CHAPTER 4
Control

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4.1 Introduction.

This chapter provides general guidelines and considerations to stimulate ideas within designers when developing a computerized control system for a lock and dam project. It is not intended to specifically address all the locks currently operating in the United States. Although much of the information presented is specific to miter gate locks, the same technology can be adapted to sector gate locks and also to the control of spillway gates. As referenced in this chapter a "new" lock control system does not refer only to a new lock construction project. Replacement or rehabilitation of an existing electrical system constitutes, for the purposes of this chapter, a "new" control system. Acronyms are defined in the Glossary. See Plate B-86 for a high-level flowchart showing the sequence of design development events for a typical lock and dam control system.

4.2 Design Considerations.

4.2.1 Operation. The standard operating procedure of a lock control system can vary greatly by district, river system, location, weather, size, and traffic conditions. Many of the concepts provided herein will have to be modified in order to meet the specific needs of different lock operations personnel. It is important to remember that coordination with personnel at the lock is of paramount importance when designing a lock control system. It will often be beneficial when visiting other sites to bring representative members of the lock operating crews to witness similar systems that are in use at other locks.

4.2.1.1 Manual Operation. For purposes of this section, manual operation of a lock is defined as equipment operation initiated by individual action from the lock operators. The control system architecture still includes a complete PLC system, but the system includes no automated sequences.

4.2.1.1.1 PLC Manual Controls. The basic control system for any lock should be individual PLC inputs from an MMI software package, hardwired pushbuttons, limit switches, encoders, transducers, and discrete PLC outputs to motor starters, contactors and pilot lights. For example, each miter gate leaf should have an OPEN, CLOSE, and STOP pushbutton for manual operation of the gate. This type of operation allows the lock personnel to control each piece of equipment individually with the full compliment of PLC interlocks, limits, and failsafe devices. This should be the minimum normal control system at any lock. Degrees of automation, as discussed herein, will vary by project site. Access to the manual controls should be at every control station, and at other areas around the lock as deemed necessary by the lock personnel. The manual controls should be simple and ergonomically designed with good visual feedback such as pilot lights and/or on-screen graphics. The manual controls should have a means of operating all the lock equipment including the miter gates, liftgates, culvert valves, tainter gates, traffic lights, bubbler systems, warning horn, emergency stop, lock lighting, small pleasure craft controls, and other equipment unique to each lock and required for day-to-day operation. The designer must spend ample time with the operating personnel to determine all the features to include in the PLC Manual Control system.

4.2.1.1.2 Back-up Control Box. On locks that use a software MMI, such as larger ones with minimal hardwired backup, consideration should be given to providing a small portable control box that can be conveniently plugged in near the main control console area or at other strategic operating locations. This control box would provide direct inputs to the PLC and hence bypass the software MMI in the event of an IPC or network failure. Operation via the control box would still have all of the PLC interlocks and limits in place but the flexibility and feedback for the operator would be limited. The control box should be kept as simple as possible consisting of pushbuttons (lighted for positive feedback) for the miter gates, filling and emptying valves, traffic lights, and other critical features unique to individual projects. While all operators should be thoroughly trained in the use of the Back-up Control Box, and while written instruction for its use should be on site at all times, the control box unit should be viewed as a seldom-used back-up system to the IPC network. The Back-up Control box should be small and light enough to be portable and easy to store yet of sufficient strength and durable material. It is good practice to allow extra space on the control box panel to add additional functions as the need arises. Laminated nameplates should be screwed to the panel to allow easy replacement because the control box functions are likely to change as the operators get used to a new system. The back-up control box offers a safe, convenient way to upgrade IPC software and hardware without expensive lock downtime.

4.2.1.1.3 Minimal Emergency Back-up. A minimal hardwired Emergency back-up system should be provided for each major piece of lock equipment. The system should be kept to a minimum number of control features and should be as simple as possible. Consideration should be given to wiring in simple interlocks to provide protection when using the Emergency controls. Over-travel and other absolutely critical and failsafe devices should be hardwired into the motor starter or variable speed drives, with no possibility of bypassing them from any of the controls. These limits should only be those designed to prevent equipment damage or personnel injury. The minimal emergency back-up system should consist of just the controls needed to operate gates, valves, traffic lights, warning horns, and other features unique to individual locks that are deemed critical. In all cases, a lock control system should include an emergency stop pushbutton that is directly wired using normally closed contacts to the motor starters and variable speed drives. Activation of this button should stop all major lock operating equipment immediately regardless of the lock's operating mode. The designer should be careful not to make the minimal emergency back-up system more complicated than the normal control system. Solid state components should be avoided since the purpose of the hardwired system is to provide emergency back-up to the normal solid state control system. Excessive numbers of relays, wiring, displays, and solid state encoders can lead to a back-up system that is more complicated and difficult to maintain and trouble-shoot than the PLC system. The emergency back-up system should be electrically isolated from the PLC control system.

4.2.1.1.4 Contractor Controls. Consideration should be given to providing pushbutton controls, perhaps as part of the emergency back-up system, at the motor control center, variable frequency drives, and at remote motor starters, for use by the Contractor during construction. These pushbuttons may save the Contractor time and may take pressure off the System Integrator by allowing the General Contractor to "bump" motors and hydraulic cylinders for mechanical alignment purposes without expecting the System Integrator to have large portions of the

PLC/IPC programming debugged prior to moving equipment. These controls can either be integrated as part of an emergency back-up system, or de-energized after construction and check-out is complete.

4.2.1.2 Automatic Operation. For purposes of this section, automated operation of a lock is defined as operation of major lock equipment, i.e. gates and valves, that is initiated by the PLC or the lock control system without direct intervention from the lock operators.

4.2.1.2.1 Semi-Automatic Lockage. At present the most automated form of lock operation in the United States is called a semi-automatic lockage. In this sequence the operator uses two pushbuttons to perform the entire lockage. The first pushbutton prepares the upstream end of the lock for entry or exit and the second readies the downstream end. When a downstream vessel approaches the lock the operator pushes the first button and the PLC checks and closes the lower miter gates, checks and closes the lower emptying valves, and opens the filling valves. At this point the PLC waits until the lock chamber is the same level as the upper pool, and initiates the opening of the upper miter gates or lowering of the liftgate and the closing of the filling valves. The signaling of vessel movement, i.e. traffic lights and air horn, are done by the operator in a semi-automatic lockage procedure. After the operator has determined that the vessel is safely in the lock chamber and secured to the mooring bitts, the second command is initiated which closes or raises the upper gates, checks and closes the upper filling valves, and opens the lower emptying valves. At this point the PLC again waits until the chamber has lowered to the level of the tailwater and then initiates opening of the lower miter gates and closing of the lower emptying valves. When the gates are fully recessed and the vessel is clear to exit the chamber, the operator signals the vessel by sounding the air horn. This process requires only one person to operate a lock and frees that operator up to enter lockage data, arrange queues, operate tainter gates, operate adjacent locks, and other duties necessary to operate a facility. A semi-automated system streamlines the operation of the lock, reduces delays, increases efficiency, and yet at the same time does not increase risk because the operator is still in command of all vessel movements and signaling. This type of system should be considered for all new lock control systems, particularly those with high tonnage where an operator’s time is critical, those with limited number of operators, or those that have operators who perform various other duties such as maintenance. Locks that have high head, especially small locks, may require refinements to the semi-automatic lockage sequence because of extreme hydraulic conditions. For example, two modes of semi-automatic operation could easily be programmed into the PLC system to allow for differences in pleasure boat and commercial boat operation. High head causes rapid filling of small lock chambers and can create excessive turbulence if not properly controlled. By implementing a special “pleasure boat mode of operation,” in which the valves stop at specified intervals to slow the filling rate, turbulence can be limited. Sequencing of the valves can also be controlled to “pin” the pleasure boats to one side of the lock, as is often done when operating manually with existing control systems. Commercial boats typically can tolerate more turbulence so the “commercial boat mode of operation” can be programmed to fill the chamber faster than the pleasure boat mode. Whatever sequences are programmed, filling times and methods of operation should be closely coordinated with qualified hydraulic engineers and lock operating staff. A semi-automated lock should also have a manual system, a hardwired emergency stop, and a minimal emergency hardwired back-up system. In most cases a semi-automated lock will have one centrally located operator. With visibility limited from a central operating point, a Closed Circuit Television system will probably be necessary for such a system. Various other forms of automation should be considered as discussed herein.

4.2.1.2.2 Automatic Lockage. To date there are no fully automated locks in the United States and no plans to implement one. The safety, security, legal, and policy issues would have to be thoroughly addressed before a lock could ever be fully automated in the United States. Currently there are plans to fully automate the Panama Canal, and there is one fully automated lock in Europe. The Panama Canal when completed will sense the motion of the vessels using optical sensors and move the miter gates and valves accordingly. It will be an expert system that will coordinate moving of the vessels, using electric mules and winches, the filling and emptying of tandem locks, and movement of the miter gates. The system will even allow for the entry of special lockage information unique to each vessel to alter the filling and/or emptying of the chambers. Such knowledge now exists only in the experience of the lock operating staff, which will likely be reduced when the canal is turned over to Panama. In The Netherlands, the Dutch operate the only fully automated lock and dam in the world. This is a trial operating mode using lasers and intelligent radar to sense the moving of vessels and operate the gates accordingly.

4.2.1.2.3 Filling and Emptying the Lock Chamber. Filling and emptying of the lock chamber can be automated in several different fashions. The first is as discussed above in the semi- and automatic lockages. A more simple level of automation would have both filling valves operate simultaneously with a single operator command. The command could either be from MMI software or from a hardwired pushbutton input to the PLC. When automating the culvert valves the PLC can be programmed for any number of different sequences for different head conditions, pool levels, filling and emptying rates, delayed opening, pleasure crafts, light boats, and empty tows. Experienced operators will have to be consulted to determine the exact extent and requirements of automating the filling and emptying valves. This type of automation is generally simple to do and usually only requires programming once the PLC and field devices are in place and can easily be altered as needs change. Automating the filling and emptying of lock chambers should be considered with all new lock control systems.

4.2.1.2.4 Water Level Sensing Equipment. One of the critical procedures of an automated lockage sequence is the reliable sensing of water levels and determination of the "pools equal" condition. In other parts of this manual actual hardware and installation are discussed. Included in this section is automation of the water level sensing system. The water level sensing system should have redundant sensors for malfunction identification (i.e. at least two sensors in each measuring location). Malfunction of one sensor should lock out semi- or fully automatic operation. The operator under these conditions would visually verify that water levels have reached a safe level for manually moving gates. Consideration should be given to providing a built-in system for determining, through a series of checks and comparisons, which sensor has failed, and allow the automated sequence to continue, if possible, with that sensor "bypassed." An alarm should be generated to alert maintenance personnel of the failure yet allow the lockage sequence to continue. Again, this type of automation does not require significant additional hardware, and the programming for such a system is fairly simple. For example, abrupt changes in signal level could be monitored through program logic to determine that a sensor has failed; if one sensor in a pair suddenly drops below tailwater or rises above pool level, then it has probably failed. The water level system can include other trouble-shooting features such as determination of type of sensor failure (i.e. power loss, signal loss, out-of-range, out-of-calibration), power supply failure, and PLC I/O failure. All of these help streamline the operation and repair of an automated system.

4.2.1.2.5 Bubbler Systems. Locks with significant ice or debris problems often rely on compressed air bubbler systems to remove such material from behind miter gates to permit the gates to properly recess. This process should be given consideration for automation. In heavy ice conditions miter gate “fanning,” or alternately opening and closing gates to clear ice, and operation of the bubbler system is a procedure requiring significant operator interaction. Automation of such a process may be difficult because of the operator judgement involved, but under more normal conditions the bubbler system can be automated. Consider operating the bubbler system when debris or ice is sensed in the recess. Eventually, viable technologies may exist that could be used to determine the presence of such obstructions. Automation of the bubbler could also be tied to operation of the miter gate so that clearing of the recess area occurs with every opening of the gate. This would be wasteful at some locks, yet useful at locks where debris is a consistent nuisance. Tempering the use of high volume air compressors through programming and automation can also realize some significant energy cost savings.

4.2.1.2.6 Tainter Gates. Regulation of the pools on a river system is a responsibility that during normal river conditions could be controlled directly by the PLC with data input from Corps district hydraulic engineering personnel. Such a system could relieve the lock operator of the burden of making gate changes and allow time to more efficiently operate the lock. During times of low river flows, constant regulation of the pool and movement of the dam gates can impact a lock operator’s time with the passing of river traffic through the lock. Conversely, heavy lock traffic can also delay critical gate changes on the dam. Design engineers should consider all possibilities when designing a new lock and dam control system or rehabilitating an existing one. Proper operating parameters should be incorporated into remote or automatic operation of dam gates. These include but are not limited to: switching to manual operation when gate is near closed, monitoring of communication loss to stop gate movement, and generating alarms for uninitiated change of state (possible pool loss), slow change of state (obstruction), or fast change of state (brake failure). Close coordination with lock operating personnel and district hydraulic engineers is imperative if automation of dam tainter gates is to be a success. This type of automation will likely become required in the future as personnel reductions continue to take place.

4.2.1.2.7 Remote Trouble-Shooting. All PLC lock control systems should be provided with the capability of remotely trouble-shooting via standard telephone lines. This provides a means for lock electricians to look at problems from an off-site location and provide guidance to lock operators when problems arise. District engineers can also provide assistance to trained, on-site lock electricians when complex programming revisions are required. The remote capabilities should allow designated qualified personnel to monitor and change ladder logic programming, operating screens, network parameters, and database files. Extensive changes to the control logic that are unsafe to make remotely or radically affect control actions should be deferred until they can be tested and debugged on-site. Designers should incorporate appropriate security firewalls into the system to prevent intrusion by unauthorized personnel.

4.2.2 Site Characteristics. When designing a control system for a lock and dam, it is very important to thoroughly review the unique features of that project. It is impossible to present a precise engineered design document that will be typical for all lock and dam control systems. That is not the attempt of this document. Rather, the attempt here is to promote ideas and consideration of certain features that affect the concept and design of a control system. Obtaining and reviewing documentation from existing lock and dam projects that have debugged and functioning control systems is a good idea. However, it is important to remember that each site is different and what works well at one lock will likely need to be slightly altered to be successful at another. Contractors will not do this. Designers have to consider these and other features very early in the design process.

4.2.2.1 Size. The size of a lock is critical when deciding the number and location of control system equipment such as consoles, I/O racks, cabling, fiber optics, CCTV cameras, IPCs, and emergency back-up controls. While it will vary by project, larger locks generally have more of this type of equipment and it will be located in a distributed manner to reduce cable lengths. Arranging control and communication equipment to reduce, as much as possible, the number of lengthy cable runs is critical to insure a reliable system. Failures from rodent damage, construction or operation procedures, weather, and lightning are less likely to occur in protected cabinets with short, protected cable runs less than 30 meters (100 feet). While the initial cost of an extra intermediate I/O rack or communication point may not appear economical during the design phase, the cost of downtime and repair associated with failure will likely be much higher and at greater inconvenience. Larger lock and dam projects will have more electrical and electronic components located at greater distances from maintenance buildings and control houses. For this reason, designers should look at the possibility of installing, in strategic locations, network connections for lock electrical maintenance personnel to monitor all the control system features. These network connections can be used by a laptop computer to instantly obtain trouble-shooting and repair information on all PLC I/O points, MMI databases, and IPC operating screens. The funding required to install such communication points will be well spent considering the time it can take to travel between locations on 366 meter (1200 foot) locks or projects with 15 or more dam gates. Also, time should be spent considering the possibility of locating these connections in areas where lock personnel will be protected from adverse weather conditions. However, the farther repair personnel are removed from the trouble location the harder and longer it will take to restore the system to proper working condition. When trying to show economic justification for the extra funding, be sure to look at the significant consequences of downtime in addition to the relatively low probability of incidents when determining the “risk” of failure.

4.2.2.2 Layout. The physical arrangement of miter gates, lift gates, dams, spillways, service bridges, galleries, guidewalls, maintenance buildings, control houses, and access to these features will have an effect on the arrangement of the control system components. Procedures such as flood control, winter shut down, ice flushing, dewatering, open river operation, and general facility maintenance can all be considerations when designing a lock and dam control system.

4.2.2.2.1 Single Locks. Single locks, the most common at Corps sites, have an obvious need for a reliable control system because they lack the built-in redundancy of a second lock. At these sites it is imperative to provide some means of hardwired emergency back-up controls as discussed previously. These types of locks are often equipped with tow haulage units that increase direct operator involvement in the locking process. However, this does not preclude the justification or need for a certain level of automation. A semi-automated lockage process can free the operator to assist vessel crew members in pulling cuts while the PLC monitors water levels and operates lock gates. Fully automating a lock where there is heavy dependence on tow haulage units is not feasible at this point given shared responsibilities between the vessel crew and the lock operating personnel.

4.2.2.2.2 Double Locks. Generally, double locks consist of one larger main lock and one auxiliary lock. In the past it has required as many as five lock operating personnel to perform lockages during heavy traffic at such sites. Federal budgets are not going to support such crews in the future so it is incumbent on the part of the designers to consider this when laying out the control system. At some double locks, the smaller auxiliary lock is used strictly for pleasure boats. These locks may warrant consideration as user-operated facilities because an operator is on-site controlling the larger lock and can assist if problems arise. If the locks are both used for commercial and pleasure traffic, a centralized semi-automatic control system where a single lock operator can perform simultaneous lockages in both locks should be a strong consideration. Given certain types of traffic, volume of traffic, proximity to other sites, and other district considerations, potential remote operation of such a facility should be reviewed and considered during the design phase.

4.2.2.2.3 Tandem Locks. Tandem locks consist of one long segmented lock chamber with intermediate gates to facilitate high head lift in incremental steps. Tandem locks are used where the lift is too large to accomplish lockage in a single step. These locks, similar to those at the Panama Canal, make excellent candidates for automation because the emptying of one chamber fills the other. Water levels must be closely controlled to keep from over-topping the lower chamber or over-emptying the upper chamber. A PLC-controlled system can very precisely repeat a prescribed filling and emptying sequence to insure a safe and efficient project. If conditions exist that alter the normal sequence they can be programmed into the system and the PLC approaches an “expert” system. Depending on conditions described above, remote control of such a site is a design consideration.

