HEAVY MOVABLE STRUCTURES, INC.
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Kirkfield Lift Lock Incident - Control System Modifications and Temporary Control System

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Introduction

The Kirkfield lift lock is a large moving structure located in Kawartha Lakes, Ontario, Canada.

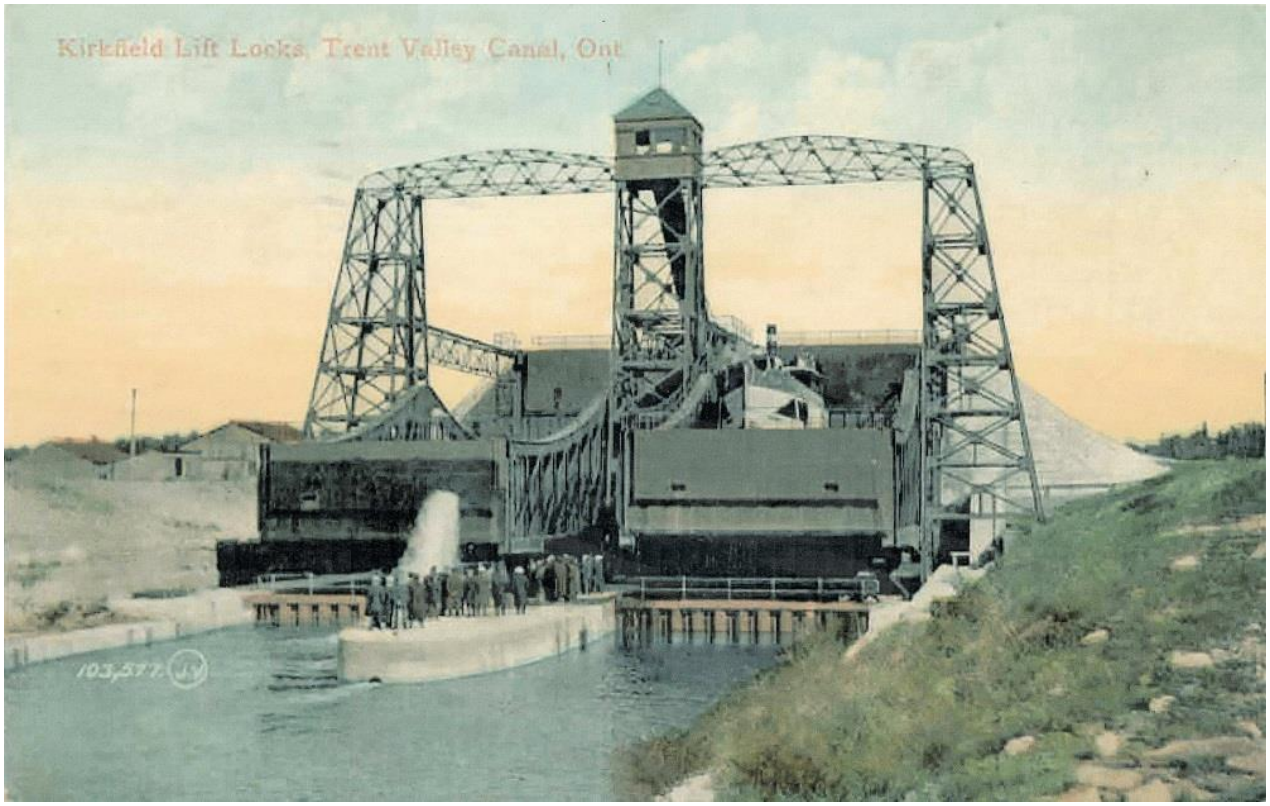

Figure 1 Kirkfield Lift Lock circa 1907

The Kirkfield Lift Lock provides lockage to boats operating on the Trent-Severn Waterway. The Trent-Severn Waterway is a 240-mile-long canal connecting Lake Ontario to Georgian Bay on Lake Huron. Parks Canada is the agency responsible for both the canal and the Kirkfield lift lock.

Figure 2 Trent-Severn Waterway map (Courtesy of Parks Canada)

The waterway and the lock itself are of great historic significance.

