On-Site

Innovation, cooperation, and courage brings Cheesman Dam into the 21st century

Location: Approximately 95 miles southwest of Denver, Colorado, on the South Platte River
Owner: Denver Water
(www.denverwater.org)

Date of Construction: 1905
Elevation: 6,842'
Dam Height: 221'
Impoundment: 79,064 acre feet
Project overview
Denver Water conceived of the renovation project in two distinct phases:

**Phase One:** The initial phase involved the installation of slide gates and control systems on the upstream end of three outlet tunnels (see diagram on page 4).

**Phase Two:** With the new slide gates safely controlling the outlets upstream, the tunnels could be dewatered, allowing for the removal of old gates and equipment, and the installation of a new jet flow valve upstream from the Auxiliary Outlet [AA].

The Hayman Fire
The Hayman Fire was a forest fire that started 95 miles (153 km) southwest of Denver, Colorado and 35 miles (56 km) northwest of Colorado Springs on June 8, 2002, and became the largest fire in the state’s recorded history. Hundreds of forestry officials and firefighters fought the fast-moving inferno, which caused nearly $40 million in damages, burned 133 homes and forced the evacuation of 5,340 people. The fire wasn’t contained until July 2, 2002 and was finally brought under control on July 18, 2002. The cause of the wildfire was found to be arson by a forest service employee.

The renovation of the Cheesman Dam, completed in 2012, was a multi-year, many-phased project that started with the identification of several key issues:

- **The aging outlet water system.** While the outlet works were renovated in 1971, the tunnels in the dam were “original” — with valves and other infrastructure exceeding 100 years of service. (Explore a bit of Cheesman’s history on page 8–9.)

- **Maintaining a viable water supply.** The Dam is part of Denver Water’s South Platte Collection System, from which over 1 million people in the Denver metropolitan area rely for water. It was imperative that the reservoir and dam remain fully functional.

- **Sediment load.** The Hayman Fire (see box, above left) had not yet affected operations, but could become a problem in the future.

- **Looking ahead.** If future maintenance operations were to be possible, upstream control of the outlet works was essential.
Owner: Denver Water

Denver Water is Colorado’s oldest and largest water utility, serving the city of Denver and many surrounding suburbs. Established in 1918, Denver Water is a public agency funded through water rates and new tap fees, not taxes. It currently serves over 1.3 million people.

The Cheesman Dam and Cheesman Reservoir — essential parts of the city’s water supply — needed some upgrades — including upstream water control.

Denver Water engineers had been concerned for many years. Without upstream control (i.e. new gates), a failure of the aging infrastructure could cause an uncontrolled release of water.

“If we had an issue at Cheesman,” said Jeff Martin, Project Manager and Dam Safety Engineer with Denver Water, “it would create a lot of headaches.”

Planning for the renovation project began in early 2006, and the area surrounding the dam and reservoir has been closed to visitors since January 1, 2010, when construction work commenced.

“Completing this project is vital to maintaining dam safety, providing a viable water supply, and ensuring smooth operations,” said Tom Roode, Director of Operations and Maintenance at Denver Water. “Cheesman is more than 100 years old, and the underwater valves [controlling the outlet] were installed in 1905 and the late 1920s!”

Site overview

The outlet work system (see diagram on page 4–5), consists of three tunnels bored through the abutment at three different levels. They are named, in order of elevation: the Auxiliary Outlet [A], the Mid-Level Outlet [B], and the Low-Level Outlet [C]. A fourth outlet was originally constructed between the Auxiliary Outlet and Mid-Level Outlet, but was later abandoned and filled with a concrete plug.

The Mid-Level Outlet tunnel joins the Low-Level Outlet tunnel to become the Primary Outlet Works [D]. Prior to this project, the Primary Outlet Works system was controlled by six 42-inch gate valves [E] located upstream of the tunnel intersections.

Construction of a downstream valvehouse in 1971 included a series of cone and free-discharge valves that provides additional control of the Primary Outlet Works.
Underwater or conventional construction?
When considering how to go about Phase One of the project, Denver Water considered two options:

- **Underwater Installation.** This method — pioneered by SEABEE divers in the 1960s and 1970s and today a global industry — would mean that installation of the new slide gates would be performed by professional divers.

- **Dewatering the Reservoir.** This would allow installing the new upstream slide gates through conventional construction and installation methods.

A thorough cost-benefit analysis was performed, and included the impact that dewatering the reservoir would have on rest of the South Platte Collection System. There was a significant risk that the reservoir would not be refilled in a single runoff season, and this would potentially raise serious supply issues.

Denver Water also considered partial dewatering, to allow for conventional construction on the Auxiliary Outlet [A] and the Mid-Level Outlet [B], and underwater installation only at the Low-Level Outlet [C].

