MODERNIZING CANAL CHECK STRUCTURES WITH BI-FOLD OVERSHOT GATES

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ABSTRACT

Modernization of canal check structures is an important step in improving canal operation and reducing operational spills. This paper is a case study of retrofitting existing manually operated concrete canal structures with automated bi-fold overshot gates on the Government Highline Canal in Grand Junction, Colorado.

INTRODUCTION

Grand Valley Project

The Government Highline Canal is part of the Bureau of Reclamation's Grand Valley Project, located in Grand Junction, Colorado. The canal construction was started in 1913 and completed during the Great Depression. The canal extends 52-miles from the diversion dam on the Colorado River flowing westward through the Grand Valley. Two Federal environmental programs spanning a 25 year period have had a dramatic impact on the modernization of the Highline Canal. This paper discusses the use of bi-fold overshot gates in modernizing four existing canal structures and a gate application in a new pumping plant.

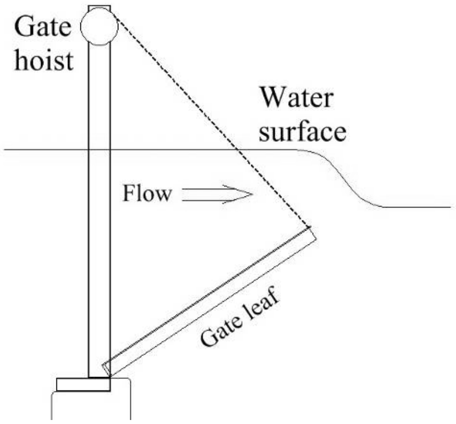

Figure1. Typical Overshot Gate

Overshot Canal Gates

The typical canal overshot gate, Figure 1, has a gate-leaf horizontally hinged near the bottom of the canal, with the gate-leaf extending downstream. Water flows over the gate-leaf, which acts as a horizontal weir. The gate actuator is a hoist mechanism that moves the downstream end of the leaf up and down, or in some designs an air bladder under the leaf is used to move the leaf.

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The bi-fold overshot gate, Figure 2, has a double leaf, horizontally hinged on the bottom frame and between the lower and upper leaf. The lower leaf extends upstream and is hinged to the upper leaf that folds over the top and is extending downstream. The hinged gate leaves form a horizontal upstream wedge, with the frame hinge and the top of the leaf crest nearly in a vertical line. Because the gate-leaf and hoist mechanism are upstream of the mounting hardware, the gate can be mounted on the vertical upstream face of an existing canal structure.

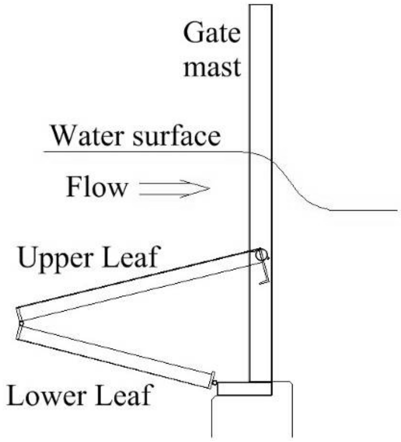

Figure 2. Bi-Fold Overshot Gate

Langemann Bi-Fold Gate

The bi-fold gates used on the Government Highline Canal were invented by Peter Langemann. The Langemann Gate and controller were developed as a cooperative effort between the St. Mary River Irrigation District in Alberta, Canada and Peter Langemann. The patented design is recognized and accepted for its simplicity, overshot technology, control capabilities, and low power requirements. Aqua Systems 2000 Inc. manufactures and sells the “Langemann Gate”.

Before embracing the technology for other applications within the irrigation project, the decision was made to install and test one Langemann Gate in an existing three bay stop-log structure, six miles from the river diversion. The stop-log structure had three 7-foot wide bays that create a fore-bay pool for a hydraulic pump penstock. Significant flow changes in the canal required adding or removing stop-logs in an attempt maintain a stable water surface level in the fore-bay. This type of control was difficult. The original check structure was made by forming four massive vertical concrete gussets that create the three 7-foot wide bays. To help install the stop-logs, the stop-log slots and gussets were sloped.

Modified Stop Log, Gate Installation

To provide a vertical surface to mount the Langemann gate, the center two gussets were cut to create two vertical columns. A short concrete stem-wall was doweled into the base of the concrete structure.

Figure 3. Gate Installed in Modified Stop Log Structure

The base frame sets on the stepped stem-wall and the mast channels are supported by vertical steel angle sections bolted to the inside of the outside concrete gussets. The completed installation has a 25-foot wide automated bi-fold overshot gate, mounted in a modified 90-year old three bay concrete stop-log structure. The assembled gate, Figure 3, was placed into the modified structure using a crane.