4.2.2.3 Traffic. The volume and type of traffic that use the lock is perhaps the biggest consideration when deciding the optimal degree of automation. It also determines whether remote control is feasible, the location of control points and CCTV cameras, and other electrical/electronic control design features. Generally, the size of the lock and arrangement of the lock equipment has been previously designed for the location and traffic concerns of the project. However, on lock rehabilitation projects, the type and volume of traffic has likely changed since the lock was built. The new control system must be designed with current and future traffic projections in mind. Automation and remote control are two features that can address these needs.

4.2.2.3.1 High Volume. High volume locks, defined for the purposes of this chapter as those with annual tonnage in excess of 36,300,000 tonnes (40,000,000 tons), such as those on the Mississippi and Ohio Rivers, can generally support automation to streamline their lockage procedures. With this amount of traffic the lock is busy all the time and automation of certain functions, including the dam, help free the operator’s time to more efficiently operate the lock. Additional costs for redundancy, remote trouble-shooting, spare parts, back-up control systems and reliability of equipment are usually easy to justify at these high volume sites. Remote control of such a facility is a potential consideration that should require very little additional cost to build into a new computerized control system.

4.2.2.3.2 Low Volume. While lower usage locks may not support the same construction costs as higher volume locks, the control system can be designed for operation by fewer personnel. Often a single electrician maintains more than one project, and remote trouble-shooting and repair capabilities can greatly enhance their ability to accomplish this. When several locks in a system are relatively close together remote operation from one point with automated lockage sequences at each site can enhance the efficiency of the system and cut operating costs. Control system designers should consider these possibilities, if not for immediate use, then for future possibilities.

4.2.2.3.3 Commercial. Commercial vessels comprise the bulk of the traffic at high volume locks, while low volume locks often have a large percentage of pleasure boat traffic. Automation is somewhat easier to implement for commercial tow lockages because vessel movement is slower, more consistent, generally predictable, and vessel operators are usually more experienced in using the locks. For this reason a semi-automated system will work well for high volume locks. Remote control may be harder to justify because a single operator would have to control multiple remote locks for economic justification. The higher volume locks have enough traffic to justify an on-site operator. However, consideration should be given to providing the potential for future remote operation, perhaps during slow traffic, because the cost is minimal after a computerized control and CCTV system are installed.

4.2.2.3.4 Pleasure Craft. At all locks, the unpredictability and inexperience of pleasure boat operators, coupled with the lack of radio communication and the vulnerability of small craft occupants, require lock operators to have more direct control over the lockage sequence. Automation of dam gates and lock filling and emptying can give the operator extra time to pay attention to the special needs of pleasure boat occupants.

4.2.3 Control Rooms. The operational success of a lock and dam PLC/IPC control system can be greatly affected by the interface between the operator and the computerized control system. Usually the point of interface is a control console located in a lock control room. Control rooms should be designed with safety and the needs of the operator in mind. From an equipment standpoint, locations of consoles, CCTV monitors and controls, marine radios, public address systems, IPC monitors, printers, and vessel logging computers can be located essentially anywhere. With today's technology, the flexibility of such equipment allows for the design of the control room to be based almost entirely on the interests of the lock operators. However, often when changing from a traditional hardwired localized control system to a computerized central control room, it is difficult for a lock operating staff to determine their exact needs for the new system. The purpose of this document is not an attempt to define the ideal control room layout, as this will vary greatly from project to project, but rather to provide designers with guidelines for determining the needs of their individual control rooms and meeting those needs with an effective ergonomic design. It is important to remember that no design will satisfy the needs of every operator, and the final product will ultimately have to be modified to meet the changing needs of the lock operators as they become accustomed to a new system.

4.2.3.1 Access. The designer should consider the accessibility of the control room and its equipment when determining the proper layout for a lock control system. The degree of accessibility required will often be determined by the type of control system employed, namely manual versus automated. Once this determination has been made, the control house layout design should proceed with the safety and convenience of the operators in mind. Following are some points to consider for accessibility of a new or refurbished control room.

4.2.3.1.1 Manual Systems. In manual systems or systems with tow haulage units that require direct operator intervention to the locking process, the control room should be located as accessible as possible from the lock wall. This may compromise the flexibility of the control room layout, but will be more efficient for an operator that must return to the lock wall often during lockages. The layout of the control system components, such as those listed herein, should allow the operator to have access to the lock wall and as much direct visibility as possible. Equipment within the control room will have to be arranged in different fashion to allow an operator to use it in a more mobile mode. Operators will often be entering or exiting the control room and will need quick, handy, control system interfaces, rather than elaborate ones designed for the operator who is at the controls on a continuous basis.

4.2.3.1.2 Automated Systems. Lock wall access to and from the control house is less significant with automated or remotely operated control systems. In this type of control system the control room can be oriented to provide the most convenient accessibility to control console components without as much emphasis on access to the lock wall. Where possible, direct visibility of the lock should always be a consideration. With access not as much of an issue, higher elevations, such as on top of a service bridge pier, provide a good location for a centralized control room. In an automated system having single operator control, CCTV monitors become the main focal point of the operator's attention. These should be positioned to give the operator not only convenient access, but also a matching orientation of the actual lock equipment so quick reference can be made when examining the monitors. In other words, downstream views made looking at the landside of the lock should be the same when looking at the CCTV monitors. Orientation of the IPC graphic operating screens should also match the physical orientation of the lock equipment.

4.2.3.2 Visibility. Direct visibility of the lock and the area around the lock should be provided if economical and architecturally feasible, even in highly automated control systems. Designers should not, however, compromise the economic justification of automating a system by providing excessive means of direct visibility of the entire lock and dam facility. Although this sounds contradictory, and on certain designs can be a fine line for the designer to walk, the designer must determine the operator's needs for direct visibility. Often a control room can be designed where direct visibility and CCTV monitors compliment rather than compete with each other. This balance creates a more efficient and convenient working atmosphere. An operator does not have to fumble around looking for the correct orientation if the monitors are set up to provide views the same that direct visibility would. In an automated centralized control room, consider positioning and orienting control consoles and CCTV monitors so that direct visibility is available without the operator leaving the console area, or continually rotating more than 90° in either direction to see the lock approach areas. In manual systems with local control houses located at the lock wall level, position consoles and CCTV monitors to provide convenient views of approach areas, guide walls, culvert valve discharge areas, dam or spillway gates, and other areas that are hard to see from the lock wall level. Little things like this will help the operator monitor the whole project while keeping distractions to a minimum. In the future it is very likely that there will be less workforce at the locks, and operators could have other maintenance and security type duties to perform simultaneously with vessel lockages. Designers need to consider and plan for this by making the system convenient and safe to operate while increasing the efficiency of the project.

4.2.3.3 Layout. A good control system that is difficult to access or use is really not a good control system. Therefore, the layout of control rooms or areas is critical to the lock operator's perception of a quality system, and hence the success of the system itself. Figure 4-1 shows a proposed new layout for the Melvin Price central control room. The new layout will accommodate operation of the two lock chambers at Melvin Price Locks and Dam plus a third remote chamber operated locally at this site. Note the use of three separate and distinct work surfaces, one for each lock. Also, note the use of rack-mounted PLC and IPC equipment to conserve valuable floor space.

As stated above, the parameters guiding the control room layout will be different between a manual lock and an automated facility. The size and type of traffic, as well as the amount of traffic, should also help determine the location, size, and layout of a lock control room.

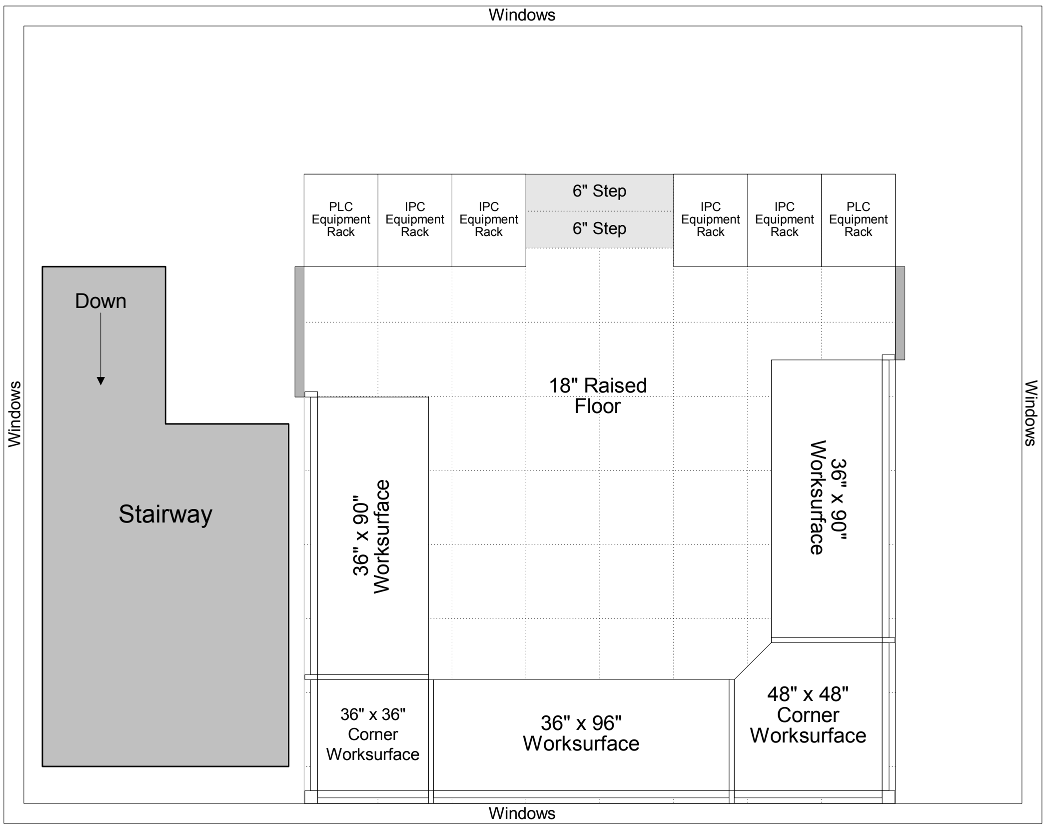


Figure 4-1 Melvin Price Central Control Room

4.2.3.3.1 Automated Systems. Automated systems require much less direct visibility on the part of the lock operator. However, as stated above, this does not mean that direct visibility will not enhance the efficiency of the lock. Designing a control house in an area to provide maximum visibility is a good practice, provided it is economically feasible. Remember that CCTV monitors can be used to provide quick, convenient visual feedback of vessel movement, status of gates, and debris in the water, while direct visibility usually provides better feedback of large, distant areas such as approach forebays. For this reason, a centralized control room usually makes a better system if it is located at a height above the lock wall with a good view of the upstream and downstream lock approach areas. Automated systems usually justify single control rooms for centralized operation of the entire facility by a single operator. Such a control room should be kept relatively small with all the control and monitoring equipment within convenient reach of the operator. Administrative areas, maintenance areas, and visitor accesses should be kept separate from the control room in order to minimize distractions to the operator. A reasonably accessible break room with restroom facilities, stove, microwave, and refrigerator should be considered where possible. Take under review the possibility of providing a means for fresh air ventilation during pleasant weather. These will all help to increase the overall efficiency of the lock.

4.2.3.3.2 Manual Systems. Because manual systems require much more direct intervention by the operator, control rooms must be kept near the lock wall area. This greatly reduces visibility of the lock approach areas and dam or spillway gate areas. A CCTV system can supplement the operator’s efficiency by providing continuous views of these areas. This type of control room will require a different arrangement of equipment because an operator will be moving in and out as they perform lock wall duties, such as operation of a tow haulage unit, that are necessary in a manual control system. Control rooms of this kind will be exposed to weather, traffic, dust, and dirt much more than a centralized control house since they share duties with administrative, maintenance, and visitor access functions. These factors could shorten the life of some control system components and should be a consideration when laying out such a control room. Protection of the equipment and convenience for the operator may be factors that require compromise in the layout of a manual control room.

4.2.3.4 Redundancy. All control systems should be provided with back-up control devices as well as redundant points of control. With the exception of a remotely controlled lock and dam, for which there should always be an on-site control room with full capabilities, the need for redundant control rooms or houses is not justified at most locks. In contrast to a control point, a control room or control house is an area where lock controls, CCTV monitors and controls, marine radios, telephone lines, vessel logging PCs, water level readouts, weather instrumentation readouts, and dam or spillway gate controls are grouped together to facilitate operation of the whole project. The enhanced reliability and piecemeal failure tendencies of modern control and CCTV systems make the probability of a catastrophic control room failure significantly less. This decreases the economic justification for a full blown redundant control room. Consideration should be given to providing local controls near the lock operating machinery. These controls can be in the form of a plug-in pendant, network connections for laptop PC’s, permanently mounted hardwired pushbuttons with pilot lights, or a combination of these depending on the needs of the lock operators and maintenance crews. These stations can be designed as local control points as well as redundant back-up controls for the primary lock control room. Redundant control points in these forms do not add significant cost to the design or construction of a new control system and will go along way to enhance the operator’s confidence in the operational reliability of the project. Often redundant controls can be used to perform maintenance duties without distracting the operator or affecting operation of the lock.

4.2.3.5 Operating Consoles. The operating consoles are the actual point of interface between a lock operator and a computerized control system. A design engineer should spend significant time reviewing all of the factors that make a control system operator interface user friendly, efficient, convenient, and most of all safe. What follows are discussions and guidelines for some of the equipment located on a centralized control console. Ultimately, it will be the responsibility of the designer to provide this equipment, other equipment unique to each lock, and capacity for additional equipment that will be added after lock personnel begin operating the facility. For locks that require smaller more localized consoles, it will be up to the designer to determine the best location for the following control devices.

4.2.3.5.1 Construction. The control console should be designed and constructed to act as a single unit. Modular off-the-shelf component construction is a good choice provided the components are of the same manufacturer and are intended to be connected to act as a single unit. Specifications should provide that all materials including metal, hinges, shelves, finishes, and paint, be of top quality with first rate workmanship and installation. This is important because repair and maintenance of the control console will affect all operations of the lock and dam. Control consoles can be of many different shapes and sizes depending on the type of control room and the functions required. All equipment contained within the control console should be easily accessible from the outside through hinged doors, slide drawers, or easily removed panels. Auxiliary equipment such as 120-volt receptacles, cooling and ventilating fans, filters, uninterruptible power supplies, power strips, radio and radar power supplies, and networking hubs should be specified in the design document. If the consoles are not thoroughly designed as part of the plans and specifications, a contractor or lock operating personnel will try to fit all of this equipment into a console structure that does not have capacity to accommodate it. The result will be an overcrowded and hard to maintain control console. All control console design and construction should include provisions for adding components to the existing structure and expanding the console itself. Equipment that the lock operator does not have need to access such as PLC I/O racks and complex CCTV switching circuitry should not be contained within the operating control console.

4.2.3.5.2 Emergency Stop. The most important control component and the one that needs to have the most convenient access is the hardwired emergency stop button. This device should be located in a conspicuous area on the front of the control console where it will not be inadvertently activated. It is a good idea to provide several emergency stop buttons at locations having good view of the lock that are frequented by operation and maintenance personnel. Emergency stop pushbuttons should be of the maintained type with red mushroom heads. Consideration should be given to illuminating them to indicate when the emergency stop is active. Illuminated pushbuttons can also be programmed to flash to remind the operator that equipment is operating. This may be important if operating from a centralized control room that is remote from the equipment. It also serves as a reminder should the IPCs fail during operations.

4.2.3.5.3 Closed Circuit Television System. While it is a good idea to consider a CCTV system with all lock control systems, automated or remotely controlled facilities require it. With this type of system, because direct visibility will be limited, the CCTV system monitors should be considered the primary means of visual feedback to the operators. It is imperative to locate monitors where they will be convenient to view. Factors such as glare, operator comfort, viewing angle, and accessibility should all be considered when placing CCTV monitors in a control console. Generally, arranging CCTV monitors at a low level near the console worksurface, at a slight incline towards the operator, will satisfy these factors. See Figure 4-2 for an example console showing the CCTV monitors placed at the working level, with control monitors placed above them.

When deciding the number of monitors to provide, a designer should consider that a lock operator needs to monitor several different views of the lock at all times during a vessel lockage. Certain areas of the facility often must be monitored for security reasons or dam and spillway gate movements.

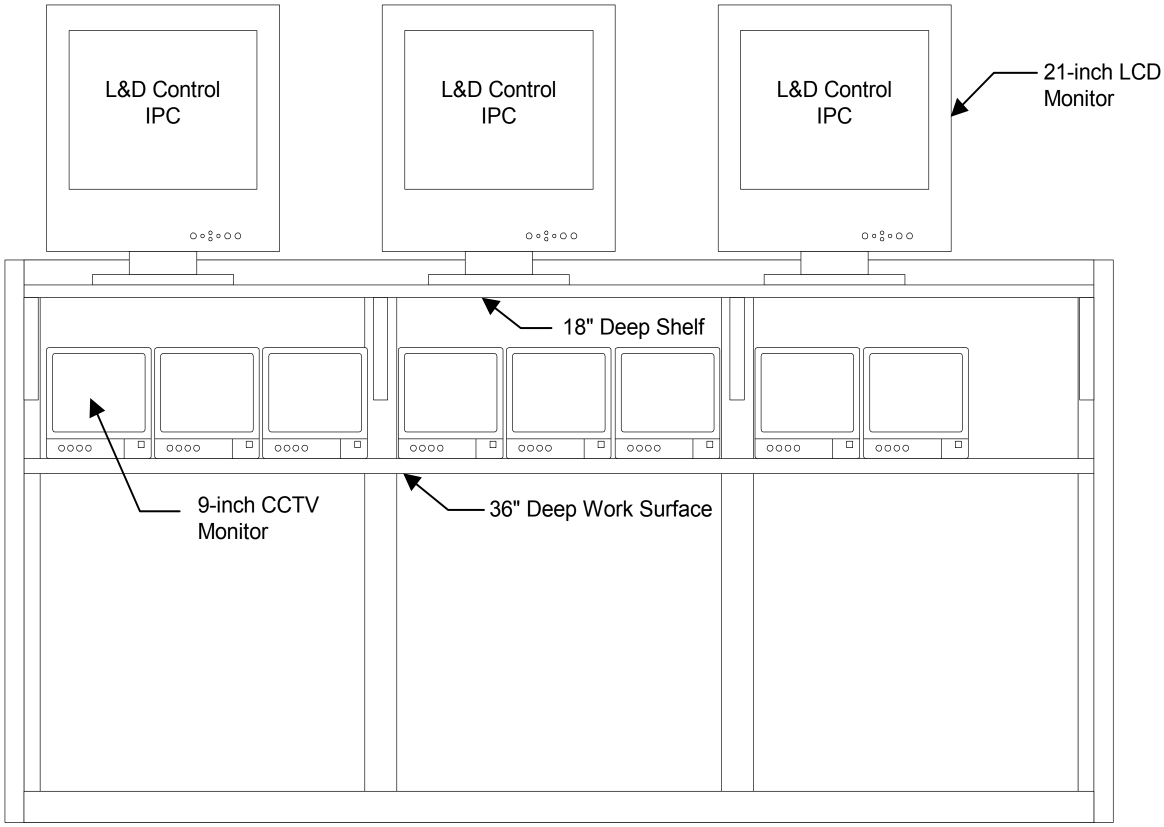


Figure 4-2 Typical Control Console Section

Switching the same monitor between cameras on a continuous basis can be time consuming and inconvenient leading to a tendency not to monitor certain areas of the lock. The cost of adding additional monitors to a CCTV system during the design phase is really not significant considering the long term flexibility, reliability, and redundancy they provide for the system.