On paper, dewatering the reservoir to allow for conventional installation of the gates was cheaper — 20 to 30 percent less than underwater installation. But the analysis also revealed that conventional installation could have significant consequences for the 1.3 million people who depended on this system for their drinking water. If Cheesman was dewatered to allow construction and installation of new equipment, there could be a significant risk of storage shortfall.

Denver Water decided that the storage shortfall risk was too great, and the increased cost of underwater installation was well worth it.

Assembling partners
Rodney Hunt engineers worked with Denver Water engineers at the earliest stages of the project, and established equipment design parameters long before the installation method was finalized.

The firm awarded the underwater installation contract was Global Diving & Salvage, Inc., a Seattle-based firm specializing in underwater construction work of this kind.

Rodney Hunt was awarded the contract for manufacturing the spool inserts and slide gates to be installed at each outlet tunnel entrance [A, B, and C] and the jet flow valve to be installed at the Auxiliary Outlet [AA] — along with all associated actuation equipment. See page 11 and 12 for a complete description of the slide gates and jet flow valve now installed at Cheesman Dam.

“All of these key partners worked together throughout the project,” said Jeff Archer, a Mechanical Project Engineer at Denver Water. “The communication between everyone was exemplary, which created a strong collaborative atmosphere that was essential to success.”
Getting underway...underwater

The underwater gate installation operations utilized two distinct diving techniques:

- **Surface Diving**
- **Saturation Diving**

All underwater work was based on an 80’ x 80’ floating barge, constructed in sections specifically for this project (see photo at right). The barge included a four-point mooring system and a 35-ton RT crane.

All equipment—including the large floating barge “sections” that were assembled on site—were hauled up over three miles of forest service road to reach the site. This access road is very narrow and winding, and some parts of the road needed to be re-engineered to make it passable for large trucks and equipment.

At the Auxiliary Outlet [A], at a depth of around 40’, diving work was done through conventional surface diving, using Nitrox (oxygen enriched air) to increase the time that divers could remain at the work site. When work was completed at the Auxiliary Outlet, the surface diving station was removed from the barge and replaced with saturation diving equipment. This included a pressurized “living chamber” for divers, where they could live at a pressure equal to the depth where they were working, and transit easily and safely to-and-from the work site via a diving bell.

Site preparation and gate installation at the Mid-Level Outlet and Low-Level Outlet [B and C] was accomplished through saturation diving.

Living under pressure

Saturation diving is a method that allows divers to work for unlimited bottom times at depths greater than 33 fsw (feet of seawater) without undergoing decompression. Decompression is not eliminated, but delayed.

Divers worked 10-hour shifts—five hours in the water, and 5 hours in the diving bell—for up to 25 days in a row before decompression. Divers lived, between shifts, in a pressurized...
chamber on the deck of the barge. They transited to and from the pressurized “living chamber” to the work site via a diving bell (see photo below).

When off duty in the pressurized living chamber, divers mostly slept, read, and watched movies. They also ate. “One of the only pleasures they have in there is eating, so we try to feed them well,” said Darryl Heath, a former diver who coordinates the diver’s cuisine. He sent steak, shrimp, spaghetti, cake, and other diver favorites through a special main-chamber opening, day and night, throughout the project.

Two diving teams worked 24 hours a day, 7 days a week, for 16 weeks to complete the slide gate installation work at the Mid- and Low-Level Outlet.

The underwater installation task

One important thing to remember when considering the boldness and courage involved in this project is that Denver Water engineers, at the outset, were relying on drawings and other specifications that were more than 100 years old. No one had seen the outlet openings since they were completed in 1905, and it wasn’t clear what preparatory work might need to be done to accommodate the slide gate installation. Some blasting work was anticipated, and indeed, was necessary.

At each of the three outlet tunnels, the existing opening was enlarged. Holes were drilled at predetermined locations, explosives placed, and a significant amount of rock was removed. This allowed the installation of the spool assembly (See Photo 5). Each spool assembly, fabricated by Rodney Hunt, was manufactured in stainless steel and ranged in weight from 24,000 to 35,000 pounds. The spool assembly creates a secure and seamless “face” necessary to install the new slide gates (See Photo 6), and each one was designed specifically for each level.

The spool assemblies were lowered into position by the RT crane on the barge, and pulled into position by divers. Once mechanically installed in the tunnel entrance, divers sealed the perimeter of the spool assembly on both ends, and the annular space around the assembly was filled with grout. After curing, holes were drilled in the surrounding rock, and anchors securely epoxied in place.

Then, each of the new Rodney Hunt slide gates was lowered into position, and affixed to the face of the spool assembly. The slide gates were designed to be attached with 52 or 72 bronze hex head bolts (depending on the size of the gate), secured to a flange on the front of the spool.