The Kirkfield Lift Lock was constructed between 1900 and 1907. The lock is a water hydraulic lift lock modelled after locks constructed in Belgium. The lock was noted for significant technological breakthroughs at the time of its construction.

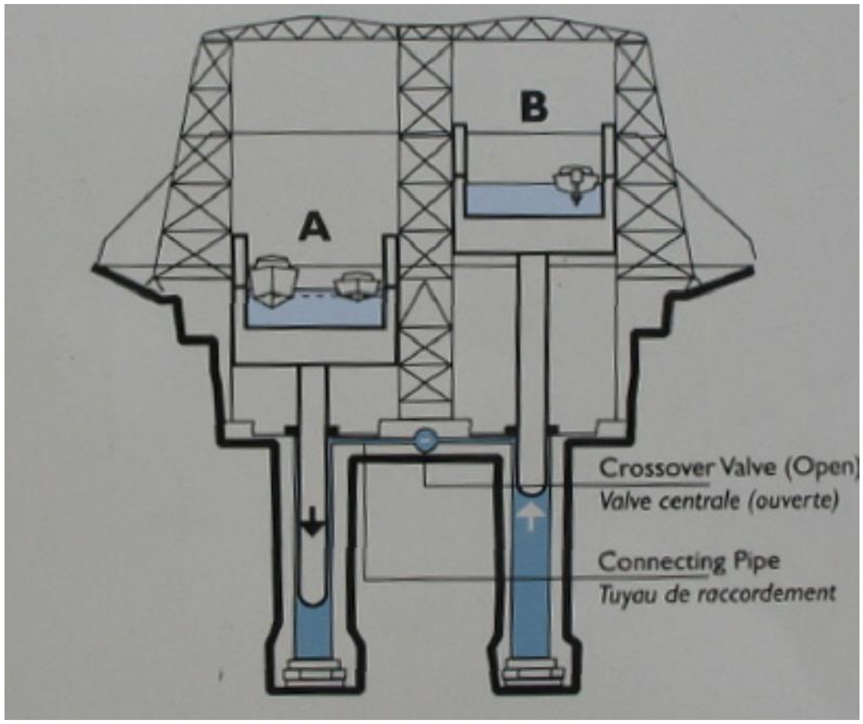

Figure 3 Kirkfield Lift Hydraulic Operating Circuit

The lock is powered by a surplus of water in the upper chamber. The upper chamber containing more water is heavier than the lower chamber. Each chamber sits atop a water hydraulic cylinder. The two cylinders are connected by piping and this piping includes a valve. This valve is aptly named the “crossover valve”. Movement of the chambers is controlled by the position of this “crossover valve” which allows water to flow from one cylinder to the other with the heavier chamber driving the motion.

Over the years the lock underwent several significant upgrades. The most significant of these occurred in the 1960s and included:

1. Relocating the Operator’s House from the top of the lock structure to a cast in place structure on the upper approach.