4.2.3.5.4 IPC Control Network. The primary means of operating a new lock control system will normally be an IPC network with workstations running an MMI software package. See Figure 4-3 for an example showing the control network used at Melvin Price Locks and Dam. This diagram shows the central control room with three computers for control of each lock. It also shows how they are networked with the rest of the facility.

Because the MMI operating screens are used to convey operator commands to the lock PLC controller, the IPC monitors should be located where, aside from the CCTV monitors, they are the easiest and most convenient control system component to view. Because an operator will often be accomplishing other duties simultaneously while operating the lock equipment, IPC monitors that are located above the CCTV monitors and at approximately shoulder level will provide a good viewing angle for the operator. IPC monitors should be as large as practicable with a recommended minimum quantity of three for each lock chamber. Three monitors will allow the operator flexibility to control different features of a lock and dam without excessively switching screens. Two monitors can be used at small low-usage locks, but this should be considered the minimum. A single MMI screen does not

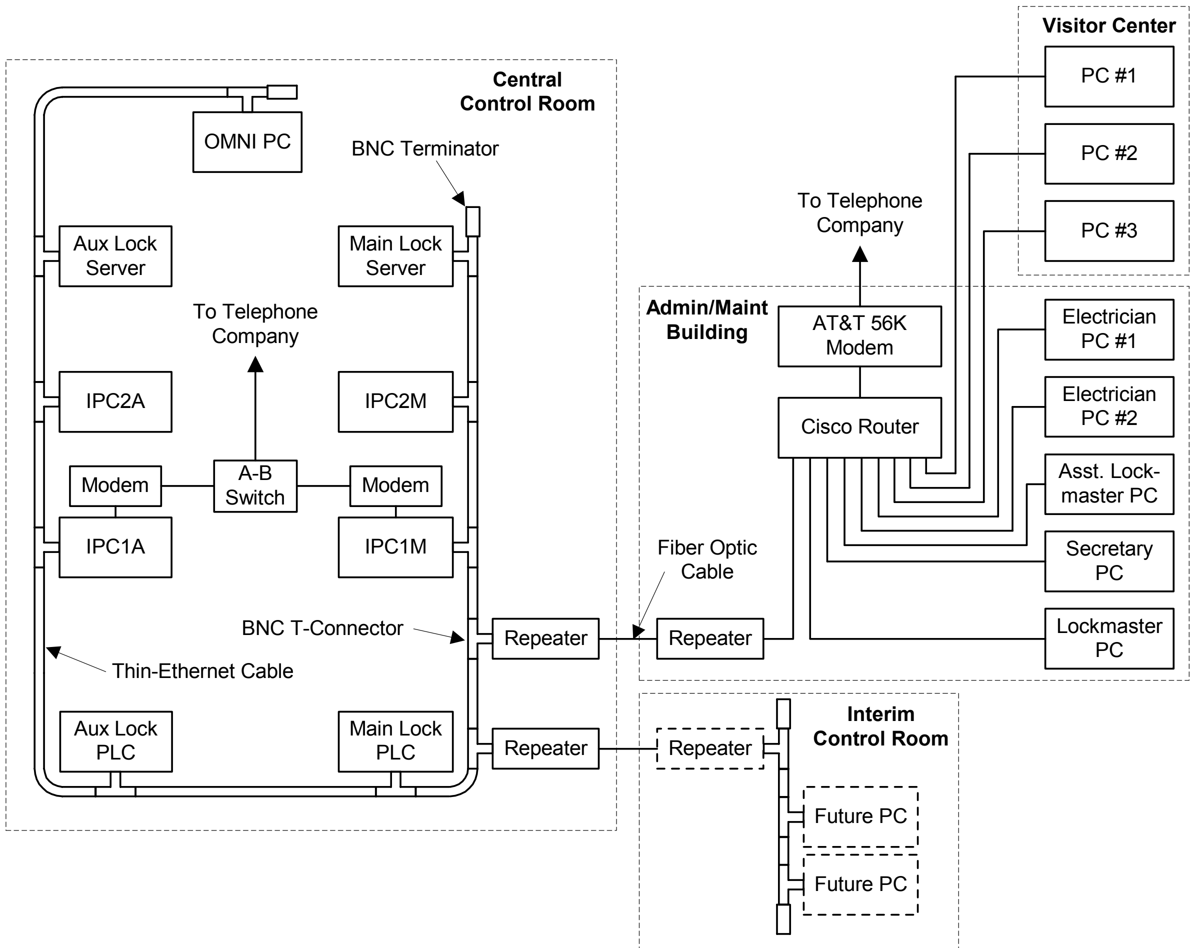


Figure 4-3 Example IPC Control Network

provide any redundancy in case of video display failure. MMI screens often use graphical representations and the monitors should be positioned to give the operator approximately the same orientation as direct visibility would. With a mouse or touchscreen as the primary operator interface, convenient drawers to store keyboards are a good consideration. This will keep the console top clear and allow more space for the operator to do their paper work.

4.2.3.5.5 Vessel Logging PC. Major locks usually have a PC dedicated to logging vessel cargo and lockage information. Busy locks, such as key locks that are the first on a river to enter vessel data, require frequent monitoring and data entering into such a system. An operator will actually spend more time at this computer than at the lock operating IPC network workstations. Therefore, this PC should be located where the operator can conveniently sit down and log information (i.e. at the standard 760 mm (30-inch) desktop elevation with convenient keyboard and mouse, extra space for vessel lists and other paper work, and a comfortable standard office type chair).

4.2.3.5.6 Marine Band Radio. An operator will spend significant time on the marine radio arranging queues, and acquiring vessel cargo information. Lock operators will likely move the radio to several different locations on the console while they are getting used to the new system. For this reason, it is probably not a good idea to provide a permanent location for mounting the radio. Rather provide means to move the radio to any location on the console allowing the operators, after they are accustomed to the new control system, to station the radio where it is most convenient for them.

4.2.3.5.7 Telephone. Unlike the equipment listed above, the telephone is not used with every vessel lockage. The location of the phone is another item that designers will have to rely on lock operating personnel to locate. Strong consideration should be given to consolidating the telephone system and the lock public address system into one integrated telephone communication system with dial-out and paging capabilities. Having such a system installed by the local telephone company will result in a better, more flexible system requiring less space on a control console. Multiple lines, zone ringing, paging, voicemail, and other features will provide even more convenience and efficiency for the lock operators and will cost less than separate telephone and public address systems. This effort should be coordinated with the district Information Management Office, Telecommunications Branch.

4.2.3.5.8 Printers. Providing network printers and/or printers for the vessel logging PC as part of the control console is a good idea. However, printers are not used with every lockage and their location should not compromise the location or accessibility of the CCTV monitors and controls, the IPC network workstations, or whatever direct visibility may be available from the control room. Printers can be shared with maintenance computers.

4.3 Main Control Equipment and Instrumentation.

4.3.1 Programmable Logic Controllers. All new lock and dam control systems should be designed with a Programmable Logic Controller as the control system backbone. The PLC should be off-the-shelf standard equipment from a reputable manufacturer. The PLC is the primary means of control for all lock and dam operating equipment. Power equipment monitoring and plant lighting control are features that can enhance the efficiency, cost, and reliability of a lock and dam facility. The intent of this document is to provide designers guidelines and issues to consider when laying out a new PLC lock control system. Size, communication speeds, capacities, performance parameters, location, and number of PLC components will vary from project to project. Ultimately it will be the responsibility of the designer to determine exactly what system is right for their project.

4.3.1.1 Central Processing Unit. The central processing unit will perform all manipulations to input data, update all outputs, provide the information for MMI software to update operating screens, and accept operator commands from the MMI. The CPU should generally be located near the central control room area but not in the main control console. The CPU is not equipment an operator needs to access on a daily basis. Whenever possible the enclosure housing the CPU should be installed in a dry, low humidity, low traffic, protected area. Only qualified maintenance personnel should have access to the PLC system CPU. Specifying an appropriate amount of memory for the CPU is an important concern when designing a PLC system. Memory usage is different between PLC manufacturers so it is important to specify an amount of memory that provides adequate capacity. Typically CPU memory is specified in terms of K units where each K unit is 1,024 words (two bytes). After becoming familiar with how memory is utilized in several PLCs, designers should determine the maximum memory requirements for the application. There are several rules of thumb, but none can be used without first knowing the approximate number of output points (i.e. real-world outputs plus internal relay coils) in the system. Once that number is known, an estimate must be made for the amount and type of instructions associated with each output (the number of words required for each instruction is dependant on the CPU manufacturer and can be determined by consulting the manufacturer's PLC literature). Then the minimum amount of memory required is simply the estimated memory required for each output multiplied by the estimated total number of outputs. It would be wise to add an additional 25 to 50 percent more memory to allow for changes, modifications, or future expansion.

4.3.1.2 Procurement. Procurement, installation, and programming of the CPU should be provided for in the contract documentation. Particular care should be taken when writing contract specification requirements to include a unit with the highest performance available. Such parameters include the largest amount of memory, fastest communication speed, highest program execution rate (scan time), maximum amount and type of I/O capacity, number and flexibility of communication ports (serial RS-232, RS-422, Ethernet, etc.), special proprietary communication ports, self diagnostics, and the largest set of internal instructions. Compromise may have to be made in order to get the ideal processor for an individual project, but an effort should be made to get the highest quality equipment with the most capacity, performance, and options in order to insure adaptability to future needs. Because PLC equipment does not become obsolete as fast as PCs and software, preparing for future capacity is a good idea. Without well-written complete specifications with well-defined parameters such as those listed above, the designer is at the mercy of the contractor to provide a quality processor. Often the "grade" of processor quality will determine the quality of the rest of the PLC system components and hence a large majority of the cost. A low bid contractor is not going to provide a state-of-the-art top of the line system unless it is well specified in the contract documents.

4.3.1.3 Remote Input/Output. Determining parameters for a good system of input and output PLC components is not necessarily straightforward. Manufacturers often provide several different grades of I/O components for a top-of-the-line CPU. Parameters such as isolation, density of points, response times, operating voltage levels, power requirements, fusing, and LED diagnostics should be considered when specifying I/O components.

4.3.1.3.1 Surge Suppression. Noise suppressors should be used to protect PLC equipment from the voltage transients, spikes, and electrical noise appearing on power circuits. Such noise suppressors would be installed in each I/O rack enclosure and connected to the power supplies feeding each I/O rack. To guard both communication modules and communication cable (metallic only) from damage, I/O interface modules should be protected with overvoltage transient surge suppressors. To accomplish this, a device that suppresses transients caused by lightning, inductive switching and electrostatic discharge must be used. In those applications where an inductive load, such as a motor starter or solenoid, is wired in parallel with an input module, a surge suppressor should be installed. A typical suppressor consists of a 0.5 μF, 400 volt capacitor with a 220 ohm resistor in series. Procurement and installation of these should be coordinated with the PLC manufacturer.

4.3.1.3.2 Digital Input Modules. A designer must first determine the basic requirements for I/O component types in different locations on the lock and dam facility. Where there are “dry contact” type inputs, digital (discrete) input cards should be provided. Such inputs could include traveling nut and mercury cam limit switch assemblies, pushbuttons, selector switches, relay and motor starter auxiliary contacts, vein and/or magnetically operated limit switches, thermostats, and photocells. Digital input cards can be specified to be isolated or non-isolated. Both types serve useful purposes in lock and dam applications, and in some circumstances both types should be provided in the same I/O rack location, even though this increases the required number of spare I/O card types. Certain digital inputs, such as control panel pushbuttons or limit switches on the same assemblies can be grouped together on input cards using a single “reference” or neutral conductor and termination point. Often a single common conductor can be connected to these types of input groups. This requires non-isolated digital input cards. More remote inputs operating at different voltage levels such as photocells, thermostats, and magnetic limit switches should be isolated from other inputs. Select a voltage level for each group of inputs to be the lowest possible without excessive voltage drop or capacitive coupling. In most cases, if voltage drop or capacitive coupling is a problem, an additional I/O rack assembly can be installed to reduce conductor lengths. A voltage greater than 120 VAC should not be used for PLC input systems except in special cases. With the reliability and “hot-shadowing” capability of most I/O power supplies, the recommended PLC control system voltage is 24 volts AC or DC. With the density of points available on today’s small I/O cards, it is usually feasible to use an extra input to monitor power supplies and alert maintenance personnel to failures as well as switching to an alternate unit without interruption in the control system process. A designer should try to maximize the number of I/O points of each type available at each location by specifying the highest available density cards. It is important though not to compromise other features such as isolation just to achieve more I/O points. It is unwise, and will ultimately cost more in inconvenience and downtime than the money saved in first cost, to provide a minimum number of I/O cards, or lower quality I/O cards with more points on each card. Therefore a good rule to follow is to first determine the type of inputs and the requirements for isolation and voltage levels. Next, specify the highest density card that meets these requirements. Specify enough cards of each type to provide a minimum of 100 percent spare I/O capacity beyond any known future expansion plans.

4.3.1.3.3 Digital Output Modules. There are many different types of digital outputs required in a lock and dam PLC control system. Some of the more common types include motor starters, solenoid and motor operated valves, pilot lights, relays and contactors, bells, sirens, and horns. As with digital input cards, some outputs can be grouped together using non-isolated output cards. These outputs, usually pilot lights or relays of the same coil voltage, utilize the same common source and the same neutral wire. Other outputs with varying voltages and/or inductive load conditions require isolated digital output cards, sometimes called relay cards. These types of cards provide a single output for each common, are electrically isolated from other outputs, and can have different voltage levels for each output. All outputs should be fused either internally to the output cards or externally at a power supply or at the load. This protects the card as well as the field wiring. Output loads should be carefully reviewed to ensure they do not exceed the load capacity of the output cards. In cases where the load ratings required are high or marginally high, or have high starting currents such as motors, pilot (interposing) relays should be used to provide a smaller, more consistent load on the output card as well as isolate it from more unpredictable power system faults. When specifying output cards, designers should follow a rule similar to that for input cards. First, determine the need for output cards at different locations in the system. Second, determine the operating voltage level, the need for pilot devices, the need for isolation and fusing, and the quality of card necessary for the system. Third, specify the highest density card that meets all of these requirements including the spare capacity as stated above for the digital input modules. Whenever there is doubt, remember it is easier to remove cards or exchange them rather than add them if there is insufficient space or capacity.

4.3.1.3.4 Analog Input Modules. Analog input devices include rotating shaft encoders, resolvers, inclinometers, pressure transducers, RTDs, and hydraulic cylinder position tracking systems. Most PLC manufacturers can accommodate several different types of analog input signals, often using the same card. Input types include 4-20ma, 0-10v, -10 - +10v, and so forth. When specifying analog input modules it is important to address features such as input current/voltage ranges, number of channels, impedance, resolution, accuracy as a percent of full scale, electrical isolation, shielding, fault detection, update time, I/O bus power requirements, and fusing. Analog signals present a much greater challenge to designers because inaccuracies, without failure, can occur very easily from electrical magnetic noise, improper grounding or shielding, mismatched impedances, or combinations of theses. If these items are not properly addressed by the contract specifications, problems with drifting signals will ultimately occur, possibly after a contractor is long finished with the job. These types of problems can be very difficult to find and correct. Specifying high quality isolated analog input modules will help keep these problems to a minimum. When designing a PLC system with analog inputs, a designer should first determine the location and type (current or voltage with range) of analog inputs required. Where possible, without making signal cables excessively long, these inputs should be grouped together to make use of multi-channel analog input modules. Full scale accuracy and resolution should be determined for each analog input by first determining the accuracy of measurement required to control the system. For example, if a gate raises and lowers a maximum distance of 9 meters (30 feet), and the operator needs to know the position to the nearest 3 mm (one hundredth of a foot), the range of travel is 3000 “counts” with each count equal to 3 mm (one one hundredth of a foot). In addition, say a rotating shaft, 4-20ma analog transducer mounted to the cable drum or chain sprocket produces a 5ma current signal at 0 meters (0 feet) and 15ma current signal at 9 meters (30 feet) of gate travel. To achieve the accuracy required by the operator the PLC analog input card must be able to resolve 10ma of travel into a minimum of 3000 counts. Because the full-scale range of the transducer is 4-20ma or 16 ma this equates to 4800 counts over the full range. This requires an accuracy of 1/4800 or roughly 0.02 percent of full scale, with resolution of 4800 counts or 13 bits of accuracy. Failing to properly perform this type of design analysis can result in a signal or analog input card that is not accurate enough through the entire range of travel to use for effective machinery control or position determination. When physical location, voltage/current range, accuracy, and resolution requirements for each analog input has been established, PLC analog input cards should be specified which meet all of these requirements. If possible a single type of analog input card should be used throughout the entire system. Often a jumper or dipswitch setting is used to configure each channel on a card for different current and voltage ranges. Specifying electrical isolation levels, register update times, and fault detection features help insure that the Contractor provides a quality product. The impedances of the analog input card, the cable, and the transmitting device should be analyzed when determining the voltage level of the power supply that drives the current loop. Shielding should always be accomplished in accordance with written recommendations from both the transmitting device manufacturer and the PLC manufacturer. Signal shield grounds should be isolated from power grounds.