The gate functions as a vertically adjustable weir. The long horizontal gate-leaf slices through the canal current like a wing. The forces are somewhat balanced; the lower-leaf has an up lifting force that is countered by the downward force on the upper-leaf. With this "balanced" load it is possible to operate the gate hoist with a fractional-horsepower DC motor, which is powered by batteries. The batteries can be charged either by solar panels or an AC/DC battery charger. The total up-lift force on the gate frame and masts is a function of the differential head across the gate and the position of the gate leaf. With a small differential head across the gate, securing only the gate masts to the adjunct structure is sufficient to counteract the up-lift force. If a large differential head is present, the bottom frame needs to be anchored the structure foundation.

Gate automation is accomplished with a programmable logic controller (PLC). Standard control options for a Langemann Gates are upstream water level control and flow control. Aqua Systems 2000 description of there, "Original Level Control Algorithm" (Level & Flow Algorithms Notes, ©2007):

> "In general, the level control algorithm senses four increments of dead band on either side of the set point, and makes gate movements that are proportional to the amount of error and that reflect the hydraulic characteristics of the site.

> As the distance from the set point increases, successive gate moves become more aggressive. All corrective gate moves are delayed by a pre-determined control cycle time. The first three moves are initially one-shot, and are only repeated after a relatively long reset cycle time. The fourth move is repeated on a relatively short retry cycle time. Gate moves are made until the water level returns toward set point, or until the preset maximum or minimum gate position is reached."

The gate PLC, with its open architecture, can be easily programmed to run custom control algorithms. In addition, this gate was supplied with an optical encoder to determine gate position, rather than the typical potentiometer indicator.

The purpose of this installation was to maintain a constant upstream water surface level in the pump fore-bay. The gate performs well, running on the manufactures automation software, and the decision to install four addisional gates on the irrigation project was implemented.

Removing The Amil Gate / Stop Log Installation

The second site is six miles downstream from the first gate. This structure contained a Waterman D-450 Amil gate and six stop-log bays, three on each side, Figure 4. The purpose of this canal check was to change and maintain the upstream water surface in the canal to prevent upstream freeboard encroachment at high canal flows, and to allow upstream turnout deliveries to be made during low canal flows. Although the structure was built in the 1990's, it was poorly designed and did not work. The Amil gate performed as expected but it was not the correct type of gate for this application.

Figure 4. Amil Gate / Stop Log Structure

Amil gates have a trapezoidal gate-leaf and massive concrete buttresses. A large concrete saw was used to cut the buttresses from the floor of the structure. The Amil gate, the concrete buttresses, and one stop-log bay on each side of the buttresses were removed. A short concrete stem-wall was doweled into the floor of the check structure.

Figure 5. Langemann Gate Installed in Existing Structure

A 28-foot Langemann gate was installed in the open span, Figure 5. There is a small difference in water surface elevation across the gate-leaf, so that the hydrostatic pressures are nearly equal. Of the remaining stop-log bays, the two adjacent to the Langemann gate were fitted with manually operated electric sluices gates. These gates are open during high canal flows and closed during low flows. The outer most stop-log bays are only half the depth of the canal and the stop-logs are permanently in place. The automation at this canal check is accomplished by the Langemann gate algorithm, similar to the previous pump fore-bay Langemann gate.

Controlling the Siphon Inlet

The third gate was placed at the entrance of an 800 CFS siphon, crossing the Colorado River. The purpose of this installation was to maintain automated flow control and flow measurement into the siphon.

Over 1600 CFS is diverted into the Highline Canal at high demand. A bifurcation five miles downstream in the canal splits the flow approximately in half. Originally the bifurcation was controlled using two radial gates, with hand-crank gate hoists. One radial gate controls the Highline Canal and the other controled the siphon. The gate on the Highline Canal had been rebuilt recently, and as part of the canal modernization, it was upgraded with an automated electric hoist. This radial gate controls the upstream water level at the bifurcation. So, if a shortage occurs here, the siphon will continue to receive the target flow, the radial gate will close as much as is necessary to maintain the level, and the canal downstream of the radial gate will receive the shortage.