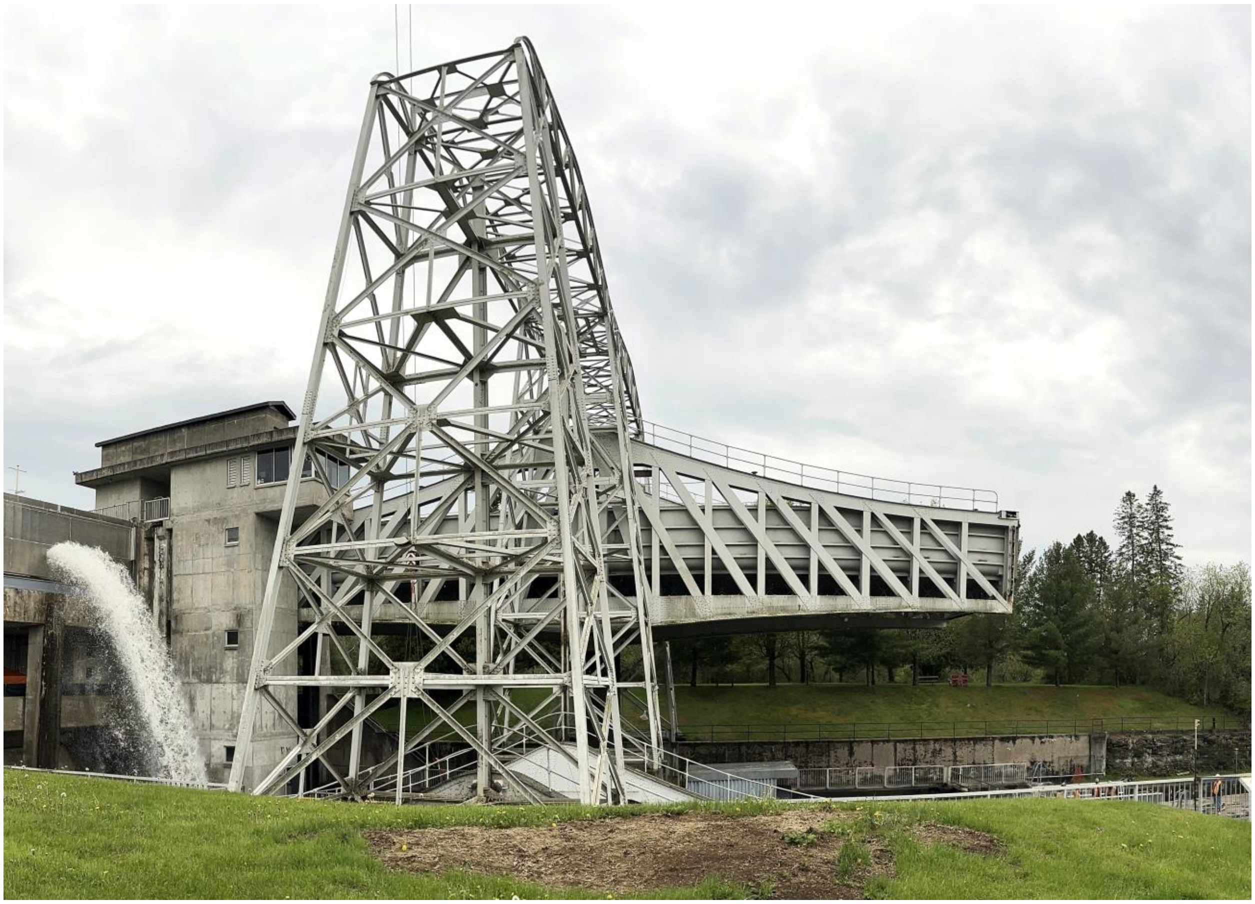

Figure 4 – Kirkfield Lift Lock 2024

2. Converting the original control system to a relay-based control