4.3.1.3.5 Analog Output Modules. When motion controllers, variable speed drives, hydraulic linear variable differential transformers, or other control equipment require current loops for speed or position reference, designers may want to use analog output cards to interface the PLC system with such equipment. Because a margin for error exists when using analog control signals, designers should, before deciding to use analog output cards, exhaust all possibilities for digitally integrating such equipment using serial communication standards. This will make a simpler, more reliable control system that will likely be more flexible because of the amount of information that can be transmitted digitally. If, however, it is determined that analog output cards are necessary, the system designer should follow the same steps as outlined above for the analog input modules. Again, the objective is to perform a design analysis on each device that is driven by the analog output points to determine the exact requirements for the output cards, wiring, shielding, and power supplies. Always try to specify the highest quality component available for the system.

4.3.1.3.6 I/O Enclosures. Remote I/O components should be installed in metal enclosures complete with power supplies, power line conditioners, isolators, I/O component racks, ventilating equipment, desiccants, heaters, air conditioners, communication equipment, pilot devices, and uninterruptible power supplies. The enclosure should be NEMA rated as required for the area in which it will be installed with locking door hardware. Outdoor enclosures should be suitably rated and shielded against sunlight if located in direct exposure to the sun. Remote I/O racks should be as required for the type of cards specified and should have at least 50 percent empty slots for future upgrades and expansions. Where applicable, I/O rack addressing should allow for the empty spaces to be used without readdressing an entire program. In order to achieve the goal of a reliable system, it is important that design engineers look at all of the components necessary in the I/O enclosures to insure they are of proper size, rating, and capacity with proper space requirements for dissipation of heat. Calculations should be accomplished for sizing heating, air conditioning, and ventilating equipment. All of this should be given in a design specification so that a Contractor will provide the highest quality equipment helping to ensure a long term reliable system. One of the critical parts of the I/O enclosure design work is the grounding of the electronic and communication equipment contained within the enclosure and the enclosure itself. The National Electric Code does not cover in sufficient detail the grounding of such equipment. Therefore, references to the NEC within plans and specifications do not guide a Contractor very well in the area of electronic ground systems. In general it is wise to keep electronic grounds separate from power and conduit system grounds even if ultimately the two are tied together at some grounding point. Keeping the electronic equipment out of the path of other potential ground surges is important. Input/Output racks, power supplies, communication interface equipment, and other electronic equipment should be mounted to the I/O enclosure metal using rubber or plastic standoffs to isolate them from the enclosure itself. Most electronic equipment is provided with a ground terminal and instructions from the manufacturer on how to ground the equipment. It is very important to properly ground and shield all electronic equipment.

4.3.1.4 Network Configurations. Programmable logic controller systems can be networked in several different configurations. The general guideline is to locate I/O racks in areas where limit switches, motor starters, and solenoids are grouped. Networking of I/O racks on PLC communication channels should be laid out in a design document with consideration given to fail override and redundancy. On navigation locks these guidelines usually require a four-corner I/O rack arrangement with land wall I/O racks on one channel and river wall I/O on another. Some locks may be able to put each I/O rack on its own channel. For general design guidance the following points are offered.

4.3.1.4.1 I/O Rack Location. The first objective is to determine the number and location of system I/O racks. A designer must first survey and chart all the I/O points necessary to operate the lock. This includes all discrete and analog points. Sorting the I/O point list by general location will give the designer an idea of where the I/O points are concentrated. Input/Output racks should be located in areas where a significant number of I/O points are grouped, taking care not to use so many I/O racks that the overall number impacts the availability of the system by increasing the number of failure points. It is difficult to determine what the minimum number of I/O points in an area is that requires installation of an I/O rack. This will vary from project to project and is relative to the overall number of I/O points. An important consideration is the number of lengthy control circuits that can be eliminated by the installation of an I/O rack. An objective that a designer should have in mind is to keep hardwired difficult-to-diagnose I/O circuits as short and accessible as possible. With fiber optic technology, lengthy communication circuits are not only possible but also easy to maintain, diagnose, and repair. Therefore, a designer should not be afraid to specify additional I/O racks in remote areas where there are relatively few I/O points. In any case, an availability analysis should be done to determine the optimum number of I/O racks for the application. In some cases, the analysis may show that fewer I/O racks, with longer cable runs, provides the optimum system availability. In cases where single I/O are remotely located from I/O racks consideration should be given to using optical switches and sensors.

4.3.1.4.2 I/O Rack Networking. After the location of I/O racks has been determined it will be necessary to connect them in a network configuration. While a star configuration offers the most reliability, PLC processors usually do not have enough communication ports to talk to each I/O rack on a separate channel. Therefore it is necessary to group the I/O racks on communication channels. If possible, adjacent locks should be on separate PLC processors. If this cannot be done, the locks' I/O racks should be separated on different PLC communication channels. This isolation will prevent a failure on one channel from shutting down I/O racks on another channel. Input/Output racks used for control of dam or spillway gates should always be on separate PLC network channels from the lock I/O racks for the same reason. Communication between I/O racks should generally be via high quality fiber optic cables as recommended by the manufacturer of the PLC system. Specifications should be so written to provide the fastest I/O network communication speed available. This will help insure that the system the contractor provides is of high quality. All PLC I/O network channels should be provided with redundant "hot-shadow" back-up fiber optic communication cables. Internal diagnostics should alarm that a problem has occurred on a communication channel while the system automatically reverts to the redundant channel without loss in process. Converters, power supplies, and other communication equipment should all be supplied by the PLC manufacturer. A third party may provide such equipment, but only as recommended by the PLC manufacturer. This also will help insure a quality PLC system.

4.3.2 Industrial Personal Computers.

4.3.2.1 General. Industrial personal computers (IPCs) are typically used in critical applications where downtime must be kept to a minimum. IPCs are built to withstand a wide variety of environments. They are specially shielded against electromagnetic and radio frequency interference and certified to meet Federal Communication Commission EMI and RFI regulations. They are also built for a wide range of temperature extremes and can withstand extreme thermal stress. IPCs are built with shock and vibration resistance for rugged and heavy-duty use.

4.3.2.2 System Design. Compared with industrial applications, operation of a lock and dam probably cannot be considered a critical process. If a control computer fails, the worst that can happen is gates stop movement, temporarily trapping tows or preventing water level regulation until operation resumes from alternate hardwired control points. This should not result in costly delays since hardwired means of operating are designed into the control system. A manufacturing plant, on the other hand, cannot tolerate even a few minutes downtime without incurring thousands of dollars in lost earnings. This may raise the question, “Why design computer control systems for locks and dams around IPCs?” This is a legitimate question because of the high initial cost of IPCs. Less expensive non-industrial PCs can typically be purchased for less than half the price of an IPC. Spare PCs can be purchased and kept on hand for quick replacement in the event of a failure. So why design around IPCs? IPCs are designed to last longer than regular PCs for the reasons listed below in the paragraph for computer system hardware. IPC manufacturers typically maintain better quality control than their traditional PC counterparts. They focus primarily on high component quality rather than cost to insure a high overall product quality. They also support their product lines longer than other computer manufactures. Most traditional PC manufacturers have about an eighteen-month turnover rate on their product lines. This means that it is impossible to purchase direct replacements for products this old. IPC manufacturers, on the other hand, typically have turnover rates of three years, or twice as long. They are also committed to providing excellent free technical support for their products. On small projects where the budget is limited, traditional desktop PCs can be used as long as they are placed in an environmentally controlled location, such as a heated and air-conditioned control room. When using traditional PCs, the life-cycle costs of more frequent upgrades should be factored into the total project costs.

4.3.2.3 Standard Products. Only manufacturers regularly engaged in the production of industrial computers should furnish such products. Where two or more units of the same type of equipment are required, they should be of the same manufacturer. This avoids the extra effort to support multiple manufacturers’ equipment. All computer components should be certified to operate with the specified operating system software. For Microsoft operating systems, the components should be listed in Microsoft’s hardware compatibility list.

4.3.2.4 Factory Assembly. When possible equipment should be completely factory assembled. This prevents possible labor disputes in the field about who installs and configures the hardware components.

4.3.2.5 Expandability. Because of the rapid changes in technology and especially new advancements in computer hardware, all hardware should be as expandable as possible. This includes extra physical space for archival devices such as tape backup units, or optical disk storage units, extra physical space for adding interface and controller cards, extra disk storage capacity, extra memory capacity, upgradability of video displays, and the addition of IPCs to the control system. The control system should be flexible enough to allow changes and additions after the system is installed.

4.3.2.6 Environmental Requirements. All computer equipment should be designed to operate without any degradation of performance throughout the following environmental requirements. Equipment should be designed to prevent the generation of electromagnetic and radio frequency interference and should comply with FCC Class B requirements both for emissions and susceptibility. Equipment should be designed for operation in ambient temperatures from 0 to 60 degrees Celsius and 5 to 90 percent relative humidity non-condensing (RHNC). Equipment should be designed to withstand shock of 10g, 3 axis and vibration of 1.5g, 3 axis.

4.3.2.7 Cabling. All cord-connected equipment should be furnished with 3-wire grounded cord and plug assemblies at least eight feet in length. Cables for transmission of digital signals and data between components of the system should be multiconductor, round and shielded with multi-pin Electronic Industries Association (EIA) standard connectors. Connectors should have metal hoods, gold plated contacts and screw or clip-type securing devices. Flat ribbon cables with crimp-on plastic body connectors should not be used except between devices in the same electronic enclosure. Cables should be extendable to long lengths to allow the use of centralized rack-mounted components in lieu of individual desktop or tower units.

4.3.2.8 Spare Parts. Except as stated below, at least one of each major component should be provided as spare. Examples include CPU cards, disk drives, video cards, mouse units, keyboard, network interface cards, network transceivers, network hubs, and so forth. In general, components that would significantly impact operations should be supplied with spares. Typically, this includes adapter cards, but not such components as video monitors. Video monitors can be replaced temporarily with any low-cost monitor until a failed unit can be repaired or replaced. Spares cannot be justified due to the current high cost of large monitors. Likewise, components that do not ordinarily fail, such as IPC chassis, do not need to be provided with spares. Printers, unless critical to operation, also do not need to be provided with spares. Consumables, such as toner cartridges, should be provided as spares to have on hand in case of model discontinuation.

4.3.2.9 Upgrade Frequency. Generally, IPCs used for lock and dam control should require upgrading less frequently than PCs used for other purposes, simply because they are designed to last longer. However, consideration should be given to developing an upgrade plan similar to many Information Management life cycle management plans. These plans typically call for upgrading all microcomputer (not PLC) hardware every five years. There are logical reasons for upgrading IPCs, even if everything is operating smoothly. Manufacturers discontinue support for old product lines. As components fail it becomes increasingly difficult to buy new hardware that is compatible with old versions of the operating system software. Likewise, new device drivers simply are not written for old hardware. When trying to support older hardware, a point of diminishing returns is reached making it almost a requirement to upgrade. Table 4-1 shows the recommended upgrade frequencies for IPCs and PLCs. Note that the frequencies listed are the maximum recommended and should be used strictly as a guideline. Depending on the type of hardware or software, the upgrade frequency may be lower or higher. The frequencies listed are for planned upgrades and not routine maintenance, such as replacement of failed or damaged components.

4.3.2.10 Power System – Uninterruptible Power Supplies. Clean, reliable power is perhaps the most important factor in assuring long life of a computer system. The simplest way to achieve this is through the use of uninterruptible power supplies (UPS). Careful consideration should be given to designing the power supply for the computer system. Large harmonic currents caused by non-linear loads should be reduced with larger, grounded (neutral) conductors and with K-rated transformers suitable for non-linear electronic loads. Note that a UPS is not a harmonic eliminator, and that multiple harmonic generating devices connected to the UPS output could affect each other. The power system design should take into account the harmonic distortion caused by the UPS on its line side. UPS should be separately circuited. For computers centrally located a large, floor mount UPS may be suitable for providing backup power and surge protection. Several smaller floor mount UPS can also be used. For remote standalone computers, a small UPS should be provided. Units should be carefully sized to handle the power loads for all of the computer components, including the IPC chassis and all internal devices, as well as the video display monitor. Peripheral components, such as printers, modems, and network hubs (if serving non-critical IPCs), may or may not need to be provided with continuous power. Consideration should be given to connecting these devices to the UPS, however, to provide them with lightning and surge protection. Rack mounted UPS can be used for rack mounted computer equipment. Depending on the application, several rack-mounted units may be required because of their limited power capacity. It may be beneficial to use UPS that include communications capabilities. The UPS can be monitored and controlled with software through a communication link to the IPCs, or to another PC.

4.3.2.11 Power System – Surge Protection. All computer systems for lock and dam control should be provided with surge protection. As a minimum, voltage surge protection should be provided for each lighting panelboard and at each power distribution panel that feeds computer equipment. It is recommended that surge-protected power receptacles or plug-in strips also be used.

4.3.2.12 Power System – Grounding. Surge protection equipment is only as good as the grounding electrode system. A good grounding system should be installed in compliance with the National Electrical Code. Ground systems at old facilities that are retrofitted or rehabilitated for computer control should be upgraded to meet the needs of modern computer equipment.

4.3.2.13 Rack Mount versus Standalone Systems. For installations where several IPCs are grouped together in a single control room, rack mount systems may offer a better solution than standalone systems. The IPC chassis, power supply bay, drive bay, and CD-ROM bay can all be mounted in a single 19-inch equipment cabinet, located outside of the control room. Monitors, keyboards, and mouse units would be located in the control room and extended with special extender devices. This arrangement provides the ideal arrangement for upgrading, troubleshooting, and maintaining the IPC equipment because all of the major components are contained within the same enclosure. Also, work on the IPCs can be done without disturbing operators. Rack mounted equipment should not limit replacement or retrofit options since industrial computer manufacturers always provide components suitable for rack mounting in standard racks.

Description	Notes	Upgrade Frequency (years)
Control System		
Industrial Personal Computer and Network		
Chassis		8
Power Supply		8
Backplane		5
CPU Board		5
Memory		5
Fixed Drive	Hard Drive, for example	5
Removable Drive or Disk	CD-ROM, Zip, Floppy	5
Video Display Adapter		5
Network Interface Card		5
Keyboard		8
Mouse		8
Monitor		5
Network Hub		7
Network Router		7
Line Conditioner		8
Surge Suppressor		8
Uninterruptible Power Supply (UPS)		8
UPS Batteries		5
System Software		
Operating System Server Software		4
Operating System Workstation Software		4
MMI Software	Version upgrade only	4
PLC System		
Power Supply		15
I/O Rack		15
Processor		10
I/O Interface Module		15
Network Interface Module	Ethernet, for example	10
Fiber Interface Module		15
Digital I/O Module		15
Analog I/O Module		15
PLC System Programming		10
Sensors and Limit Switches		
Rotary Position Sensor		15
Inclinometer		15
Limit Switch		15
Water Level Sensor		15

Table 4-1 Recommended IPC and PLC Upgrade Frequencies

4.3.2.14 IPC Chassis. The chassis should be made of cold rolled steel to provide rigidity and structural integrity and to eliminate EMI emission and static discharge sensitivity. At least one filtered fan should be provided in the front of the chassis for positive air pressurization. This keeps airborne contaminants out of the chassis. A second filtered fan can usually be added for more extreme environments. Most traditional PCs have a single fan mounted on the power supply for cooling. Power supplies should be highly reliable industrial grade, sized to allow for expansion, and equipped with a filtered cooling fan. Other features should include: lockable front panel door to prevent unauthorized access, fixed disk drive shock mounts for protection against vibration, hold-down brackets to insure adapter cards remain firmly seated, and front and rear keyboard connectors. The chassis should be sized to accommodate the required number of slots as well as those required for future expansion (at least one of each type).

4.3.2.15 Processor. Microprocessor technology changes at a rapid pace. IPC manufacturers typically lag behind traditional PC manufacturers by a few months in their development cycle. The key to effective computer control systems is to design around the latest microprocessor technology so that the system is not obsolete by the time it is installed. Working with manufacturers during the design, it is possible to specify components that do not become available until the bid process. This is the optimum situation to guarantee the system is not obsolete, or only marginally obsolete, by the completion of the installation contract. While it may seem like overkill to utilize the fastest and latest microprocessors to control a lock and dam, there are two reasons that justify it. First, using the latest microprocessor insures forward mobility with technology. Incorporation of alternate input technologies, such as voice control, requires powerful processing capabilities. Graphic displays with video and animation also require fast processors. While these features are not currently found in graphic user interfaces (GUIs), it is only a matter of time before they are. These features can be implemented with little change if the computer control system is designed using high-speed computers. Second, utilizing the latest technology extends the lifetime of the computer system. Manufacturers do not support product lines forever. Maintenance and repair become a problem once the manufacturer ceases support. By designing around the latest products, the system lifetime is maximized.

4.3.2.16 Backplane. Most PCs sold today have a single active motherboard with slots for adapter cards. The CPU, memory, and controller circuits are installed on the same motherboard. The passive backplane found in IPCs has several key advantages over the traditional active motherboard based systems. The passive backplane consists almost entirely of adapter slots and has minimal on-board circuitry. It is mounted horizontally on the bottom of the IPC chassis, where the active motherboard in traditional PCs is mounted. This allows the CPU and controller card to be mounted vertically, allowing air circulation, critical to cooling, on both sides of the card. It also prevents the build-up of airborne contaminants on the card's components, thus helping to prevent overheating. The inherently modular aspect of the passive backplane approach makes it possible to achieve improved serviceability, low mean time to repair, simplified troubleshooting, quick problem isolation, and forward mobility with technology. With the passive backplane design, upgrading to a faster CPU is as simple as replacing a card.

4.3.2.17 Controller. The controller is a card that mounts vertically in the CPU slot of the backplane. The controller contains all, or most, of the control components for the IPC. Depending on the type of CPU used, the CPU may be included on the controller card or mounted separately on the backplane. Other components that may be integrated into the controller card include: memory, fixed disk controller, floppy drive controller, SCSI controller, video controller, real time clock, serial ports, parallel ports, speaker controller, keyboard controller, and mouse controller. Depending on the model, many of these components require ribbon cables to connect to the actual device. Serial and parallel ports may require additional brackets to accommodate connectors. Because video capabilities continue to change, it is probably better to use controller cards that do not include on-board video controllers. Not only is it easier to update a separate video controller card, it also reduces the possibility of a video failure propagating through the controller card and damaging other components, forcing a complete replacement of the entire controller card.

4.3.2.18 Memory. The operating system and man-machine interface (MMI) software will determine the amount of required memory. Consideration should be given to providing the maximum possible amount of memory to insure optimum performance and to allow for future software upgrades. The IPC manufacturer should be consulted when specifying particular types of memory.