Additional underwater tasks included the installation of...
piping and other mechanisms necessary for hydraulic actuation, and trash rack installation to protect the entire gate and actuation assembly.

Dewatering the tunnels

Work on Phase Two (see page 3) of the Cheesman Dam project began after the completion of slide-gate installation, hydraulic control equipment installation, and testing.

Now, with slide gates securely closed at the upstream end of the outlet tunnels, these tunnels could be fully dewatered for inspection. No one had been able to see or inspect these tunnels since 1905! The plan was to remove all old equipment in these tunnels and also install a new jet flow valve at the Auxiliary Outlet.

Challenges

Unforeseen site conditions presented challenges before Phase 2 work could get underway.

Before dewatering could take place, the discovery of weak masonry at the mouth of the Low Level Tunnel [C] required an additional excavation to secure bedrock. Also, the failure of one of the 42" gate valves (installed in 1899) at the Mid Level Tunnel [E] — on its last scheduled operation — made initial dewatering operations difficult. The underwater blasts associated with the additional rock removal at the Low Level Tunnel [C] also slightly damaged the existing steel pipe associated with control operations at the Primary Outlet Works [D].

“It took swift, critical thinking and problem-solving by all partners to successfully manage these unexpected issues,” said Jeff Archer at Denver Water.

Removal of old equipment

An important aspect of Phase 2 involved the removal of the six gate valves located in both the Mid-Level and Low-Level outlet tunnels. The opening left by the removal of this equipment has been sealed with new tunnel sleeves. Also, bulkheads have been installed at these locations for future access.

In addition to removal of old equipment, new platforms, handrails, and ladders have been installed in the “manways” (See photo at left), as well as a small tunnel air/fill line so that the upstream control gates can operate under balanced head conditions.

Continued on page 10
The historical context

By the late 1800s, access to water in many western areas of the United States had become a serious problem. In the Denver Colorado area, as in other rapidly expanding agricultural and cattle territories, ranchers were trying to feed and water their cattle, while growing urban areas needed an increasing amount of reliable water throughout the year.

It was also a time when the federal government — working with local businessmen, entrepreneurs, and politicians — played a crucial role in shaping water access policy, while also providing funding for implementing a range of water management projects that helped prepare and shape our nation for the challenges of the future.

When Cheesman Dam spilled for the first time on May 9, 1905, President Theodore Roosevelt had just completed a hunting tour of the West. Theodore Roosevelt’s policies, for better or worse, have helped shape our nation’s attitudes about conservation and environmentalism for over 100 years. He was also a pragmatist, and recognized the importance of industrial development.

So on May 9, 1905, President Theodore Roosevelt joined a range of Denver businessmen, politicians, and socialites at a banquet celebrating the completion of Cheesman Dam. Walter S. Cheesman and David H. Moffat — the two key business “entrepreneurs” in the Denver area at the time — were in attendance, and both were very involved in the development of water policy.

Like Roosevelt, Walter Cheesman and his colleagues saw their roles not as exploiters of nature but as builders and artists, creating an oasis on the High Plains. Looking at the dam, it is easy to see how it reflects this intention to shape — rather than to conquer — the environment. The native granite construction of the dam blends visually with the surrounding canyon. The spillway design lets water cascade down the abutting cliff rather than over the face of the dam. From the right angle of vision, it looks like a natural cascading waterfall.

Dam construction

The original plan was to build an earthen dam north and east of the present-day site. But in 1893, after Chief Engineer Charles P. Allen identified an ideal dam site in Platte Canyon, a much larger dam was envisioned and engineered.
The first design was a pure gravity dam: rubble protected by steel plates. Crews were assembled, and foundation work began in Platte Canyon in 1899. After a setback in 1900, when floodwaters destroyed much of the construction that has been completed to date, engineers redesigned the entire structure to incorporate both gravity and arch dam features. Although the curved surface was known to be stronger than a flat one, there were no mathematical models at the time to calculate its strength.

Another lesson from the flood was experiencing the sheer destructive power of rampaging water, and the new design employed Portland cement (see box at right) to solidify the fill. Although Portland cement had been gaining in popularity in Europe since the 1850s, it was not manufactured in the US until the 1870s, and was a relatively new technology when engineers were designing the Cheesman Dam. The use of Portland cement required the development of a complex transport system to get the material to the construction site, as well as developing on-site systems to monitor its mixing and placement. The result paid off, and when Cheesman Dam was completed it was immediately lauded as not only the highest dam in the world — at 200’ and impounding 79,000 acre-feet of water — but also as a model of strength and solidity.

Construction took five years, but Cheesman made its first contribution to Denver residents well before it was even completed. In July of 1902, during a severe drought, water was released from the incomplete dam to ease the water shortage.