system centrally located in the Operator's House.

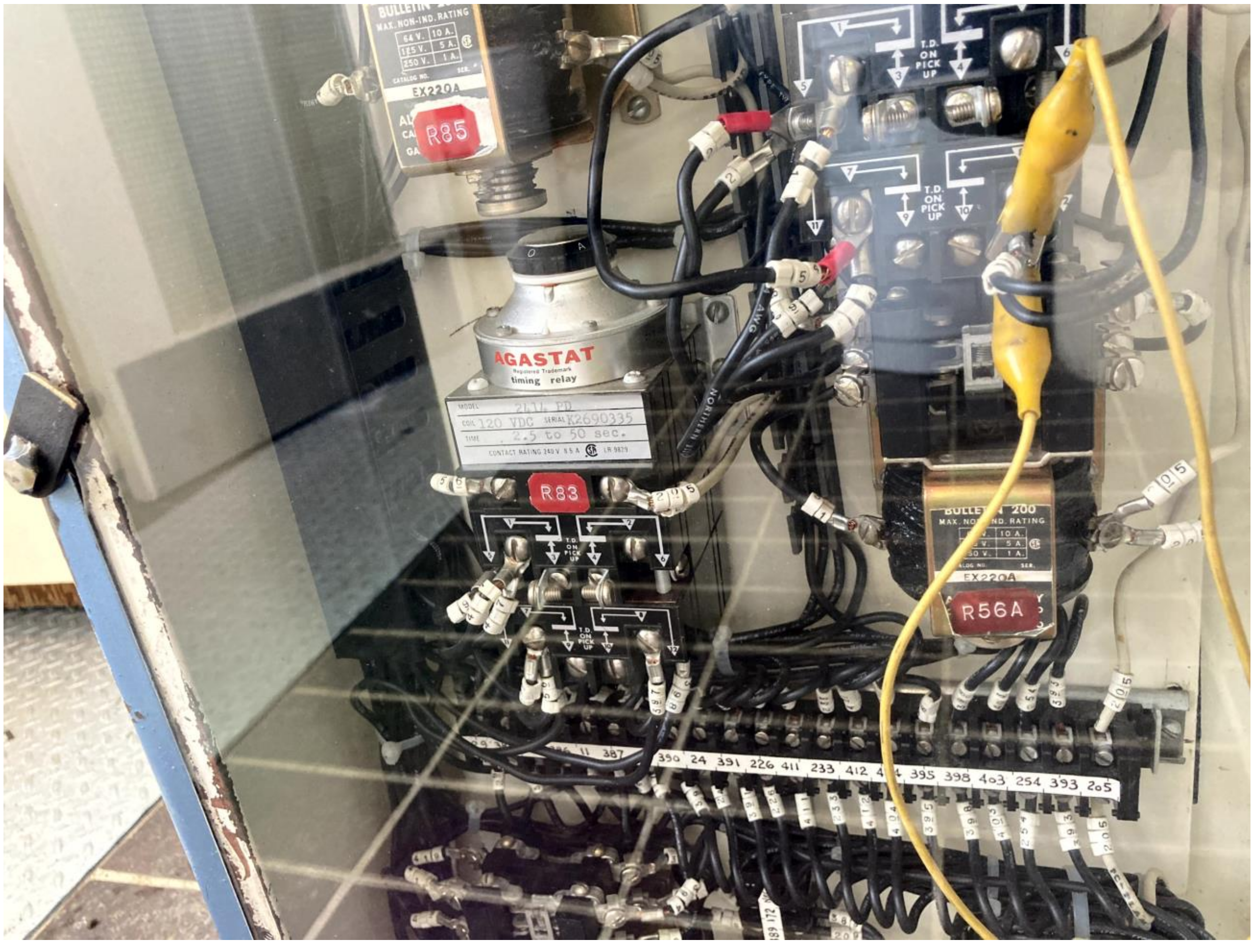

Figure 5 Portion of Relay Based Lock Control System.