4.3.2.19 Storage Devices. There are new storage technologies emerging all the time. Magnetic storage is currently widely used, but the limitations of this technology will force development of new ones. It is important to consider these new technologies to insure forward mobility with technology and to maximize the lifetime of the system, while also avoiding the mistake of adopting unproven and short-lived technologies.

4.3.2.20 Hard Disk Drive (Fixed Drive). Hard disk drives are currently the storage technology of choice for most computer users. The cost per megabyte of storage has decreased dramatically. IPCs should be provided with hard drives sized large enough to accommodate the operating system, MMI software, and other application software required for control. Consideration should be given to future operating system upgrades and future application software upgrades. New versions of software are rarely smaller in size than old versions. Transfer speed is another consideration when selecting a hard drive. Older interfaces, such as SCSI, have traditionally provided the fastest transfer speeds, but other interfaces, such as EIDE and ATA are rapidly closing the speed gap.

4.3.2.21 Floppy Disk Drive. Floppy drives provide a convenient method of copying small files between non-networked PCs. Advances in floppy drive technology have provided drives that store many megabytes, yet are backward compatible with older, limited capacity, floppy disks. Again, consideration should be given to these new types of drives, especially because file sizes are quickly outgrowing the capacity of older style floppy disks.

4.3.2.22 CD-ROM Drive. Much commercial software is distributed on CD-ROM. Microsoft Windows NT Server, for example, is only available on CD-ROM. The reason for this is cost. It is much less expensive to write a CD than to write hundreds of floppies. It also makes it much more convenient to install the software. For these reasons CD-ROM drives should not be treated as optional and should always be provided with IPCs.

4.3.2.23 Tape Backup Drive. Unless a great deal of data logging is planned, tape backup drives are difficult to justify in IPC systems used for lock and dam control. Such systems should have more than one IPC networked together. Important data files such as PLC software or MMI screens and databases should be backed up to all IPC hard drives so that if one IPC fails, the files can be restored across the network from one of the functional IPCs. Important files should also be backed up to removable disk and stored off-site in case of natural disaster or catastrophe. Operating system and application software can be restored from original CD-ROM discs. Consideration should be given to complete system rebuilds, that is reformatting and reinstallation of all software, in the event of regular system crashes. The district should have a plan in place for such an event.

4.3.2.24 Removable Disk Drive. This type of drive is growing in popularity and provides a convenient method of backing up large files for removal off-site. These drives come in internal and external versions. The external versions can interface to the IPC's parallel port or SCSI port. The parallel version is considerably slower, but offers more flexibility because most computers have parallel ports, but not all have SCSI ports. The entire external drive can easily be taken off-site so that the removable disk can be copied to or read from another computer. If removable disk drives of the same type and compatibility are available off-site, then it makes more sense to use an internal removable disk drive in the IPCs. Internal drives are faster and take up less space than external units.

4.3.2.25 Input Devices. Input devices include keyboards, mouse units, and touch screens. Other input technologies, such as voice, may be used in the near future.

4.3.2.26 Keyboard. Because of its widespread use, standard IBM AT keyboards should be used with IPCs. Small footprint versions may be used depending on console design. Custom-built consoles or racks with pullout drawers may be used to house keyboards. Protection against dust and liquid contaminants can be achieved using protective keyboard overlays.

4.3.2.27 Mouse. Mouse units are the preferred input devices for lock and dam control. Either a standard two-button Microsoft compatible mouse or a heavy-duty unit can be used. Considering the heavy 24 hour-per-day, 7 day-per-week use of an IPC, a mouse with no moving parts may be justifiable. Traditional mouse units are prone to clogging from dust and dirt and require regular cleaning for proper operation.

4.3.2.28 Touch Screen. Touch screens come in several varieties, including infrared, surface acoustic wave (SAW), and resistive types. Experience has shown that operators prefer the tactile feedback of a mouse to touch screens. Of the touch screens implemented for lock and dam control, the SAW type is less prone to false inputs. The infrared type touch screens are best used in applications that required a second acknowledgment for confirmation of each input. SAW type touch screens are much more forgiving due to their design. They require firm pressure applied to the screen before registering as an input.

4.3.2.29 Video Display System. The video display system consists of a CRT or LCD video monitor and a compatible video adapter.

4.3.2.29.1Video Display Monitor. There are two common types of video display monitors: cathode ray tube (CRT) and liquid crystal display (LCD). Advantages of CRT monitors are low cost, excellent picture quality, and wide availability in large sizes. Disadvantages of CRT monitors are excessive heat generation and large footprints. Experience has shown that CRT video monitors are prone to phosphor burn-in from extended continuous use. The same images are displayed on the screen and results in damage to the monitor. Newer monitors are less prone to this problem, however. CRT video monitors also generate a lot of heat, require a large footprint, and consume a lot of power. They also are difficult to view in bright sunlight without special overlay filters. Recent advances in LCD flat-screen video monitors are making them an appealing alternative to CRT types. Advantages of LCD monitors are low heat generation, small footprint, and light weight. LCD flat-screens are available in large sizes, high resolutions, and wide viewing angles. Power consumption is typically less than half that of CRT monitors and heat generation is correspondingly less. Their flat design, small footprint, light weight, wide viewing angle, and brightness are ideal for lock and dam control. Note, however, that there are many flat screen display manufacturers and that not all models are equivalent. The primary characteristics to look for are high resolution and wide viewing angles typically found in CRT monitors. The big disadvantage of LCD monitors is their high price. Large flat screen displays are very expensive compared to CRT displays. In the long run, however, flat screens may pay for themselves because of their improved design.

4.3.2.29.2 Video Adapter. A suitable video display adapter, compatible with the video display monitor, should be provided separate from the IPC controller card. The adapter should provide resolution and colors compatible with or better than the video display monitor's. Video memory for 24-bit color (65,536 colors) can be calculated as follows:

$$\text{Bytes Required} = \frac{X \text{ pixels} \times Y \text{ pixels} \times 24 \text{ bits per pixel}}{8 \text{ bits per byte}}$$

Round up to the next multiple of 2 megabytes.

4.3.2.30 Sound System. Sound should be considered as a form of feedback to the operator. While not absolutely necessary for control, it can enhance the user interface by augmenting visual feedback with audio information, such as voice acknowledgment or warning alarms. A sound system should be provided to insure forward mobility with technology.

4.3.2.30.1 Sound Card. The sound card should be from a reputable manufacturer widely used by computer users. The card should have at least 16-bit stereo sound with playback rates from 5 kHz to 44.1 kHz minimum, be capable of recording using microphone, stereo line-in, and CD-audio inputs, and include its own output power amplifier.

4.3.2.30.2 Speakers. Stereo speakers should be provided to match the output power from the sound card, and have a frequency range of at least 95 Hz to 16 kHz.

4.3.2.31 Printing. Printers are convenient during the development and testing stages of a new control system, but can also be used for data logging and vessel report generation during normal use. Consideration should be given to using networked printers so that any IPC on the network can print to all of the printers. This provides the most flexible printing arrangement. With Windows NT, printers can be connected directly to one IPC's parallel port and shared for all IPCs to use. Alternatively, and perhaps the more flexible arrangement, printers can be provided with their own network interface card so that they act as an addressed network device. This allows IPCs to be shut down without disrupting printing capability.

4.3.2.31.1 Black and White Printers. A black and white laser printer should be used for normal printing. It should be a printer intended for heavy business use to insure high quality. Important features include a fast print speed and sufficient memory to print high-resolution graphics. The printer should be capable of accepting a network interface card compatible with the network, but should also include a compatible parallel interface. The printer should be provided with large-capacity (500 sheets, or one ream) trays for holding paper.

4.3.2.31.2 Color Printers. Currently, the high cost of color laser printers makes it difficult to justify them for use at a lock and dam. An inexpensive alternative is the color ink-jet printer. This type of color printer is acceptable for the occasional need to print color, such as printing MMI screen images. Print speed is not as much of a concern as for black and white laser printers since the color printer will be used much less frequently. Enough memory should be provided to allow printing of high-resolution color graphic images. As with the black and white laser printer, it should be capable of accepting a network interface card compatible with the network, but should also include a compatible parallel interface.

4.3.3 Networks.

4.3.3.1 Network Fundamentals. It is important to review the fundamentals of networks before discussing their application to lock and dam control systems. A network is a group of two or more computer systems linked together. There are many types of computer networks, including local-area networks (LANs) and wide-area networks (WANs). With LANs the computers are geographically close together (that is, in the same building or group of buildings). With WANs the computers are farther apart and are connected by telephone lines or radio waves. In addition to these types, the following characteristics are also used to categorize different types of networks.

4.3.3.2 Topology. The geometric arrangement of a computer system. See Figure 4-4 for the three principal topologies used in LANs.

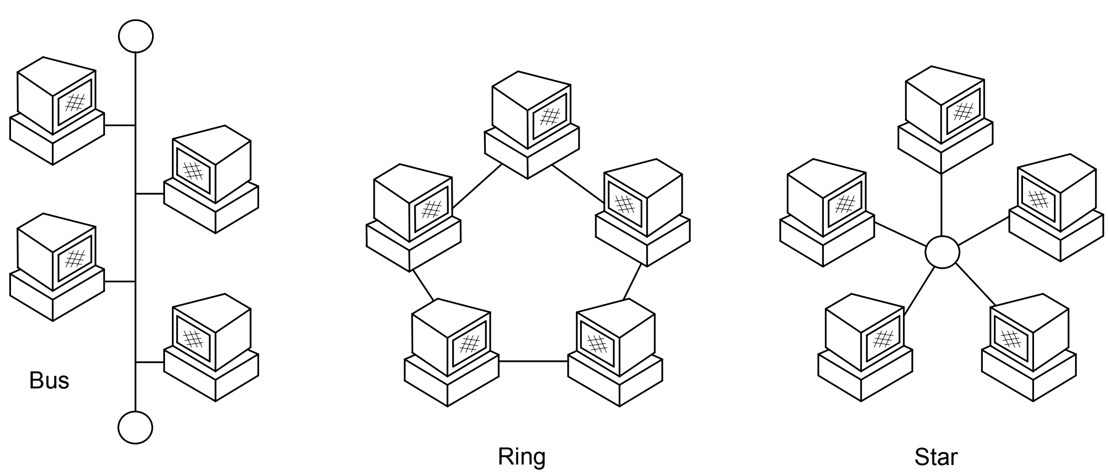


Figure 4-4 Principal LAN Topologies

- Bus Topology: All devices are connected to a central cable, called a bus or backbone. Bus networks are relatively inexpensive and easy to install. Ethernet systems use a bus topology.

- Ring Topology: All devices are connected to one another in the shape of a closed loop, so that each device is connected directly to two other devices, one on either side of it. Ring topologies are relatively expensive and difficult to install, but they offer high bandwidth and can span large distances.

- Star Topology: All devices are connected to a central hub. Star networks are relatively easy to install and manage, but bottlenecks can occur because all data must pass through the hub.

Variations on these topologies exist. The bus and star topologies, for example, can be combined to form a hybrid LAN. This arrangement is useful where several remote IPCs need to be networked to a central LAN, such as in a control room. The remote IPCs connect back in a star configuration to a network hub that is connected to a local bus. See Figure 4-5 for an example of a hybrid LAN. This topology has worked well at Locks No. 27 on the Mississippi River.

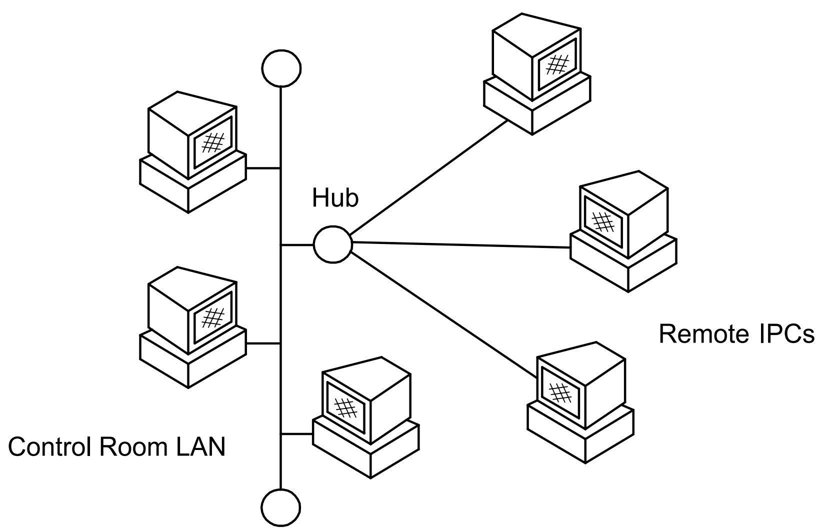


Figure 4-5 Hybrid Bus and Star LAN Topology

4.3.3.3 Protocol. The protocol defines a common set of rules and signals that computers on the network use to communicate. One of the most popular and widely used protocols for LANs is called Ethernet. Ethernet was developed by Xerox Corporation in cooperation with DEC and Intel in 1976. Ethernet supports a bus topology and supports data transfer rates of 10 Megabits per second (Mbps). The Ethernet specification served as the basis for the IEEE 802.3 standard, which specifies the physical and lower software layers. Different physical layer versions include 10BASE-2 (ThinNet coaxial cable), 10BASE-5 (ThickNet coaxial cable), 10BASE-T (twisted-pair wires), and 10BASE-FL (fiber optic cable). A new version of Ethernet, called Fast Ethernet, supports data transfer rates up to 100 Mbps. The IEEE standard for Fast Ethernet is 802.3u. Different physical layer versions include 100BASE-TX (two pairs of high quality twisted-pair wires), 100BASE-T4 (four pairs of normal-quality twisted-pair wires), and 100BASE-FX (fiber optic cable). An even newer standard, called Gigabit Ethernet, supports data rates of 1 Gigabit per second (Gbps). There are two IEEE standards for Gigabit Ethernet: 802.3z for fiber and

802.3ab for copper wires. Different physical layer versions include 1000BASE-SX, 1000BASE-LX, and 1000BASE-T.

4.3.3.4 Architecture. Networks can be broadly classified as using either a peer-to-peer or client/server architecture.

4.3.3.4.1 In a peer-to-peer network each workstation has equivalent capabilities and responsibilities. Peer-to-peer networks are generally simpler and less expensive, but they do not offer the same performance under heavy loads.

4.3.3.4.2 In a client-server network each computer or process on the network is either a client or a server. Servers are powerful computers or processes dedicated to managing disk drivers (file servers), printers (print servers), or network traffic (network servers). Clients are PCs or workstations on which users run applications. Clients rely on servers for resources, such as files, devices, and even processing power.

4.3.3.5 Network Considerations for Lock and Dam Control. The same considerations apply to lock and dam networks that apply to any sizeable network. They include reliability, availability of management and troubleshooting tools, scalability, and cost.

4.3.3.5.1 Reliability. Highly reliable networks are critical to the success of a network at a lock and dam, so ease of installation and support are primary considerations in the choice of network technology. Ethernet networks are by far the most widely used, representing more than 83 percent of all installed networks by the end of 1996. Because of this popularity, equipment and wiring systems have become increasingly reliable. They are also relatively simple to understand and administer.

4.3.3.5.2 Availability Of Management And Troubleshooting Tools. Management tools for Ethernet, made possible by widespread adoption of management standards including Simple Network Management Protocol (SNMP) and its successors, allow an administrator to view the status of all desktops and network elements, including redundant elements, from a central station. Ethernet troubleshooting tools span a range of capabilities, from simple link indicator lights to sophisticated network analyzers. As a result of Ethernet's popularity, large numbers of people have been trained on its installation, maintenance, and troubleshooting.

4.3.3.5.3 Scalability. The Fast Ethernet standard, approved in1995, established Ethernet as a scalable technology. Now, the development of Gigabit Ethernet extends the scalability of Ethernet even further. Independent market research has indicated a strong interest among network users in adopting Gigabit Ethernet technology, specifically Fast Ethernet hubs and switches with Gigabit Ethernet uplinks, Gigabit Ethernet switches and repeaters, and Gigabit Ethernet server network interface cards (NICs).

4.3.3.5.4 Cost. Prices for Fast Ethernet hubs, switches, and NICs have decreased rapidly overall. Although initially expensive, Gigabit Ethernet technology is expected to track the rapid decrease in price of Fast Ethernet technology.

4.3.3.6 Network Design for Lock and Dam Control. To design a reliable network, it is important to understand some of the limitations of the different technologies available and to decide which features are required for the particular application. An important design consideration for a lock and dam network is the size of the facility. If the lock and dam is controlled from a single point, with no plans to add control points away from the main control room, then distance is not a problem. However, for distributed control, in which control points may be hundreds, or thousands, of feet apart, distance becomes a critical factor in the design of the network.

Table 4-2 shows that Fast Ethernet and Gigabit Ethernet may only be implemented at large facilities with widely separate control points using fiber optic cable. In most instances, Fast Ethernet will also require fiber optic cable between distant control points. For 183 and 366 meter (600 and 1200 foot) locks control points located at each end of the lock exceeds the maximum network distance for copper wiring for all speeds except 10 Mbps Ethernet.

Table 4-2 Rules for Maximum Network Distance

	Ethernet 10BASE-T	**Fast Ethernet 100BASE-T**	**Gigabit Ethernet 1000BASE-X**
Data Rate	10 Mbps	100 Mbps	1 Gbps
Cat 5 Unshielded Twisted Pair	100 m (min)	100 m	100 m
Shielded Twisted Pair/Coax	500 m	100 m	25 m
Multi-mode Fiber	2 km	412 m (half duplex) 2 km (full duplex)	500 m
Single-mode Fiber	25 km	20 km	3 km

4.3.3.6.1 Noise. Another important consideration in network design is noise from radio and electromagnetic interference. Locks and dams can be extremely noisy environments, especially with large motors, variable speed drives, and so forth. Lightning and surge protection is another important consideration. Fiber is naturally suited to protect against noise, lightning, and surges because it is non-conductive, using glass as the media of transmission instead of copper.

4.3.3.6.2 Operating Plan. During design of the network an operating plan must be developed, a network topology based on the operating plan must be selected, a suitable network protocol must be selected, and the network architecture must be selected. The operating plan includes selection of operating locations, number of control points at each location, and primary versus secondary control points.