In 1973, Cheesman Dam was designated a National Historic Civil Engineering Landmark by the American Society of Civil Engineers, and in October of 2005, the society held a second ceremony to reaffirm the honor.

According to the American Society of Civil Engineers:

Cheesman Dam is...of such historical significance and contemporary importance that it should never be forgotten, but placed side by side with other national and historical landmarks of the engineering profession.

Portland cement

In 1824, Joseph Aspdin, a bricklayer and mason in Leeds, England, took out a patent on a hydraulic cement that he called Portland cement because its color resembled the stone quarried on the Isle of Portland off the British coast. Aspdin’s method involved the careful proportioning of limestone and clay, pulverizing them, and burning the mixture into clinker, which was then ground into finished cement.
Jet Flow Valve installation

The installation of the new Jet Flow Valve at the Auxiliary Outlet [AA] involved removing the 62-inch Larner-Johnson Needle Valve (see photo above) that was installed in the 1920’s, and replacing it with a 60-inch Rodney Hunt Stainless Steel Jet Flow Valve.

The new Jet Flow Valve was installed in an existing tunnel, but closer to the water inlet to reduce objectionable spray and icing that had been associated with the operation of the Needle Valve. Although smaller in size, the hydraulic capacity of the Rodney Hunt Jet Flow Valve is greater than the Needle Valve it replaced.

The same hydraulic power unit that operates the three upstream Rodney Hunt slide gates will also operate the Jet Flow Valve.

Rodney Hunt…
On-site at Cheesman Dam!

Rodney Hunt manufactured the following components now installed at Cheesman Dam.

Slide Gate Spools
Size: Two 10’ long and one 15’ long
Weight: Two at @ 24,000 pounds and one at @ 35,000 pounds
Material: One piece, stainless Steel Type 304L, with 2” radius corners.

Slide Gates
Size: Two (2) 48” x 84” and One (1) 96” x 96”
Slide, Frame, Stiffeners, Yoke, Guide angles: Stainless Steel 304L ASTM A-276
Frame Seats: Mechanically attached bronze
Disc Seats: Stainless Steel 304L
Threaded stem, Stem guides: Stainless Steel Type 304L
Fasteners: Stainless Steel Type F593-316, Bronze B98 CA655
Thrust Nut: Bronze B584 CA865

Contact Rodney Hunt for additional specifications and safety features.
One of the three spooled inserts is prepped for underwater installation.

This 60" Jet Flow Valve, shown here just before leaving the factory, provides optimum control of the Auxiliary Outlet (AA) at Cheesman Dam.

Jet Flow Valve

Size: 60"
Flow: 30 cfs (minimum) 975 cfs (maximum)
Maximum Head: 60 feet
Weight: 30,000 pounds
Materials:
- Body: Stainless Steel, conforming to ASTM A516 grade 70
- Mounting flange: In accordance with AWWA C207 Class "D" with an O-ring gasket
- Gate: Interior sliding surface is bronze, with the gate constructed of Stainless Steel, conforming to ASTM A516, grade 70.

Actuation System

Overview: Single hydraulic power unit with dual integral pumps and motors, integral drift prevention accumulators and control valves. Integral NEMA 4X stainless steel HPU Control Panel.

Operating Speeds:
- 48” x 84” slide gates: 5.1” to 7.35” per minute (12 to 17.25 minutes for full stroke).
- 96” x 96” slide gate: 6.2” per minute (extending); 7.35” per minute (retracting). 13.6 to 16.1 minutes for full stroke.
- Jet Flow Valve: 9.0” per minute (opening); 7.6” per minute (closing).

Gate Cylinders: Field installed at up to 210 feet of water. To facilitate underwater installation, the hydraulic cylinders are equipped with factory-installed stainless steel ball valves at each cylinder port and with a bypass line connecting the rod and cap end lines outboard of the port-mounted ball valves. All ports on the hydraulic pumps and valves on the HPU are SAE O-ring type.

Interconnecting Piping: 8 lines of 1” x 0.148 wall tubing and Schedule 160 SS304 socket welded pipe

Hydraulic Fluid: Equipment designed for use with a pressurized hydraulic fluid for low temperature applications.

Operating Pressure: 2,850 PSI. Cylinders are sized to provide the thrust required under severe operating conditions at a nominal pressure of 2,600 PSI.
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Additional resources:


Global Diving, “Cheesman Dam: Upstream Control Project–Phase I”

Brad Friedman, “Underwater repairs to Cheesman Dam start today,” examiner.com

Lori Obert, “Divers head almost 200 feet under water for Cheesman Reservoir repairs,” 9news.com


For more information about Rodney Hunt products or to contact a sales representative, visit the Rodney Hunt website (www.rodneyhunt.com) or call 978-633-4362.