3. Converting the water driven pumps to electrically driven motors and pumps.

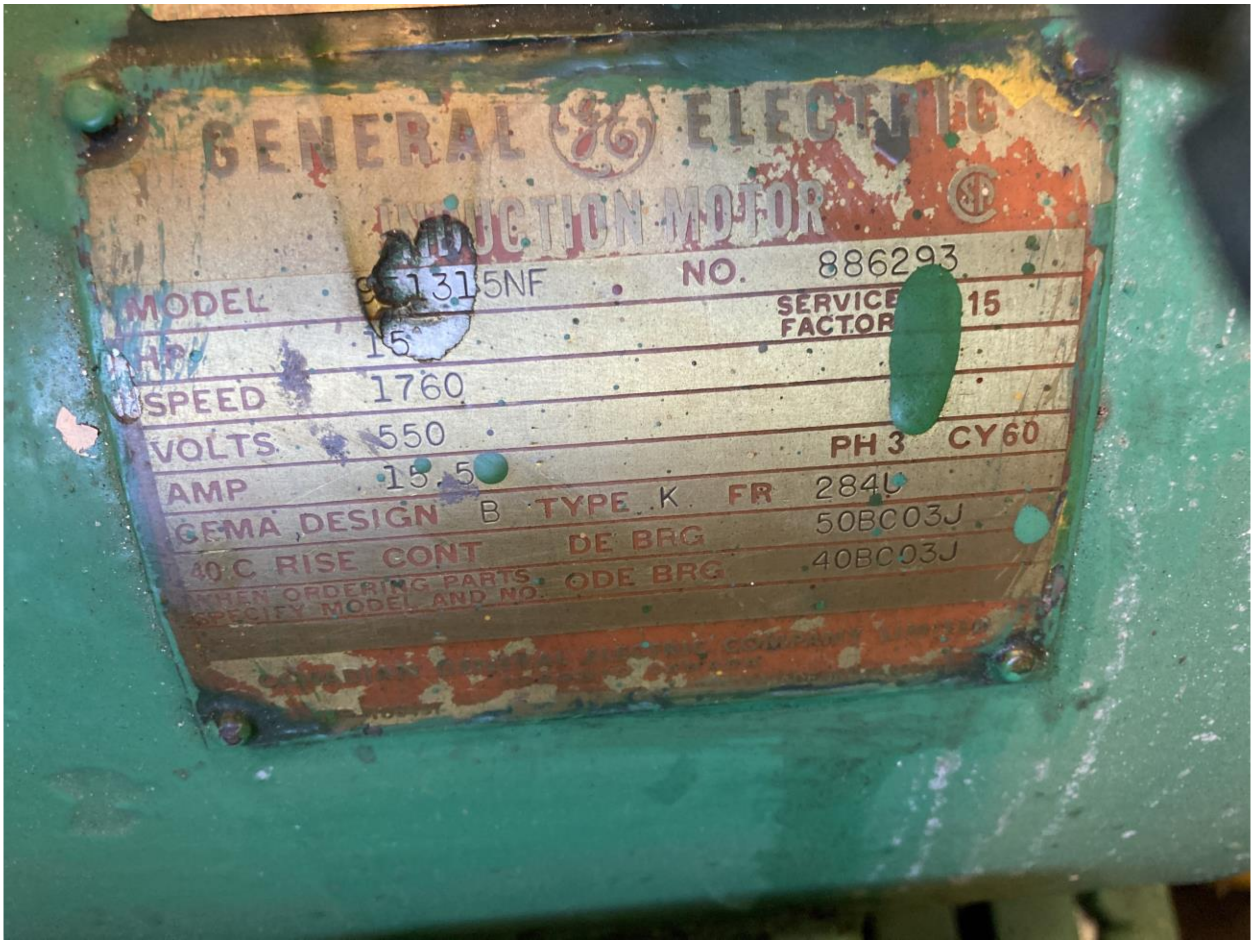

Figure 6 Water Hydraulic Pump Motor

The power and control systems had reached the end of their useful service lives at the time of the incident.

Incident

On September 2, 2022, an incident occurred while locking through a large tourist vessel.

Figure 7 Incident at Kawartha Lift Lock September 3, 2022. (Courtesy of Kawartha 411)

At the time of the incident, the vessel was in the process of locking through from the north chamber to the upper reach. While the upper reach and chamber gates were open, the north chamber began moving in the absence of a controlled Lockmaster input. This incident resulted in damage to various components associated with the operation of the north chamber. In addition, during the recovery efforts, the lower level of the lift lock structure was flooded with several feet of water

The incident occurred near the end of the navigation season and Parks Canada staff operated the undamaged chamber of the Lock structure in a reduced capacity mode using electrically driven pumps and additional staff. This allowed stranded boats to return to their home ports. Once this was complete the lock was shut down for the season and planning began for its repair.

Recovery

Parks Canada retained our firm to perform a thorough analysis of the condition of the lift lock and make recommendations for its repair and develop a plan to allow for single chamber operation of the lift lock until the repairs could be completed and the lift lock returned to its earlier state.

This report solely discusses the electrical and controls portion of the work.

We began by reviewing the condition of the electrical and control systems for the lift lock. Water was found in the lower levels that had compromised the functionality of the limit switches associated with chamber location and the position of the crossover valve and it's locking pins. Additionally, terminal power and control junction boxes had also been flooded. We recommended these devices be replaced. Minimal physical damage to the lift lock electrical distribution and control systems had otherwise been caused by the incident.

Once the condition assessment had been completed plans for operating the lift lock in "single chamber mode" began.