4.3.3.6.3 Operating Locations. The operating locations may include a central control room with backup control points situated at strategic locations at opposite ends of the lock chambers. At each of these control points the total number of operating workstations must be determined. Typically, primary control points, or those that are used for normal operation, may have two workstations in case one fails. Secondary, or backup, operating points may have only one workstation depending on how critical and how frequently that location is used.

4.3.3.6.4 Operating Points. Using the maximum network distances as a guideline, the operating points should be grouped by distance of separation. Those that are within 100 meters of each other should be considered local, while those beyond 100 meters should be considered remote. One operating point should be selected as the primary control point if there is no central operating location. The most logical network topology should become clear naturally from this analysis. In most instances, the topology will be the bus topology, star topology, or a combination of both.

4.3.3.6.5 Protocol Selection. Next, the network protocol must be selected. Ethernet is the protocol of choice, but consideration should be given to other protocols depending on the application. Ethernet has several shortcomings of which network designers should be aware. Foremost is the fact that it is a non-deterministic protocol. This means there is no guaranteed time in which communication between two or more nodes has been completed. This is probably not a problem for lock and dam control, but some industrial applications require determinicity to insure control of critical processes. The designer should keep this in mind when designing the network, especially since most programmable logic control (PLC) systems are deterministic. Reflective Memory Network is quickly becoming the standard for determinicity protocols.

4.3.3.6.6 Architecture Selection. Finally, the network architecture must be selected. The client-server model is the architecture of choice. There are applications where a peer-to-peer architecture is suitable, such as when only two or three IPCs are networked, but the client-server architecture provides several key benefits. One benefit is simple network administration. The server provides user authentication so that a common user profile can be used for all users. A common user profile insures that all IPCs present the same interface for each user who is configured to use the profile. This means that if the user makes changes while logged in or accidentally deletes icons or reconfigures the system, it reverts back to the original configuration the next time they log in. Another benefit is the ability of clients to access shared resources on the server, such as databases, printers, or modems. A third benefit of client-server systems is scalability. They can be scaled horizontally or vertically. Horizontal scaling means adding or removing client workstations with only a slight performance impact. Vertical scaling means migrating to a larger and faster server machine or multi-servers.

4.3.3.7 Design Details. Once the network is designed, the details can be completed. This includes selection of hardware and software (operating system).

4.3.3.7.1 Network Routers. Routers are used for controlling communications between two locations. Routers are typically not used in lock and dam networks. They are used, however, to provide control communication from the lock and dam back to the district office for the lock performance monitoring system (also known as OMNI system). Routers may have application in remote control of locks and dams. The network should be designed keeping the option of remote control in mind.

4.3.3.7.2 Network Hubs. A hub is the center of a star topology network system. Hubs can be used to convert between different physical network media, such as fiber to twisted pair and vice versa.

4.3.3.7.3 Network Repeaters. Repeaters are used to extend the length, topology, or interconnectivity of the physical network medium beyond the limits imposed by a single segment. They perform the basic actions of restoring signal amplitude, waveform, and timing applied to normal data and collision signals. The designer should be aware that there are limitations in extending networks using repeaters and plan the network accordingly. For example, repeaters add delay when re-transmitting communication signals. The overall delay for all repeaters in a chain must not exceed the acceptable limit.

4.3.3.7.4 Network Interface Cards. Network interface cards (NICs) provide the connection between the computer and network. NICs are available in many varieties for connection to ThinNet, ThickNet, twisted pair, and fiber networks. Consideration should be given to using the type of NIC best suited for direct connection to the network. For example, fiber NICs should be used for direct connection to fiber media, without converting to a different media using a transceiver. The drawback to this approach is that more than one type of NIC is required for the computers attached to the network. The advantage of this approach is that fewer components are required and the system reliability consequently should be higher.

4.3.3.7.5 Network Transceivers. Network transceivers provide a single physical connection between standard Ethernet and Ethernet communication equipment. Transceivers are typically used to convert between media types. For example, a 4-port hub with ThinNet network connection and AUI (attachment unit interface) ports may be available while the same unit with fiber ports is not. Fiber can be connected to the AUI ports using fiber-to-AUI transceivers. This is an important consideration in network design because communication equipment is not always available in the desired configuration and port types.

4.3.3.7.6 Dial-Up Networking. Dial-up networking is becoming increasingly popular. A dial-up network router is typically attached to the LAN and is provided with analog telephone ports. The router allows remote users to dial into the network and access it off-site for software maintenance and troubleshooting. The router should support TCP/IP, IPX routing, PPP, and Multilink PPP (MP) protocols. It should also provide user authentication for security management and firewall technology as an option. Proper Corps of Engineers security measures should be implemented and coordinated with Information Management and District Security offices.

4.3.3.7.7 Wireless Networking. For rehabilitated locks and dams, as well as new facilities, wireless LANs may provide an excellent alternative or supplement to wired versions. For control points that are very infrequently used for operation, for example, it may make more sense economically to operate from that location with a notebook computer equipped with a wireless Ethernet card. Such devices can interface with existing Ethernet LANs and operate at high data rates up to 3 Mbps using frequency hopping spread spectrum technology at 2.4 GHz. The range of wireless LAN devices varies from one to several kilometers(3,000 feet to several miles) depending on the antenna used. Wireless LANs also allow mobility and roaming; gates can be operated while positioned at the gate. This ability to operate equipment from anywhere can be invaluable for troubleshooting and maintenance.

4.3.3.8 Cabling. Good network cabling is essential to a reliable network. There are essentially three types of cables used for transmission in a network: coaxial cable, twisted-pair cable, and fiber optic cable.

4.3.3.8.1 Coaxial Cable. A type of wire that consists of a center wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference. 10BASE-2 (also called ThinNet) is one adaptation of the IEEE 802.3 Ethernet standard and uses 50 ohm coaxial cable (RG-58 A/U) with maximum lengths of 185 meters. This cable is thinner and more flexible than that used for the original 10BASE-5 (also called ThickNet) Ethernet cabling standard and is both less expensive and easier to install. The maximum cable length in 10BASE-5 is 500 meters. Cables in the 10BASE-2 system connect with BNC connectors. Network devices connect to the network with a T-connector so that cables can connect to other devices. Any unused connection must have a 50 ohm terminator.

4.3.3.8.2 AUI. Short for Attachment Unit Interface and is part of the Ethernet standard that specifies how a cable is to be connected to an Ethernet card. AUI specifies that a coaxial cable connects to a transceiver that plugs into a 15-pin socket on the network interface card.

4.3.3.8.3 Twisted-Pair Cable. A type of cable that consists of two independently insulated wires twisted around one another. One wire carries the signal while the other wire is grounded and absorbs signal interference. Twisted-pair cable is the least expensive type of LAN cable. 10BASE-T is one adaptation of the IEEE 802.3 Ethernet standard and uses a twisted-pair cable with a maximum length of 100 meters. 100BASE-T (also called Fast Ethernet) is another adaptation of the Ethernet standard and is ten times faster than 10BASE-T. Cables in both systems connect with RJ-45 connectors. Star topologies are common in 10BASE-T and 100BASE-T systems.

4.3.3.8.4 Fiber Optic Cable. A type of cable that uses glass or plastic fibers to transmit data. A fiber optic cable consists of a bundle of glass threads, each of which is capable of transmitting messages at close to the speed of light. Fiber optic cables have several advantages over traditional copper communication lines: fiber optic cables have a much greater bandwidth which means that they can carry more data, fiber optic cables are less susceptible to electromagnetic interference, and fiber optic cables are much thinner and lighter than copper wires. The main disadvantage of fiber optics is that the cables are expensive to install. There are two basic types of fiber: multimode and single mode. Multimode fibers have a large core (25 to 300 μm) and permit nonaxial light rays or modes to propagate through the core. Single mode fibers have a small core (5 to 10 μm) and allow only a single light ray or mode to be transmitted through the core. This virtually eliminates any distortion due to the light pulses overlapping as in multimode fiber. Multimode fiber is more commonly used in small LANs while single mode fiber, because of its higher capacity and capability, is used for long distance transmission. Telephone companies typically use single mode fiber because of its ability to transmit long distances without the need for repeaters. There are a variety of connector types for fiber optic cable. Two common ones are ST and SMA. ST connectors are metal with a “straight tip” and are the preferred type. They join by pushing and twisting. SMA (Sub Miniature Assembly) connectors are used with multimode fiber and are screw-on type. Both types of connectors are available with metal, plastic, ceramic, and glass tips.

4.3.4 Motor Control Centers. The demarcation point between the PLC/IPC computerized control system and the traditional electrical distribution and control system is the motor control center, or in some cases a 480-volt switchboard type motor controller enclosure. With new lock construction, or rehabbed lock electrical distribution and control systems, consideration should be given to using standard 90-inch off-the-shelf motor control center construction. This type of construction allows for easy future additions or changes to the distribution system. It also allows monitoring and control of the power distribution equipment contained within the MCC. Programmable Logic Controllers, "intelligent" circuit breakers, network lighting panels, automatic transfer switches, variable speed drives, and "smart" relays and motor starters are just some of the control features available with standard MCC construction. As with any electrical component there are high quality and low budget MCC components and it will take solid specifications for a low bid contractor to provide quality components throughout the MCC system. Traditional guide specifications are a good place to start preparing plans and specifications, but many of the features mentioned above and herein are not included in the guide specifications. Therefore, a designer must pay particular attention to the needs of the lock control system when designing the MCC system. This is not intended to be a design document for specifying motor control centers, but rather guidance for the designer when designing MCC systems. Following are some general guidelines for this effort but the designer will be responsible for determining the features necessary for a particular system.

4.3.4.1 Number, Size, and Location. Unlike smaller, less costly PLC I/O racks, redundancy in MCC applications comes with a high price. However, the addition of extra vertical structures and empty buckets allows for future expansion as the number of loads increase. For traditional locks of medium 183 m x 33.5 m (600 ft x 110 ft) to large 366 m x 33.5 m (1200 ft x 110 ft) size, a four corner MCC arrangement, with perhaps a main distribution MCC or switchboard, will serve the project well. Most electrical loads can be fed from one of four MCCs located near the four miter gates. Some older and/or smaller locks may require only one or two MCCs or 480-volt switchboards to handle control and distribute power to all lock loads. When designing MCC systems for new lock construction, a designer should first consider a four-corner arrangement. Most new facilities can economically support such an arrangement and most loads can be fed from one of four corners without significant over-sizing of conductors to account for voltage drop. Loads located on the dam can usually be served from standalone 480-volt gate controllers and/or distribution panels. When rehabbing existing projects it may be economical to install new MCCs in the same locations as the existing electrical distribution gear to be removed to take advantage of existing raceways or other features of the project. However, when considering expensive lock closure time, it may actually be more economical to place new motor control centers in different locations to facilitate installation and pulling of cables prior to lock closure. Rehabbed lock and dam projects may not always require the same number of new MCC structures as the original construction. Loads are usually added, changed, or moved on the system creating a need for more MCC capacity on a structure. Existing switchboards on old projects may have been overloaded over the years, and a designer may want to distribute the loads differently with a new MCC arrangement. After grouping all electrical loads by MCC location, ampacity, duty cycle, and diversity factor, load factor calculations should be done to determine the rating of the main circuit breaker and horizontal bus at each MCC. Consideration should always be given to future expansion when making final determination of MCC ampacity ratings. Following this determination, the designer should perform short circuit, motor start, and coordination calculations to determine AIC ratings and circuit breaker types and settings. When rehabbing a project, if the existing MCCs or switchboards are located in a building or control house it is a good idea to locate the new MCCs in such protected areas. Often there is a location in the control house where a new MCC can be located prior to removing the existing gear during lock closure. This decision goes beyond the individual designer although they will have a big part in providing all the information for making such a decision. The more construction activities that are moved outside the lock closure window, the better chance the contractor will have of completing the work on time and reopening the lock on schedule. On construction of a new lock, the electrical designer should lobby for protected areas to install MCCs. These areas should have easy access to gallery cable tray systems or lock wall conduit banks, sufficient access for maintenance, and elevation out of flood plains if possible.

4.3.4.2 Distribution Arrangement. Electrical distribution to remote MCCs will vary by project with no one arrangement clearly better than the rest. After locating and sizing the lock motor control centers, the designer must size and locate feeders to each MCC unit. This effort will require ampacity, voltage drop, and future expansion calculations. Designers should always provide alternate feeders to each MCC to continue power in the event of feeder failure. Redundant interlocked circuit breakers should be provided at each MCC to facilitate isolation of the two feeders. In a four corner arrangement, consider providing a main MCC or 480-volt switchboard for distributing redundant feeders to each MCC. At facilities with one or two MCCs, consider providing redundant feeders and control circuits to loads located at significant distances from the MCCs.

4.3.4.3 Motor Starters. Appropriately sized starters should be provided for each 480-volt motor load on the project. Starters should be provided with sufficient auxiliary contacts to provide both hardwired and PLC feedback. It is always a good idea to have extra contacts for future use. Overload heaters should be provided with auxiliary contacts for input to the PLC system. This will provide enhanced remote trouble-shooting capabilities. Solid-state motor starters with PLC network connections are also good considerations for critical motors. While the primary means of energizing motor starters will be the PLC input/output system, it is a good idea to provide means of energizing the starters at the MCC. This can be via simple “deadman” type pushbuttons that can be de-energized when the PLC and minimal hardwired control systems are completely functional. When using a hydraulic system these MCC pushbuttons should be accompanied by similar pushbuttons for energizing hydraulic solenoids. By doing this the designer provides a way for the general contractor, during construction, to “bump” motors and cylinders for shaft alignment, cylinder attachment, clevis pin attachment, shim and key installation and so forth. This will relieve the system integrator of the burden of providing untested solid state controls prior to actual gate operation. This will also provide the system integrator with opportunities to check transducer signals and feedback devices without the responsibility of operating the equipment.

4.3.4.4 Control Relays. In general, motor starters should be provided with pilot control relays to interface them with the PLC I/O cards. While some PLC isolated output cards are rated for enough current to energize smaller starters, larger starters will require pilot relays. Pilot relays provide a way to isolate the PLC system from starters and potential damage from 480-volt system faults.

4.3.4.5 Variable Speed Drives. Mechanical loads that require soft starting, multiple speeds, or ramp up/ramp down features, warrant consideration for a variable speed drive. This could be a DC drive or a variable frequency AC drive. Traditionally, DC drives have been used because they provide much greater control of motor speed and torque. Varying the voltage changes the speed and inversely changes the torque of a DC motor in a linear manner. In contrast, AC drives provide very fine control of speed with varying or constant torque. In addition, AC drives can be supplied with the inherent feature of an across-the-line bypass contactor in the event of solid state inverter failure. Therefore, when specifying variable speed drives, first consideration should be given to an AC adjustable frequency drive (AFD) with either constant or varying torque. It is a good idea to require that the AFD be of the same manufacturer as the MCC. Large drives that do not fit in MCC type construction will require free-standing enclosures to house them. Space is an important requirement and a designer should consider that an “engineered” drive occupies significantly more space than the inverter itself. An engineered drive consists of the following features.

4.3.4.5.1 Isolated Bypass. Except in cases where emergency across-the-line starting will damage mechanical or structural equipment, AFDs should be provided with an isolated bypass, across-the-line contactor. The AFD should include full controls, accessible from the PLC system, for switching to the inverter-bypass starting mode. Control features and/or operational procedures that will require special consideration in order to start the load in this fashion should be determined. Such considerations should be programmed in the PLC and/or AFD controller. These details should be well covered within the specifications in order to insure proper coordination by the AFD manufacturer and the system integrator.

4.3.4.5.2 Network Communications. The AFD should be provided with means to communicate digitally via serial interface directly with the PLC processor. This networking capability should be an inherent feature of the drive and will require the AFD to be of the same manufacturer as the PLC system. This may limit the number of PLC manufacturers who can supply the system, but it is a necessary requirement when providing a reliable coordinated PLC/AFD system. The network communication should provide all status and diagnostics of the drive to the PLC system for remote trouble-shooting capability. Specifying the network communication speed is also a good way of specifying a higher quality product.

4.3.4.5.3 Hardwired Stop Override. The AFD should be provided with a means of stopping the drive independent of the PLC control system. Activation of this override should come from the lock hardwired emergency stop system. Indication of the status of the stop override should be available on the PLC network.

4.3.4.5.4 Dynamic Braking. All AFD systems require dynamic braking of the load. Gates and bridges that are lowered by gravity require excessive dynamic braking to control the speed of the falling load with the electrical-magnetic braking torque of the motor. Manufacturers should be consulted to calculate the exact amount of dynamic braking required for the system. A conservative approach to such calculations will prolong the life of the resistor banks and possibly the inverter itself.

4.3.4.5.5 Isolation Transformer. All AFDs reflect harmonics back to the power distribution system. Such harmonics can damage transformer neutrals as well as affect other digital switching loads. For this reason an appropriately sized K-factor rated isolation transformer should be provided with each AFD. The designer should consult the manufacturer of the AFD to determine the exact size and ratings of the isolation transformer.

4.3.4.6 Lighting Panels. While lighting panels can be located outside the motor control center structure, the purpose of discussing them in this document is the possibility of connecting them to the PLC/IPC control network. Remote switching and monitoring of branch circuit breakers is a very useful tool for facility power management. Energizing lighting circuits via the PLC network, without contactors and extra wiring, is a feature that should be considered when laying out a lock and dam control system. Such control can reduce installation and maintenance costs, aid in trouble shooting, and reduce energy consumption by using zone lighting with near unlimited capabilities.

4.3.4.7 Power Monitoring Equipment. Switchboards and motor control centers can be provided with equipment for monitoring the status of electrical power, i.e. current, voltage, kilowatts, phase imbalance, loss of phase, and frequency. Remote switching and monitoring of power circuit breakers is also possible with such equipment. On less busy projects this may not be cost effective. The remote trouble shooting benefits for critical or remotely operated locks will likely justify the additional costs.

4.3.4.8 PLC Equipment. It is often convenient to install PLC I/O racks in motor control centers. This allows MCC starter buckets to be factory prewired to I/O cards which usually results in a cleaner installation.

4.3.4.9 Automatic Transfer Switches. Most locks have diesel driven standby generators to provide power during utility outages. The generator is usually tied to the lock main distribution bus with a transfer switch or interlocked circuit breakers. When building a new lock or replacing an existing lock electrical distribution system, consideration should be given to using an automatic transfer switch for transferring power from the normal utility source to the standby generator unit and retransfer when utility power is restored. Most ATSs can be furnished in motor control center type construction with digital communication ports for incorporation in the PLC control system for alerting the processor if the facility is on normal or standby power. This feature should cause the designer to consider requiring that the ATS be of the same manufacturer as the PLC system. By doing this the following control features can be programmed.