The Langemann gate in the entrance to the siphon is used to control flow. Aqua Systems 2000's "flow control" (Level & Flow Algorithms Notes, ©2007):

> "The algorithm can perform automatic flow control based on an operator adjustable flow set point. The flow control routine continuously monitors the head on the gate (H) and compares it to the desired head for the current gate flow set point (Q_{sp}). The gate flow set point is calculated by subtracting the current gate flow from the total system flow:
>
> $Q_{sp} =$ System flow set point – Current gate flow
>
> If the difference between the actual head and the desired head (error) is greater than the control dead band, the flow control cycle timer will start timing. If the error becomes less than the control dead band before the timer times out, then the timer stops timing and is reset. If the error is greater than the control dead band when the timer expires, the gate is adjusted based on the instantaneous head error."

The installation was similar to the previous Langemann gates, but flow conditions were different, Figure 6. The entrance water velocity is over 6-feet/second and the water freefalls over the gate-leaf into the throat of the siphon. Even though the bi-fold leaf balances the approach velocity head on the gate, the hydrostatic difference across the leaf causes the gate to want to float or lift.

Figure 6. Siphon Inlet Flow Control

To counteract this lift force, the bottom beam of the gate was securely anchored to the concrete stem-wall and the upstream side plates were bolted to the concrete side walls. The greater hydrostat force across the gate-leaf required high inrush current to the motor to start the gate moving. Because of increased the inrush current through the motor, the DC motor solenoids were replaced with a solid-state soft-start device. DC motor soft starters were installed on all five of the project gates, and are now standard equipment on Langemann gates.

One unexpected site improvement was a significant reduction in the trapped air belching back from the siphon inlet. The high velocity discharge under the old radial gate pulled air into the siphon. The water velocity over the Langemann gate-leaf is reduced and the energy is dissipated in the siphon intake. The gate at this site is presently operated in local hand mode. When the flow control performance has been field tested and the site tied into the SCADA radio network, it will be locally automated and remotely operated.

Side-Channel Spillway Control

The forth gate was placed downstream of an emergency siphon on a side-channel spillway from the canal, Figure 7. The purpose of this installation is to maintain an automated constant upstream water surface in the canal, and to measure the canal water operational spilled into Highline Lake, Figure 8. Historically a siphon would be started by a high water level in the canal and then break suction when the canal water level was drawn down ½-foot. With the Langemann gate installed in the spillway, the three sluice gates in the bottom of the canal are opened and the siphon is inoperative.

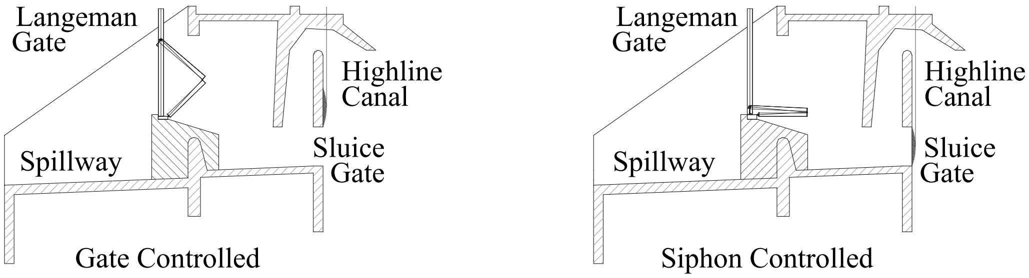

Figure 7. Side-Channel Spillway, Siphon & Gate

Figure 8. Highline Lake, Side-Channel Spillway

This Langemann gate has the same hydraulic control challenges as the gate at the bifurcation siphon inlet. The lake spill is 44-miles from the canal diversion point, and there are a series of 14 canal check structures upstream from the spill.

The canal checks are operated in upstream control mode, and the mismatches between canal diversion and irrigation deliveries are accumulated downstream at the Highline Lake spill. The Water Users' Association has "short-term storage arrangement" in Highline Lake. Operational spillage can be pumped up for use in the canal within 72 hours of the time that it spilled.

This gate is 13-feet wide and the spill flow ranges from 0 to 200 CFS. The gate must respond quickly to maintain the canal water surface level. Aqua Systems 2000 responded to this situation with "Fuzzy Logic" (Level & Flow Algorithms Notes, ©2007):

> "The main problem with the original Langemann level control algorithm is that its response is usually somewhat sluggish when dealing with rapid, large upsets in the upstream level. In a few applications, even a temporary drift from set point was unacceptable. In these cases, if the algorithm was tuned to be more aggressive for large errors, it could result in being too aggressive on small system upsets and system stability was compromised. Originally, this problem was addressed with a redundant emergency level control relay to immediately drive the gate in the correct direction if a dangerous upstream canal level appears. This concept was successful in most, but not all applications.