The lock was initially operated after the incident using small electrically driven pumps to provide water to move the single chamber. These pumps are used during normal operation to "trim out" the level of the locks and typically provide only small amounts of water. These pumps required over 4 hours to complete one operation of the locks. As such they were not suitable for other than incidental use. However, as the water hydraulic piping supported this type of operation already, larger water hydraulic pumps were considered as replacements to increase the speed of the chamber operation. After some study, it was decided that a temporary operating plan centering on providing a 150hp, electrically driven pump to support single chamber operation was the preferred option.

Figure 8 New 150 hp Pump for Single Chamber Operation

This plan posed two major challenges. They were:

1. There was no available source of power on site that could support operation of the 150Hp pump.

Figure 9 Electric service transformer prior to upgrade which was inadequate to support 150hp operation.

2. The existing relay-based control system was not designed to allow for single chamber operation.

These challenges were made more difficult due to the need to have the lift lock operational in time for the beginning of the next navigation season, 6 months away.

Source of Power for the New 150hp Pump

One of the key lessons learned during this process is that communications within the design team and with partners and the Owner are key to reducing time delays and accelerating the design and construction process. The resolution to this issue is a perfect example of this.

Our electrical team was presented with a request to develop design documents necessary to install a standby generator which could support the electrical load imposed by the new 150hp pump. Other disciplines had held discussions and made plans based upon the standby generator prior to this request. However, our electrical staff felt that increasing the capabilities of the existing 3-phase utility service was a better option and would probably reduce the risk of delays caused by procurement lead time of a suitable sized standby generator. Concerns were raised about whether the service upgrade request could be completed by the electric utility to meet the project deadline. We contacted the electric utility who felt they could meet the deadline if Parks Canada could provide documentation indicating the importance of the upgraded electric service. Our electrical staff and Parks Canada developed the documentation and submitted it the electric utility and followed up on a bi-weekly basis to ensure the utility had what they needed to meet the project deadline.

We also developed design documents for the upgraded electric service and its distribution to the new 150hp pump skid.

Modifying the Control System to Allow Single Chamber Automatic Operation

The existing relay-based control system was never intended to allow single chamber operation of the lift lock. However, limited movement of individual chambers was possible to accommodate chamber leakage and maintenance. This movement was controlled manually by the Lockmaster. We call this mode of operation “maintenance mode”. Our electrical team took advantage of this for our control system design.

There were several design criteria for this temporary control system design. They were:

1. Single chamber operation must be as similar as possible to the “normal” mode of operating of the lift lock. This was intended to minimize the need to retrain the lock staff.
2. All chamber position limit switches incorporated in the normal control system must be incorporated into the new control system. This necessitated tracing the existing limit switch circuits to ensure the available as-built documents were accurate. Interposing relays were also required as interfaces between the existing control system and the new temporary system.
3. The type, number and connection requirements for the control devices provided with the 150 hp pump would not be provided prior to design and fabrication of the control system.
4. The materials necessary to construct the new control system must be available in a timeframe that supports the project deadline.

Based upon these criteria, we determined that an HMI based digital controller system operating in “piggyback” mode with the existing control system would be the most suitable solution. “Piggyback” mode in this instance means that the HMI based digital control system would be used to control the motion of the chamber and pick up all necessary limit switches and permissives from the control desk. The lock operators would use the existing control desk to perform the remaining control functions such as opening and closing the chamber gates.

Figure 10 Piggyback control system mounted on existing control desk.

The solution was expected to provide flexibility to accommodate changing system requirements and reduce overall wire counts. Quicker installation and return to normal operation were also benefits of this approach. Additionally, this solution met all the design criteria including limiting retraining.

The key challenges to developing the new "piggyback" control system included:

1. Multiple conflicting versions of the as-built drawings for the existing control system.
2. Non-standard nomenclature used on the historic as-built drawings for the existing control system.
3. Damage to the existing control system from an earlier short circuit fault on the system that hadn't been repaired.
4. Portions of the existing control system had been "removed" from service via application of shorting jumpers. Lock staff were unable to explain why these changes had been made.
5. A lack of understanding of how the system was supposed to work versus how lock staff thought it should work.
6. Limited available space to install the new equipment.
7. Limited contact with the Lockmaster during the design process.

We developed bid documents for the piggyback, including an HMI based control system as well as the power distribution upgrades and worked with Parks Canada to support the procurement and installation.