4.3.4.9.1 Loss of utility power usually cannot be anticipated. However, when utility power has been restored the PLC can prevent the ATS from switching back to the normal source until the operator has completed a lockage and is ready for the power to be interrupted again. This can save unnecessary wear and strain on the machinery. The PLC can also perform orderly shutdowns if necessary before transferring power back to the utility.

4.3.4.9.2 Often generators are not sized to handle as much load as the utility service. To relieve the load when operating on generator the PLC can stagger start motors, turn off non-critical lights, limit use of air compressors, and perform other load shedding procedures.

4.3.4.9.3 Operators for remotely operated locks may not know that power has been interrupted or that the lock is operating on generator. Such information, available by PLC communication with an ATS, could be useful in contacting the local utility for repair to the incoming service.

4.3.5 Software. Because most general contractors do not have the expertise to install and configure IPC and PLC networks, a system integrator should be used for this purpose. A system integrator is a company that regularly designs, installs, programs, and provides start-up and maintenance services for commercial/industrial control and computer systems. The successful implementation of a computerized control system depends largely on the capabilities of the system integrator. It also depends on the capabilities and support of the engineers responsible for the control system after it is installed. Few control systems are perfect immediately after they are installed. Most require “tweaking” to incorporate missing features or to adjust parameters that were not defined during testing and start-up. On lock and dam applications, often after the project is operating the lock personnel will request some changes as they become accustomed to the system. There are three major software components in a computerized lock and dam control system: operating system software, PLC software, and MMI software.

4.3.5.1 Operating system software. The operating system is software that every computer must have to run other applications. It performs basic tasks, such as recognizing input from the keyboard or mouse, sending output to the display screen, keeping track of files and directories on the disk, and controlling peripheral devices such as modems and printers. Operating systems provide a software platform on top of which other programs, called applications, can run. The application programs are written to run on a particular operating system. The choice of operating system determines which applications can be run.

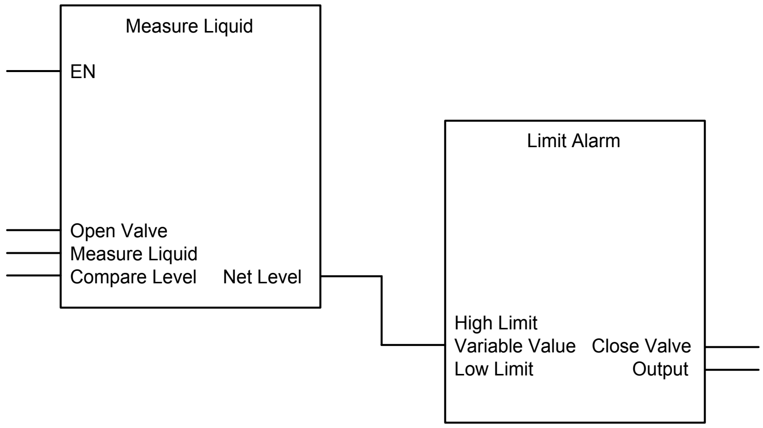
4.3.5.1.1 There are many different operating systems, including DOS, Windows, OS/2, and Unix. In the United States Microsoft Windows NT is becoming the preferred operating system for industrial control. Many MMI software packages available are written to run under Windows NT. Windows NT has built-in support for networking. This means that third-party networking software is not required. Windows NT is the only software required to fully implement the network.

4.3.5.1.2 Windows NT comes in two versions: Windows NT Server and Windows NT Workstation. The Workstation version is also known as the client software. Depending on the facility, more than one server may be used. A domain network model should be used when planning the network. A domain name should be chosen for the network and all users should be authenticated for this domain. For networks with more than one server, one should be configured as the primary domain controller and a second one should be configured as a backup domain controller. Using this approach, the backup controller automatically assumes the responsibilities of the primary controller if the primary shuts down for any reason.

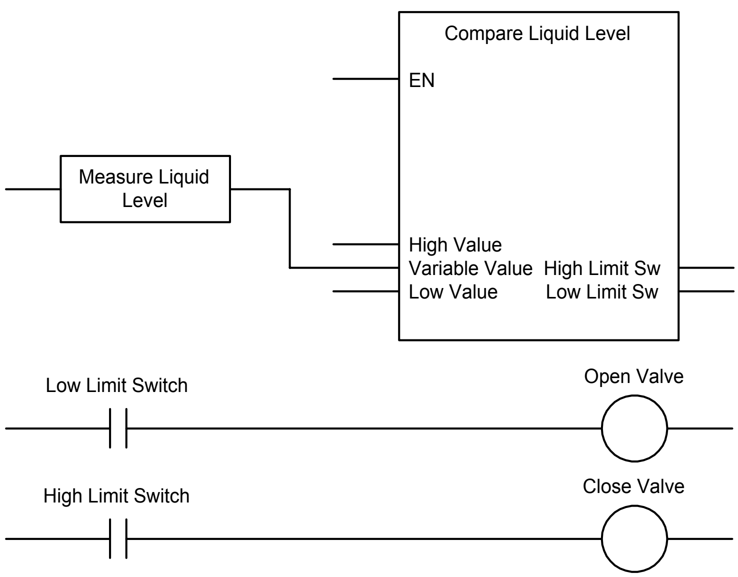
4.3.5.1.3 The designer should work closely with the system integrator during initial configuration of the operating system and network to set up user accounts and passwords. Since operating computers typically are used 24 hours a day seven days a week, a single operator account should be used so that all shifts use the same account and password. Administrator accounts should be set up for system administrators or engineers who administer the computers and network.

4.3.5.2 PLC Programming Software. The PLC processor programming software should be as provided by the PLC manufacturer. It may be a third party product of which the PLC manufacturer OEMs or recommends in its written literature. The PLC programming software should have provisions for configuring I/O rack addresses, simulating program execution for debugging, and downloading to the PLC processor. The programming software should conform to part 3 of IEC 1131, the standard for PLC programming languages, should operate on a Microsoft Windows NT platform, and should include the following editors:

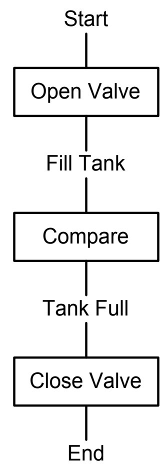
4.3.5.2.1 Function Block Diagram. This editor depicts process data flow suited for discrete and continuous control application functions and should include predefined elementary function blocks as well as user-defined function blocks. Language written in other editors, as listed below, can be nested within the Function Block Diagram. In FBD, control sequences are programmed as blocks which are “wired” together in a manner resembling a control circuit.



4.3.5.2.2 Ladder Diagram. This language allows programming in the familiar left to right contact and coil arrangement in an order that is familiar to most electricians and maintenance personnel. The ladder logic editor should allow the use of other editors such as Function Block and Structured Text to be incorporated into the ladder programming. This will simplify the programming as electricians and maintenance personnel will not have to be familiar with the complex logic of the other editors. The Function Block or Structured Text editors simply perform predetermined logic within the body of the ladder diagram. These can be grouped in subroutines to simplify the appearance of traditional ladder logic.



4.3.5.2.3 Sequential Function Chart. This editor provides a graphical method of organizing a control program using programming from other editors nested within. The SFC editor should include three main components: steps, transitions, and actions. Steps are individual control tasks comprised of programmed logic operators used to perform a particular control function. Actions are the individual operators of that task. Transitions are merely mechanisms to move from one task to another. With SFC the processor continues to perform the actions in a step until the transition conditions is true, i.e. repeat the **step** containing the **action** of filling a tank until the **transition** condition of comparing level against "full" is true then move to **step** of close the valve.



4.3.5.2.4 Structured Text. The Structured Text editor is a high-level language resembling Pascal or Basic used to perform control logic programming. Structured Text often proves to be the easiest way for the novice to write and understand control logic because of its inherent resemblance to sentences.

```
LET LowLimit = Low_Limit
LET HighLimit = High_Limit
LET Value = Liquid_Level
WHILE Value < HighLimit
   IF Value < LowLimit THEN
       DO Open_Valve
    END IF
END WHILE
DO Close_Valve
```

4.3.5.2.5 Instruction List. Instruction List editor is a text based Boolean language. The basic Boolean operators can be used to create more complex control applications. Similar to Assembly Language, the Instruction List editor is a low-level language that is very useful for simple control processes whose logic is repeated often. Instruction List allows the logic for these processes to be programmed once and then recalled in latter instances in the program.

```
Start:  LD   Liquid_Level     :Move value of liquid level into argument
        GT   Low_Limit        :Compare with Low Level Limit
        ST   Open_Valve       :Move (1 or 0, based on above) into output
        GT   High_Limit       :Compare with High Level Limit
        ST   Close_Valve      :Move (1 or 0, based on above) into output
End:
```

It is important to specify the PLC programming software in sufficient detail using the IEC 1131.3 standard because this will insure that the Contractor provides a quality software package that complies with worldwide industry accepted standards.

4.3.5.3 Man-Machine Interface Software. MMI software refers to the software that provides the graphical user interface for operating the lock and dam. This software should run on any of the IPCs on the network and communicate to the PLC through the network. The designer should plan the system to determine which IPCs need to communicate directly to the PLC. Most MMI software can operate either as a client node, in which it "piggy backs" off of another computer for access to the PLC, or as a server node, in which it communicates directly to the PLC processor. Typically, only one or two IPCs in the same control room would need to be configured as an MMI server, while most of the IPCs located remotely would need to be configured as MMI servers. The intent is to limit the potential for failure of one IPC to inhibit operation from another IPC while minimizing direct communication to the PLC. In general, a small number of MMI servers on the system will enhance the communication speed with the PLC processor. Note that the MMI server need not be the Windows NT server.

4.3.5.4 User Interfaces. One of the key ingredients to a successful computerized control system is the general perception of the system by the operators. Most operators are not going to care what operating software is used or how much memory or what the scan time of the PLC processor may be. Therefore, an argument can be made that the most important part of the control system is the interface that allows the operator to use the system. For most new lock and dam control systems this will be the operating screens on the IPCs. These must be designed and programmed with considerable care to ensure a completely user-friendly interface that is convenient and, most of all, safe to operate. The IPCs located in the main control console should have all the operating screens necessary to control and monitor the entire project.

4.3.5.4.1 Semi-Automatic Operating Screen. On locks with Semi-automatic operating systems a screen such as Figure 4-6 should be included to facilitate complete normal lockage from one operating screen. The screen should include control of both ends of the lock, the traffic lights, warning horn, emergency stop, and other critical features unique to each project.

The designer should try to keep the semi-automatic or automatic operating screens (Figure 4-8) complete, yet compact and concise, since too much information or control of auxiliary equipment can make the screen confusing to operate. Remember there are other IPCs (minimum of three per lock) on which screens can be loaded for other feedback or control of auxiliary equipment. Animated graphics, based on real time data from transducers and sensors, makes the screen more "friendly" to the operators. The screen should be designed to allow a busy operator to take a look and very quickly ascertain the status of the major lock operating equipment.

4.3.5.4.2 Manual Operating Screens. The system should include screens for manually operating each piece of equipment, see Figures 4-8 and 4-9. Special, seldom used, operating procedures such as "interlocks bypassed" should be included on these screens. The system should probably include a special operating screen for each major piece of lock equipment, i.e. gates and valves. This control will still be through the PLC system with the full compliment of safety interlocks and permissives, but it will allow independent non-automatic operation of the individual pieces of equipment.

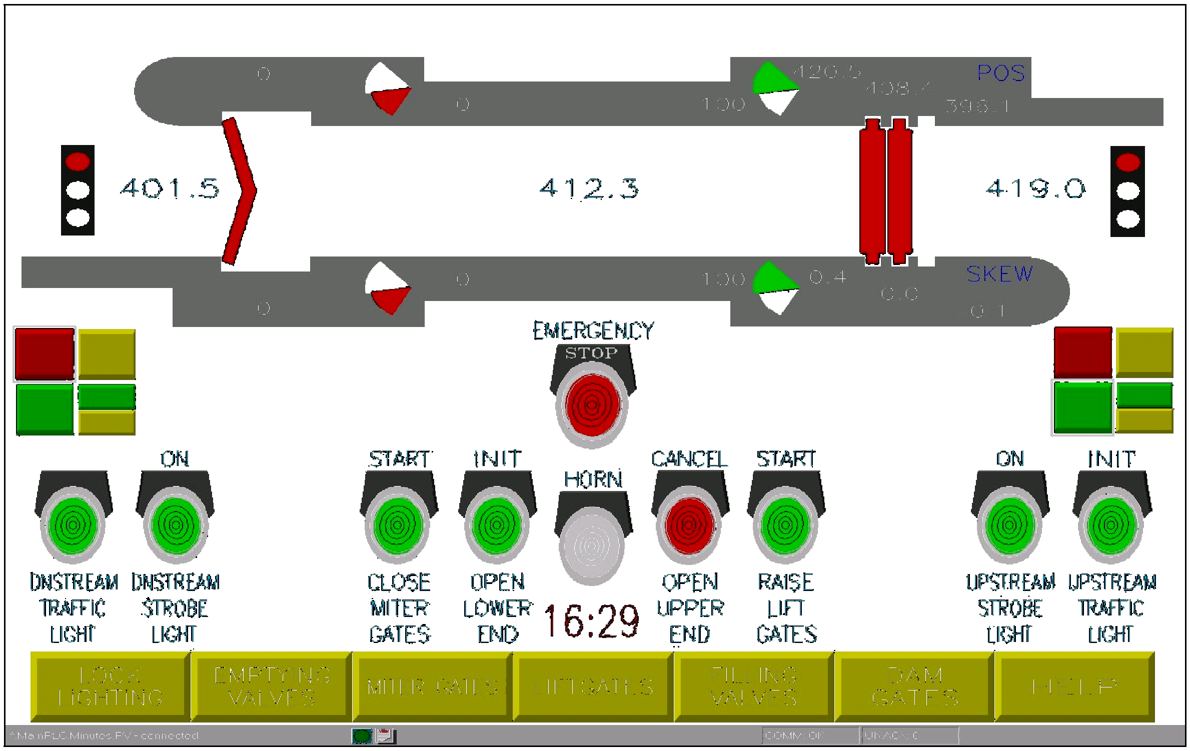


Figure 4-6. Semi-Automatic Operating Screen Currently in Use at Melvin Price Locks and Dam

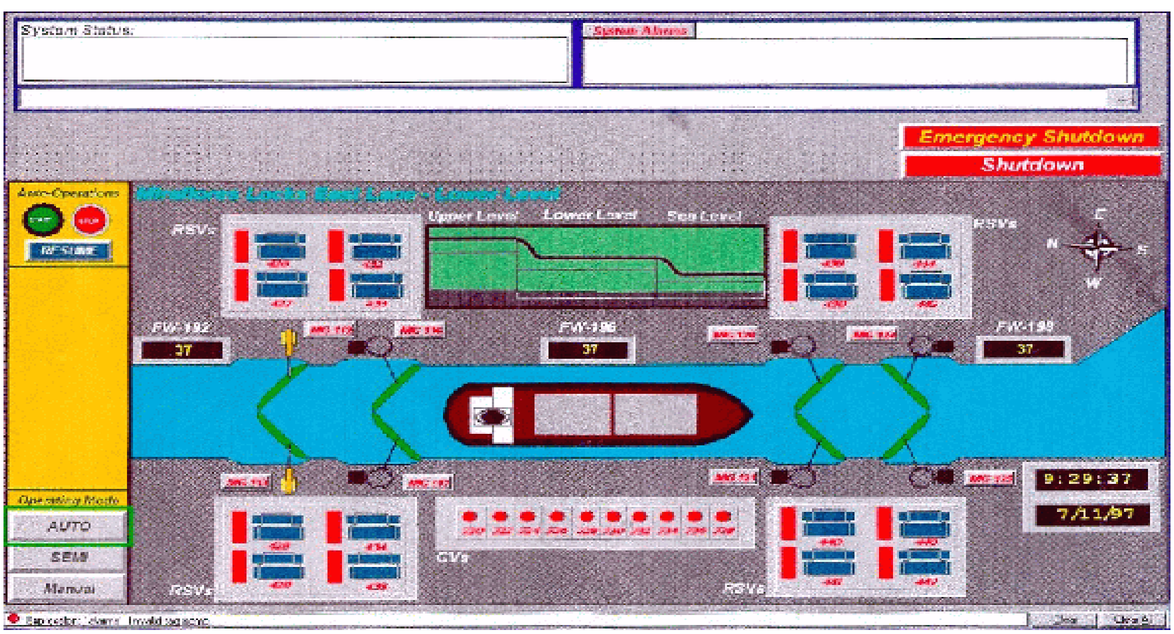


Figure 4-7. Automatic Operating Screen Proposed for Use on the Miriflores Locks at the Panama Canal

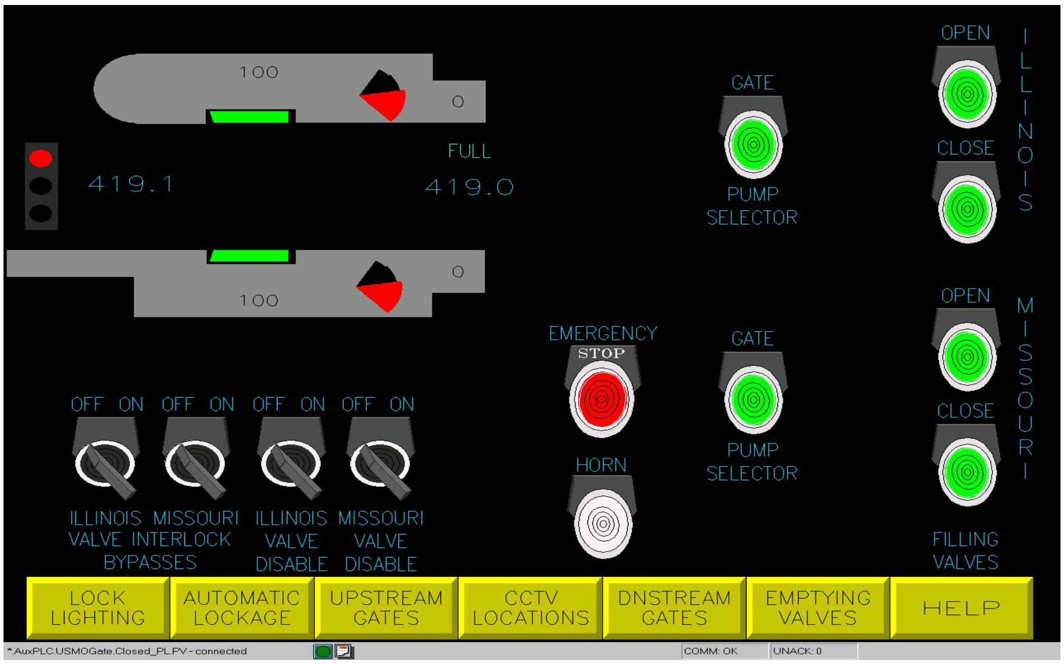


Figure 4-8. Miter Gate Manual Operating Screen Currently in Use at Mel Price Locks and Dam