> Aqua Systems 2000 Inc. decided to undertake development of a new algorithm to achieve higher performance while maintaining stable operation. AS2I refers to this new algorithm as the ‘Fuzzy Logic’ level controller because the original intent was to start with a blank sheet of paper and develop an entirely new algorithm that followed formal Fuzzy Logic programming techniques. Through research and development, it was determined that the original Langemann algorithm has a great deal of merit, and already contained ‘fuzzy’ style elements. The result was to take some additional fuzzy logic concepts and apply them to the original algorithm to create a new high performance control algorithm that overcomes the pitfalls of the original design. The new algorithm probably does not truly qualify as ‘Fuzzy Logic’ in a strict academic sense; however it is very simple, reliable, and stable. In addition, it has fantastic set point holding power for both large and small system upsets, and is easier to tune than the original Langemann Algorithm.”

The Fuzzy Logic algorithm was used on the side-channel spillway gate to make the gate move aggressively. Events upstream from this gate have caused dramatic and rapid changes in canal flow. Even with the use of Fuzzy Logic, canal water level control has not been completely successful. Effort to tune the algorithm continue, but it is unknown if this control algorithm will be able to control the water level at this site.

Pump Station Debris Guard

The fifth gate was placed at the entrance of the Highline Lake pump back station, Figure 9. The pump station is operated to supplement canal supply during short-term increases irrigation demand or supply shortages. The purpose of this gate installation is to prevent debris from building up on the pump screens when the pumps are not running. A trash rake cleans the screens when the pumps are operation. A low water level in the canal will cause the Langemann gate in the spillway to rise and stop the spill. If the canal water level falls below the pump target level, the pump PLC will lower the pump station Langemann gate in front of the screens prior to starting the pump. When the pumps stop, the gate is raised to block debris from entering the screens.

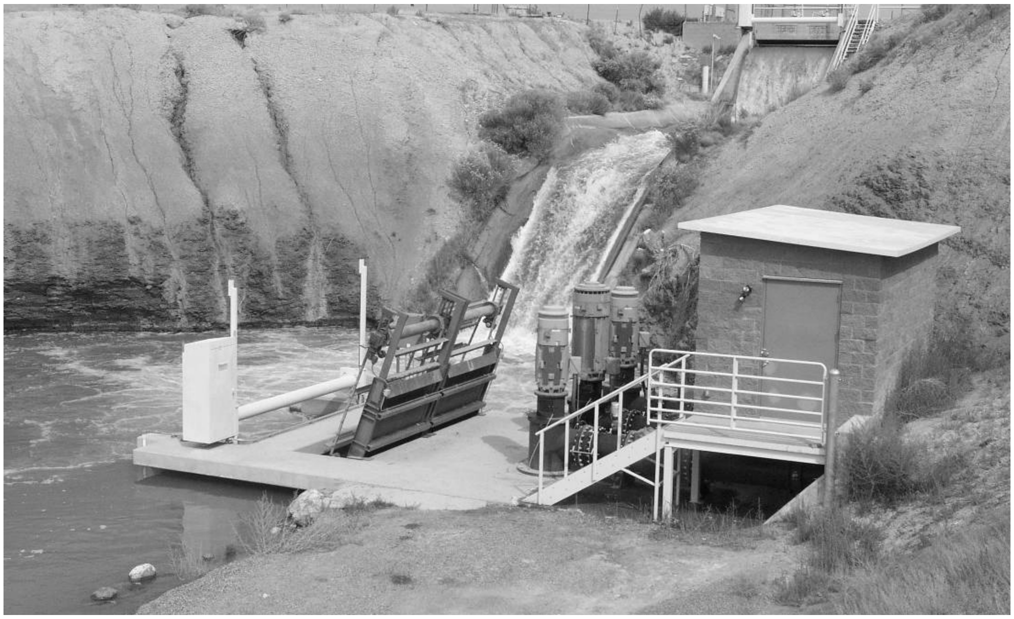

Figure 9. Langemann Debris Guard

CONCLUSIONS

Canal modernization, with bi-fold overshot gates was successful on the Highline Canal. The gates performed well in most water control applications. With more algorithm "tuning" control may meet system requirements at the remain sights. These gates are custom engineered for each site and designed with the water control feature desired by the user. With simple modification of existing structures or simple design of new structures, the bi-fold design is extremely cost effective. The low power requirement and the minimal concrete work needed for installations, makes the Langemann gate a versatile and economic tool for modernizing old canals or constructing new canals.

REFERENCES

Robinson, Gerald, R.E.T., Aqua Systems 2000 Inc., personal communication

Level & Flow Algorithms Notes, ©2007 Aqua Systems 2000 Inc., #5, 4006 – 9th Avenue North Lethbridge, Alberta, T1H 6T8