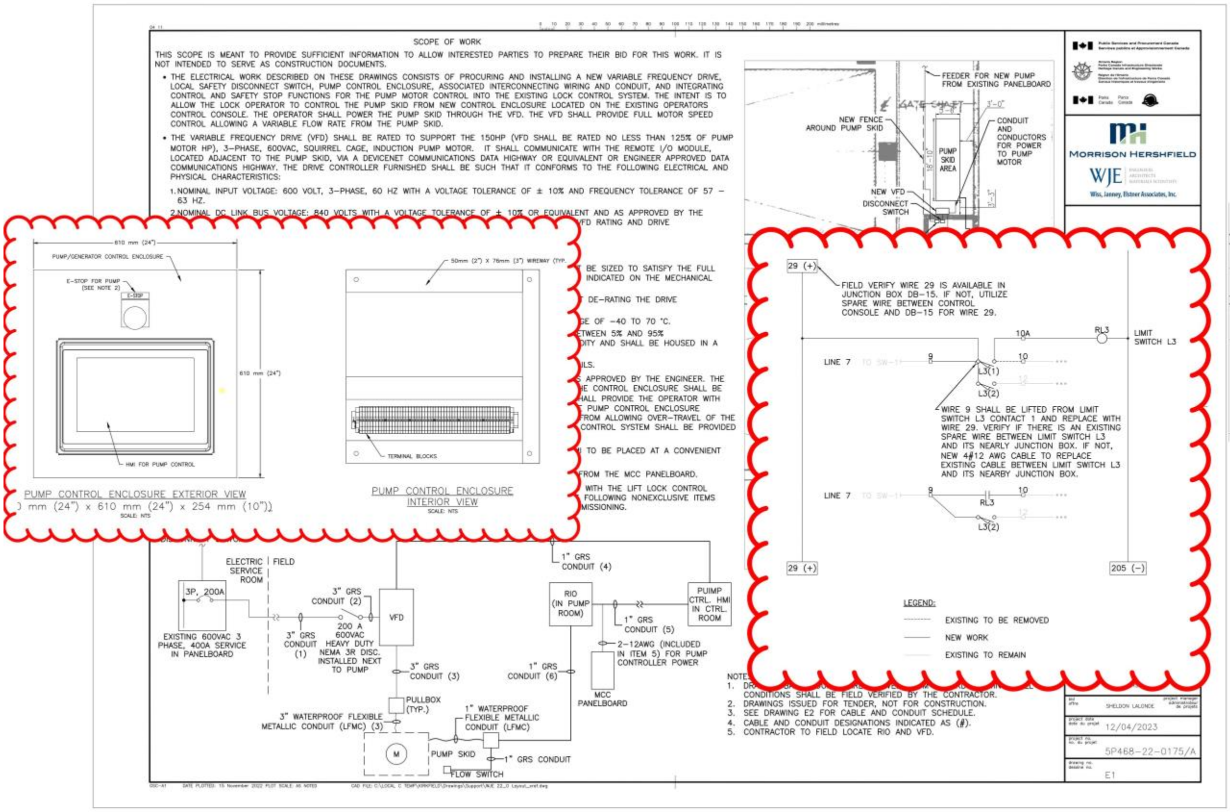

Figure 11 Portions of the control and power system bid documents.

Western Mechanical Electrical Millwright Services won the overall construction contract. Their forces performed most of the construction work under this contract.

The winning control system vendor was Panatrol Corporation. They provided the HMI based control cabinet, an RIO enclosure and all programming and installation support. They went above and beyond to meet the project schedule requirements. The design and procurement of this equipment occurred during the COVID epidemic and despite the difficulties presented by this all equipment was delivered on schedule.

Installation and Commissioning

Our electrical staff supported the work in a flexible manner and provided on-call support to install and test the power distribution and control equipment.
Where electrical distribution and control installation could be performed it was performed early to allow for the inevitable slippages elsewhere during project construction. Where work couldn't be performed early due to the need to allow other trades to complete their work, testing and development of streamlined acceptance criteria took place.
This allowed for accommodation of construction delays and necessary but additional and unforeseen pump equipment control points to be incorporated into the system. The additional pump control points were not unexpected and occurred due to the unique nature of this installation.

