customer requested an initial inspection to determine the proper bulkhead design and to propose any necessary sediment removal, along with a method to remove and replace a section of trashrack to allow access.

Because of the level of error inherent to the previously performed bathymetric survey, Hibbard Inshore used an ROV that could fit between the 12-inch vertical gap of the trashrack beams while also having the capability of carrying video cameras, two-dimensional sonar, three-dimensional sonar, and an ultrasonic thickness sensor. In addition, a special tool skid would be built to transport the 3D sonar unit through this gap. The 3D sonar uses similar principles as the 2D sonar but is able to create more complete images of complex shapes. Because of its size and power, Hibbard Inshore chose a modified Seabotix LBV600-6 ROV to accomplish this task.

Due to the length of the tunnel, other challenges were the hazards encountered that can cause the ROV tether to get caught at the trashrack. Hibbard Inshore was able to use another of its ROVs, the Sub AtlanticTM Navajo, to keep the tether away from those hazards.

Bringing an ROV able to swim through the trashrack bars was a good decision. When the ROV descended to depth, it revealed that the primary intake was sufficiently uncovered to allow the ROV to enter the tunnel multiple times for each aspect of the inspection. The 2D sonar, 3D sonar and ultrasonic thickness measurements were performed in separate penetrations. The ROV travelled the 1,700 feet to the pressure piping, where the ROV operator was able to determine that each conduit could be plugged. Video images of the surfaces to be sealed, surrounding concrete and steel were used in conjunction with sonar measurements and ultrasonic thickness measurements to accurately determine the condition of the structures and accuracy of drawings. With this data in hand, Hibbard Inshore and the project owner determined that both pipes should be plugged concurrently to minimize risks to each pipe from the other during the valve replacement, and two bulkheads would be manufactured. This inspection gave the customer the data needed to move to the construction phase of the project.

The timing of the construction phase is being planned.

Managing the unexpected

The second example of this procedure is a dam in Puerto Rico that impounds water for a hydroelectric plant. This dam had more than 600 feet of head pressure and two 42-inch-diameter pressure pipes. The valves needed to be replaced due to age and are part of a more extensive powerhouse upgrade. The owner wanted to run one of the two units while the valve for the other unit was being replaced. The project was ultimately separated into discovery and bulkhead placement phases.

During this work, the main considerations were that the plug had to stand up to pressures caused by operation of the adjacent penstock, and the two penstocks to be bulkheaded were more than 900 feet downstream from the closest access point at the surge shaft.

Again, an initial condition assessment was performed using video, dual 2D sonar units and a 3D sonar unit. During this inspection, it was discovered that at the point of bifurcation of the tunnel into the two penstocks, there was a divider post that was not shown on as-built drawings. This divider post caused a narrowing of the tunnel on each side of the post to 40 inches while the conical mouth of each penstock further downstream was 57 inches, necking down to 45 inches.

The data collected by the ROV showed that the due to the dividing pillar, the bulkhead could not be installed perpendicular. In this case, not only was the inspection important to determine sizing for the bulkhead, it was also essential in establishing the bulkhead design and insertion method. As a result, a bulkhead was designed that could be rotated 90 degrees by the ROV to enable it to fit past the 40-inch tapered area. The bulkheads have been designed and manufactured. Once dredging and other underwater site preparation work is completed, bulkhead placement will begin.

Converting a dam for power generation

The final example is a dam in Spain that is used for irrigation and water supply. The dam has 185 feet of head pressure and was built with two intakes fed through a concrete structure on the upstream face, leading around a 90-degree bend and into two sections of 2-meter-diameter steel-lined concrete pipe. The dam owner saw the opportunity to convert this dam to allow for hydroelectric generation by using the existing structure and intake piping. These pipes were lower outlets that would be used as penstocks. The pipes are conical at their mouths and neck down to a 2-meter diameter.

However, the owner realized the existing valves were not operational and thus must be replaced. The owner concluded that because the intake pipes were in a confined area and diver safety was a concern, an unmanned method was needed, which meant using an ROV.

Once it was decided that ROV use was viable, attention turned to looking at conditions in the intake, as it had not been examined in many years. This meant determining if sediment and debris needed to be removed for the plugging; establishing dimensions of each pipe to allow for the plug design; determining if there was any variance from as-built drawings; and determining if the structures could withstand the change in pressures that would occur during the plugging of one or both pipes.

