Application of Fail Safe Canal Control Techniques

by

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INTRODUCTION
The automation of canal facilities includes numerous considerations to assure a successful and reliable system. Even the best canal control algorithm is susceptible to failure if the system is not designed for reliability and does not incorporate fail safe designs. A well designed system will include redundancy, failure detection, alarms and alternate modes of control. Control algorithms, installation procedures, fail safe software and hardware, and testing techniques will be discussed.

This presentation is based on the application of automatic gate control at two sites. The Government Highline Canal, Grand Junction, Colorado had an existing control system and was plagued with unpredictable and incorrect control operations. This work was completed with the cooperation and assistance of Ram Dhan Khalsa from our Grand Junction Area Office, Grand Junction, Colorado.

The second site, Strawberry Highline Canal, Payson, Utah, was a new automatic control site set up using the techniques learned from the Government Highline Canal. This work was implemented in the field by Roger Hansen, Arlen Hilton and Frank Woodard from our Provo Area Office, Provo, Utah, with our assistance.

GOVERNMENT HIGHLINE CANAL
In order to find the problems at the Government Highline Canal two control structures were equipped with data recorders. The water level, gate position, time, and temperature were recorded. Water level was obtained from the 4 to 20 milliampere output of a Bristol water level encoder in a stilling well. The stilling well was also subject to periodic clogging due to the sediment load in the canal. Analysis of the data showed a rapid falling in water level once or twice daily. This caused a large gate movement to correct the apparent low water level in the canal.

The equipment was removed from the site and brought into the laboratory for further testing. The equipment included a PLC (programmable logic controller), a Bristol float-operated water level transmitter, and the associated power supplies. The problem could not be duplicated in the laboratory, but a second water level encoder was installed and the program modified to select the most valid water level signal from the two. The software routine checked validity by looking first for readings within the expected limits and then within the control deadband. A rapid change factor was also included in the control algorithm.

The gate limit switches were readjusted and the limit switches status was brought into the control algorithm. The gate limit switch status was used to inhibit gate control outside of these limits. The modified program and hardware were functionally tested in the laboratory. All error functions were verified by simulating the various error conditions. The gate position was not included in the final control algorithm because the gate encoder was only a temporary installation for data collection purposes.
The equipment was returned to the site and reinstalled using a pressure water level transmitter (probe) for the second water level input. The transmitter was installed upstream of the gate and adjacent to the gate sidewall. Figure 1 shows two error periods (low spikes) in the float output during the field test of the revised control algorithm. The two water levels were offset to provide a clear record on the chart. No gate operations were observed because the controller used the water level derived from the probe. Note that with the exception of the large errors the two water levels tracked very close.

![Figure 1](image.png)

**STRAWBERRY HIGHLINE CANAL**

The second site was an existing site with a new inflatable bladder gate. The bladder positioned a steel gate hinged at the bottom. The photograph, figure 2, shows the control site.

![Figure 2](image.png)
An Omega CN76000 PID (proportional-integral-derivative) controller and an Omega air control system were installed to control air into and released from the bladder. The system was monitored using Campbell Scientific CR10 telemetry. The control was slow and the PID controller was always inflating or deflating the bladder. This was a solar operated site and the constant power drain exhausted the batteries. Additionally, the deadband for control was too small and could not be changed. The equipment is shown below in figure 3.

The photograph, figure 3, shows the air controls and PID controller on a shelf at the bottom. The CR10 used for data collection is in the white enclosure.

The PID controller and air controller were removed. Two solenoid valves were installed to control the air input and releases. The CR10 was reprogrammed with a PID algorithm with water level limit checking. Digital outputs from the CR10 were used to operate two solenoid valves. Again the data were recorded to analyze operation of the PID control program.

Telemetry from the site was monitored daily. Four weeks of data from monitoring after the modifications are shown in the graph (figure 4). Note the reduction in air rates about midway on the chart when the deadband for the water level was increased. The test results are from the telemetered data available from the CR10. The data, after reprogramming and derived from telemetry, are shown in figure 4.
The water level remained almost constant at 5 feet, the desired target elevation. The air in and air out are graphic (not to scale) accumulations of the air input to the bladder and air releases from the bladder. The larger air out is due to the lower pressure differential for air releases to the atmosphere.

**DISCUSSION of PROBLEMS and SOLUTIONS**

Potential problems in development of control systems and their solutions are summarized below:

1. Sensor failure: Sensors have several modes of failure. The most common are open circuit failure and short circuit failure. Sensors are also subject to drift both from aging and temperature. Drift is hard to detect unless it is a large amount.

   Sensors can easily be monitored by checking lower and upper values for the sensor output. Drift can also be checked. For example, a 0- to 10-foot range transducer is used in a canal with a canal bank of seven feet. A reading of 8 feet is obviously in error. Similarly a lower limit of 2 feet might also be appropriate. The water level could be limited to valves between 2 and 7-1/2 feet. Although the water level could conceivably be 2 feet, this would not be a normal operation.

   A third parameter to check would be rate of change. A rapid change in water level, more rapid than normal response can also indicate a problem. This condition indicates a potential problem and should cause the closed loop control program to halt and provide a central site alarm.

   While too high a water level is certainly due to a failure, the other two conditions could conceivably indicate a canal problem.

2. Parameter checking used to further define the normal operation of a process: For example a gate can be expected to operate within a certain set of limits based on downstream deliveries. By identifying excursions outside of the expected range of gate opening, a control process
that is out of control can be identified. Dynamic checks can also be included for gate operation. These checks include:

The gate stops when the control operation ceases.
The gate moves when a move operation is requested.
And, the gate moves in the proper direction.

3. Duplicate hardware, sensors, limit switches used in software routines to verify correct operation: Duplicate sensors can be used to check the validity of various data such as water level and flow. A software routine to analyze the two values can be written to control the process based on the most logically correct value. Limit switches can be used to check validity of data. If a sensor indicates a water level or gate position below a low water level switch or a low gate limit switch then the logic should treat that input as a failed input. If it is not a low value, perhaps other telemetered data can verify correct or failed operation.

4. Laboratory testing and failure analysis: The software logic should be tested, preferably in the laboratory. The interaction of each check routine can be verified without waiting for the occurrence of an event or causing the event to happen with its accompanying disturbance to the canal system and water deliveries.

5. Short and long-term field testing and data collection: No installation, new or old, is complete without field verification. Field data can easily confirm the success or failure of the system and indicate where parameter adjustment is required.

CONCLUSIONS

Automatic control should include laboratory testing to verify all phases of operation. Field testing should include both short term and long term testing and data collection. Failure to include these features can lead to loss of valuable water, damage to the delivery system, damage to users' crops and facilities, and improper water deliveries to farmers and other users.

Automatic canal control algorithms should be practical, well matched to the application, and not overly complicated. Algorithms should include limit checking and failure analysis. Duplicate subsystems, such as water level measurement and high and low water level sensors or gate position with limit switches, should be incorporated where possible.

Automation of canal facilities includes numerous considerations to assure a successful and reliable system. Even the best control algorithm will fail if the system hardware is not accurate and reliable. Various components can fail, but a well designed system will include redundancy, failure analysis and detection, alarms and alternate modes of operation.

Algorithms should include limit checking and failure analysis. Duplication of subsystems such as water level measurement and high and low water level sensors or gate position with limit switches, should be used.

Considerations for program and installation:

2. I/O limit checking.
3. Duplicate hardware, sensors, limit switches.
4. Laboratory testing and failure analysis.
5. Field testing data collection short and long term.