Electrical commissioning began once the Contractor had completed the mechanical work necessary to operate the 150 hp pump. The process consisted of initially testing the control points to ensure they were seen by the control system and functioned correctly. Once all control points were clear, emergency stop functionality and interlocks were tested. Then piecewise testing of smaller elements of the control system began, followed by combining these elements into larger control sequences and finally fully integrated operation at reduced speed.
Commissioning of the lift lock for single chamber operation was completed on schedule.

Reversion to normal operation

Work on the lift lock continued during the winter of 2023. The goal was to return the lift lock to normal, dual chamber, operation by the beginning of the 2024 navigation season (May 18, 2024).
The original intent was to remove the piggyback control system and 150 hp pump and store them, offsite, for use when needed at Kirkfield or elsewhere. We had designed the control system modifications to allow for quick and easy reversion to and from dual chamber and single chamber operation.
However, the system provided so much benefit, in terms of redundancy, that Parks Canada requested they be retained in a reduced capability form. Due to this we modified the reversion plans to retain the pump and control system.

We had also learned from the 2023 commissioning that the existing chamber position limit switches could pose problems during testing and commissioning. Particularly since the chamber position limit switches on the North (damaged) chamber hadn't been moved in over a year. As such we tested the switches and found several were faulty and recommended, they be replaced. However, due to limited access to the switches, the work of other trades in that area and parts availability replacement was not possible.
Our team, Panatrol Corporation and Parks Canada developed the programming necessary to support Parks desire to retain the 150hp pump and uploaded it to the digital controller.

Electrical and control is always a lagging discipline and particularly in this situation where the control system "rollback" could not be tested until the mechanical and structural repairs were complete, and movement of the north chamber was possible. The north chamber was ready for control system testing on May 15, 2024.

Our electrical staff, Parks Canada's lock operating staff and Western Mechanical's electricians performed the reversion and testing and commissioning process over the next two days. The commissioning process followed the procedure developed for the 2023 commissioning.

Issues that arose during the testing and commissioning were:

1. Limit switches had been removed during repairs and were not reset properly. This issue wasn't communicated to the testing team and caused delays to the testing.
2. Limit switches that had been removed had new mounts and targets provided which did not have adequate adjustability.
3. Devices that had been flooded as a result of the incident had not been replaced and were faulty or failed.
4. Existing limit switches had worn contacts and were only making intermittent contact.
5. Timing relays failed causing out of sequence operation.
6. Faulty field wiring had to be identified and corrected.
7. Interposing relays had been designed to allow both single chamber operation and double chamber operation. These had been mis-wired and double chamber operation would not function.

Once these issues had been identified, corrected and testing completed, one day of operational "burn-in" was performed to stress test the system while staff capable of making repairs were on site.

Lessons Learned

This project was high intensity from the start to the finish. The project moved fast, and this amplified issues that would be minor on another project. Some of the issues that arose were:

1. A single point of contact for a project like this will not work. Trickling down information takes time. Having all discipline leads constantly involved saves time and reduces errors due to incomplete information.
2. Goals were constantly evolving due to newly uncovered damage or design selections by other disciplines. Expect these changes and design flexibility into your solutions.
3. Non-experts will present "solutions" to other disciplines problems. Try not to dictate outside your wheelhouse. Present the problem, not the solution.
4. Decisions were put off due to incomplete information about product lead times. Have this information on hand before deciding upon timing for decisions.
5. Equipment necessary for programming and factory testing wasn't always available early enough to meet the project schedule. Consider procuring an identical or similar product to allow programming or testing to continue rather than stacking up the work later.
6. The existing control system was designed in a modular fashion. Chamber motion was one block, gates were another, etc. Take advantage of this to reduce the construction duration.
7. Locks and bridges are unique structures and often equipment suppliers and designers can't anticipate everything, and changes must be made in the field. Anticipate changes and design with flexibility.
8. The overall schedule compressed greatly reducing the electrical and control system testing and commissioning time. Communicate schedule compression and preposition staff to meet the project needs.