The project would be split into two phases. The first phase would be to confirm the viability of plugging by using an ROV to examine the structure. Data would be gathered to complete the design and manufacture of the plug and to help engineers decide whether one or two plugs would be used. The second phase would involve debris removal necessary for the plug insertion, along with inserting and monitoring the plug to ensure a proper seal during the valve replacement. This was also a cost-effective approach as the initial inspections could be conducted using a small ROV (a Sub-Atlantic Navajo), and the bulkhead insertion would require a larger, more costly ROV for power purposes (a Sub-Atlantic Mohican).

To address concerns that pressure changes might wrinkle or collapse the pipelines if the structure was degraded and that the bulkhead plug would not have a single point of failure, Hibbard Inshore brought a small inspection-class ROV with a variety of tools. In addition to standard video, dual sonar units were added to the vehicle to allow it to navigate and dimension in the forward-looking direction and to take cross-sectional profiles once in the intake. In addition, the vehicle was outfitted with a 3D sonar unit so that accurate computer-assisted design models could be made.

The final sensor used with the ROV was an ultrasonic thickness sensor to confirm the steel thickness of each pipe so that engineers could determine whether the steel was suitable to withstand the forces generated by a partial dewatering. If the steel had corroded too much, the pipes could buckle or collapse during the sealing and dewatering process. In addition to the sensors, the ROV was outfitted to guide dredging equipment and carry a jetting nozzle in case the intake was full of sediment. This decision proved a good one, as about 50% of each pipe was filled.

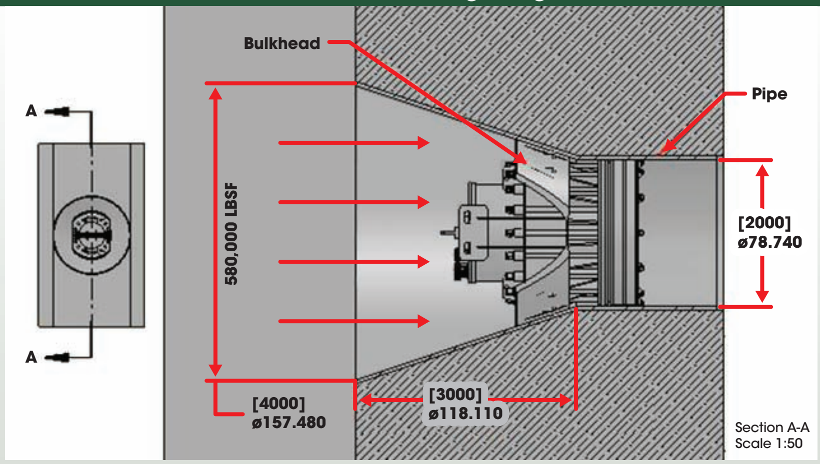
Once the 3D sonar measurements and visual inspection were complete,

Modifications such as the installation of multiple sensors can extend the range of use of remotely operated vehicles.

it was determined that a single, conical-shaped bulkhead would be placed in one pipe (see Figure 1). It would provide triple redundant sealing, give the ability to monitor pressure and be inserted and removed solely by an ROV. The bulkhead would be inserted in one of the pipes and the valve replaced. Then the bulkhead would be removed, its seals would be replaced, and the bulkhead would be inserted in the second pipe.

The inspection and planning phase of the project is complete, and the construction phase is awaiting scheduling.

FIGURE 1 Conical Plug Design



This conical bulkhead plug design can be used for sealing pipes at hydro plants and is designed to be inserted and removed solely by a remotely operated vehicle.

Conclusion

The lesson found in these projects is that for dam owners looking to evaluate replacement of gates or valves, using a properly outfitted ROV and ROV-installed bulkhead is a solution that can shorten project duration, reduce costs and improve safety. These methods are particularly useful for dams with higher head, long dewater schedules, large reservoirs requiring multiple seasons to refill and reservoirs that would affect navigation with low water. ■

Hibbard Inshore

Dave Malak
Director of Marketing and Senior Project Engineer
Hibbard Inshore, LLC.
Cell +248.891.5019
Office +248.745.8456 x.13
Fax +248.745.4958
Dave.Malak@hibbardinshore.com

www.hibbardinshore.com