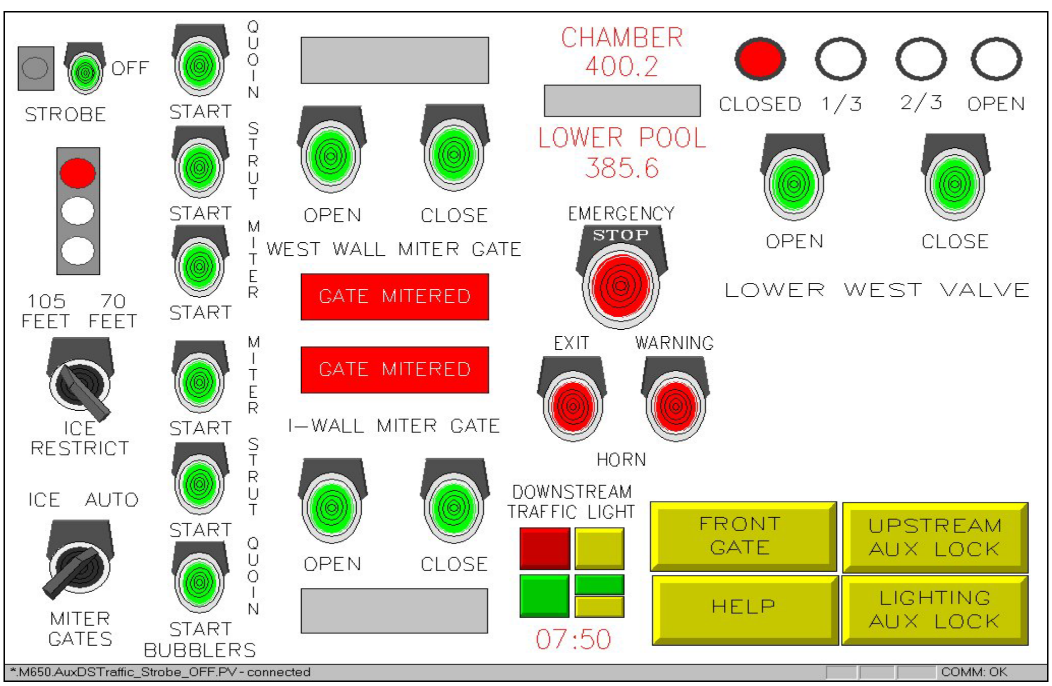


Figure 4-9. Manual Operating Screen Currently in Use at Locks No. 27

4.3.5.4.3 Trouble-Shooting Screens. A good operating system interface should include simple trouble-shooting screens that the shift chief can use to identify problems. These screens alert the shift chief of situations that can stop or affect the operation of the lock but are not necessarily equipment failures. These instances could be emergency stop pushbuttons that have been left depressed; equipment access doors with lockout switches; interlocks that have been bypassed on an auxiliary control panel; and emergency controls that are being used somewhere on the locks. This screen is intended to alert the shift chief of these situations so they can begin investigating and correcting the situations. This is intended to be the first screen the shift chief pulls up when equipment will not operate properly.

4.3.5.4.4 Alarm Screens. Alarm screens should be provided to alert operators and maintenance personnel to failure of lock operating equipment. Included on such a screen should be failure of any PLC component that can be diagnosed by reading registers in the processor (most PLC equipment failures can be found this way). These would typically include PLC communication failures, I/O failures, AFD failures, water level sensor failures, and position sensor failures.

4.3.6 Closed Circuit Television (CCTV) Systems.

4.3.6.1General. CCTV systems provide multiple functions in a lock and dam control system. A CCTV system provides a greater visibility of lock activities and allows the operation of multiple locks from a single control room. Employing video cassette recorders, the CCTV system can also serve to document accidents. With the appropriate cameras in place the system can inform the lock operator of fisherman or other boats near discharges or dam spillways. CCTV cameras can also be placed to provide additional security for entrance gates, storage areas, and visitor access areas. See Figure 4-10 for an example of a typical CCTV system.

4.3.6.2 System Purpose. Every lock and dam facility will place different requirements on the CCTV system. The system designer must identify the requirements and determine all of the roles of the CCTV system to provide a suitable design. Answers to the following questions can be used to begin the design. Will the system be used to provide better visibility of the lock for operators in control rooms at both ends of the lock? Is the system suppose to provide a means of operating a single or multiple locks from only one central control room? Do the lock operators need to watch the dam or spillway gates? Does the system provide security for the facility? Will remote monitoring or control be a possibility? Answers to these questions can help identify where on the project the video monitors, keypad controllers, and cameras are needed. Refer to Army Technical Manual TM 5-853-4 for detailed application guidelines.

4.3.6.3 Control Locations. For surveillance of the project during operation, control rooms equipped with video monitors and keypad controllers will be required. Currently on facilities requiring a complete CCTV system, lock operations will be from a single control room. However, even on these facilities there may be other CCTV control locations as described herein. The number of control locations will be needed to determine the number of monitors and keypad controllers the CCTV system must support. The system designer must know the total number of monitors and keypad controllers required when specifying other components, such as the matrix switcher.

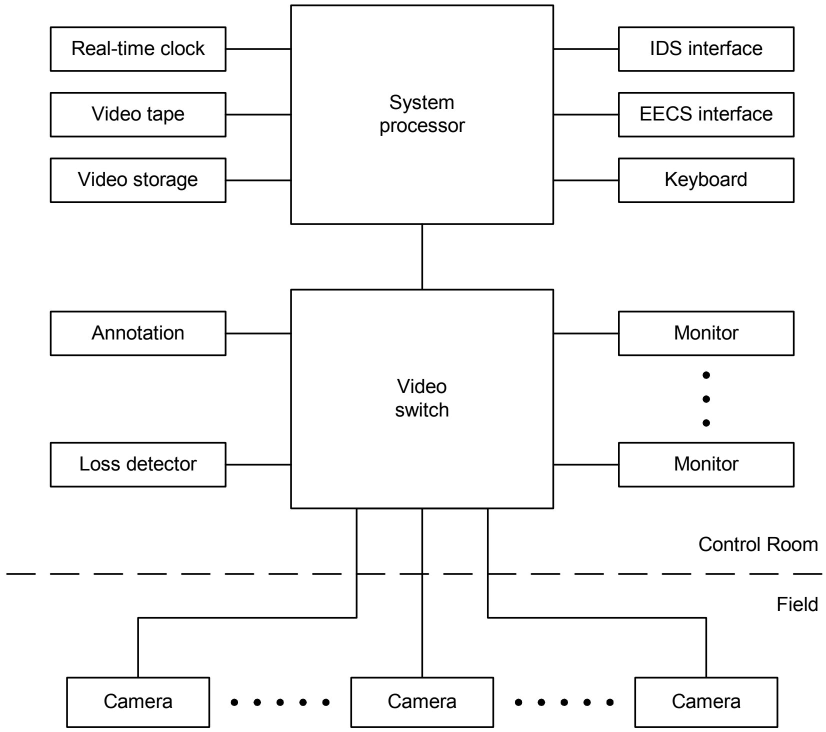


Figure 4-10 Typical CCTV System

4.3.6.3.1 Lock Control Room.

Single Lock, Multiple Operators. In this method of lock operation a control room is usually located at each end of the lock. Each control room should be equipped with a minimum of four video monitors and a keypad controller for operation of the lock. The four monitors provide a view of each side of the lock gates, an upstream (or downstream) view of the lock approach, and the fourth for a general view of the lock. Additional monitors should be added as required by the facility for viewing the security cameras, coverage of the dam, discharges, etc.

Single Lock, Centrally Operated. A central control room should be equipped with at least six monitors and a controller for the operation of the lock. The six monitors provide a view of each side of the gates, upstream and downstream, and a view of the upstream and downstream approaches. Additional monitors should be added as required by the facility for viewing the security cameras, coverage of the dam, discharges, etc.

Multiple Locks, Centrally Operated. A central control room should be equipped with at least six monitors and a controller for the operation of each lock. Most central control rooms have separate control consoles for each lock. Placing a CCTV system controller at each console reduces operator movement between the consoles. The six monitors per lock provide a view of each side of the gates, upstream and downstream, and a view of the upstream and downstream approaches. Additional monitors should be added as required by the facility for viewing the security cameras, coverage of the dam, discharges, etc.

4.3.6.3.2 Lockmaster Office. The Lockmaster may require a video monitor and keypad controller in his office. This provides the Lockmaster a means to monitor the lock activities without disturbing operations in the main control room.

4.3.6.3.3 Lock Electrician Office. It is also convenient to provide a separate control location for the lock electrician. The electrician can troubleshoot system problems or test the cameras without disturbing operations in the main control room.

4.3.6.3.4 Visitor Center. A visitor center could be equipped with video monitors. The public could view the same cameras as the lock operators. The visitor center would not require a keypad controller. The matrix switcher can be programmed to automatically display various cameras on these monitors.

4.3.6.4 Camera Requirements. Another question to be answered by the designer is the use of color cameras. In the security industry black and white cameras are the standard because of the higher resolution. However, color camera technology is becoming more accepted. In most cases the contrast provided by the color image makes up for the lower resolution. Also, the designer should consider the appropriate use of pan/tilt/zoom (PTZ) vs. fixed mountings for cameras. Certain types of coverage, such as fixed security views or dam gates, do not necessarily warrant the extra expense of a PTZ mounting. Typically, however, complete coverage of a lock requires multiple views from each camera, which means cameras should include PTZ.

4.3.6.4.1 Lock. Camera coverage of the lock chamber is provided for all lock gates. Lift gates require one camera on each side of the lock. Miter gates require four cameras: one upstream and one downstream of the gate leaf for both sides of the lock. Because the lock chamber alternates between two water levels, cameras must be placed such that it can still see the water level when the chamber is empty. Cameras must also provide a good view of the gate recesses. Cameras located at the ends of the upper and lower guidewalls provide coverage of the approaches. These cameras should all be equipped with PTZ capability.

4.3.6.4.2 Dam. Cameras can be placed on the upstream and downstream sides of the service bridge to provide coverage of the pool and tailwater. Some facilities may require a camera at each tainter gate to watch its movement during pool changes. PTZ is an option to strongly consider for these cameras.

4.3.6.4.3 Security. Cameras may be placed to cover entrances to the lock and dam, storage areas, and visitor access areas. An integrated dome camera can provide indoor coverage of visitor centers or public access areas. PTZ may not be required for these cameras.

4.3.6.5 Documentation of Accidents. Recording the CCTV cameras can provide valuable documentation for accidents at a lock and dam. The designer must determine the level of documentation required for the facility. The more cameras recorded, the greater the amount of documentation available, but at a higher cost. One method is to record the output of one of the monitors to an elapsed-time VCR which is constantly recording. The lock operator can select the camera closest to the accident and display it on the recorded monitor. The operator can then pan, tilt, and zoom the camera to capture the accident. A real-time VCR can be substituted in place of the elapsed-time VCR to obtain a smoother recording. The real-time VCR should be equipped with a remote switch so the lock operator can turn the recorder on to capture the accident. This method places much responsibility on the lock operator. Operators may be busy preparing for or responding to the accident. For additional documentation, a multiplexer may be used to record multiple cameras to a time lapse VCR. The multiplexer can provide a recording of up to 16 cameras. During playback, the multiplexer can display multiple cameras or display the recorded frames from a single camera. The designer must note that the time lapse increases as the number of recorded cameras increases.

4.3.6.6 Star vs. Daisy Chain. All camera receivers and keypad controllers require a connection to the matrix switcher. Common practice is to connect the units in series or “daisy chain” them together as shown in Figure 4-11. Two loops are created. One for the camera receivers and the other for the keypad controllers. Daisy chained units may require less wire for installation, but a failure somewhere in the chain can affect all of the units after the failure or possibly every unit in the chain. The star configuration uses a distribution unit to essentially provide a point-to-point connection from the switcher to the receiver or controller and helps to isolate a failure to only a single unit. A further hybrid is to daisy chain two or three units at the end of a star connection. This provides the best qualities of both installation techniques. Ease of installation and failure isolation. The daisy chain configuration is an acceptable design, but the system designer should consider the impacts to reliability, maintainability, and future expansion.

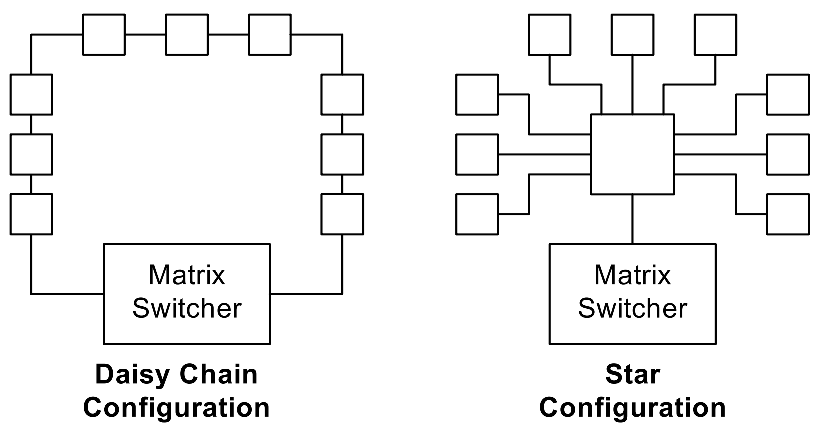


Figure 4-11. Receiver/ Keypad Controller Connections

4.3.6.7 Lighting Conditions. For a CCTV system to work properly, adequate lighting must be provided. The sensitivity of a camera refers to its ability to produce a usable image given a minimum lighting level. The CCTV market contains many cameras with various sensitivities, but the designer must remember that just because a manufacturer’s specification sheet states a certain sensitivity, it does not mean the picture will be usable at that level. For exceptionally low light level areas consideration should be given to the use of monochrome cameras or cameras specially designed for use in low light levels.

4.3.6.8 Lightning Protection. While fiber optic communication and composite video signals are immune to problems caused by lightning, cameras, coaxial cable, pan/tilt units, and receivers are not. Therefore it is critical to the success of the CCTV system to provide proper protection from transient surges caused by lightning. All metal portions of camera and receiver mounting material should be well grounded and the CCTV system manufacturer should be consulted for proper lightning protection components for the cameras and receivers.

4.3.6.9 Matrix Switcher. This device is at the center of the CCTV system. Each monitor, camera, and keypad controller is connected directly to the matrix switcher. As a minimum, the matrix switcher consists of a card cage, CPU, camera input cards, and monitor output cards. The CPU within the switcher performs the operations necessary to switch any camera input onto any monitor output. For example, a 256 x 256 switcher is capable of controlling 256 cameras and 256 monitors. Most systems are modular in nature meaning the addition of camera input cards increases the switcher's input capabilities. In this example input cards could be added for a total of 256 camera inputs. Card cages can be cascaded as the system grows. Monitor outputs can also be added in this fashion, however some manufacturer's may require additional card cages to increase the number of monitor outputs.

4.3.6.9.1 Switcher Capabilities. Software within the matrix switcher CPU provides additional functions and will vary by manufacturer. The CPU may restrict or partition which cameras are displayed on the monitor outputs. This may be useful in a multi-lock control room. Camera restrictions placed by the CPU may prevent the operator of one lock chamber from inadvertently displaying the cameras of the other lock on his monitors. The CPU may partition monitors to the keypad controllers. This restricts the control of monitors to certain keypads. This may prevent an operator from accidentally changing the camera displayed on another monitor. The CPU can sequence cameras on a monitor. Cameras provided for security can be sequenced on a single monitor rather than dedicating the use of multiple monitors to security.

4.3.6.9.2 Keypad Controllers. All of the keypad controllers provided with the CCTV system are connected to the matrix switcher. The keypad controllers generate the commands to perform switching operations within the matrix or other capabilities described above.

4.3.6.9.3 Pan/Tilt/Zoom. The switcher generates the pan, tilt, and zoom (PTZ) commands for the cameras contained in the system based on inputs from the keypad controllers. Receivers, located at each camera, are connected to the switcher to decipher the PTZ commands for the camera.

4.3.6.9.4 Alarm Interface Unit. This is a separate unit that is cabled to the matrix switcher. The unit provides annunciation for a set of normally closed contacts. Depending on the manufacturer, the interface unit provides a minimum of 16 alarm inputs, however the units can be cascaded to provide a greater number of inputs. When an alarm condition occurs, the CPU, based on programming, is directed to display the video where the alarm occurred. For example, the system could be programmed to monitor the entrance gate during the night shift. When the entrance gate is opened, an alarm sounds and the camera showing the gate is displayed on the video monitor. Similarly, certain monitors can be programmed to cover the lockage of a vessel at it moves through the lock. The interface unit may be equipped with an auxiliary relay output to activate a VCR or other device. In this manner the CCTV and IPC/PLC systems become one integrated control system.

4.3.6.9.5 Time/Date/Titler. This device may be contained on a card resident in the switcher card cage or in a separate enclosure cabled to the switcher, dependent upon the manufacturer. Its purpose is to display the time and date on the video monitors. Additional lines of text are provided for camera identification. Camera titling is programmed through the switcher CPU. The titler may provide different lines of text for camera identification during an alarm condition.

4.3.6.10 Multiplexer. For smaller CCTV systems, this unit can be substituted for a matrix switcher. A multiplexer can create a single output signal from multiple input signals. An example of this is when multiple cameras are displayed on a single monitor. A 16-input multiplexer can be switched to display 1, 4, 9,or 16 cameras. One drawback to the multiplexer is picture resolution. If a video monitor has 525 lines of horizontal resolution, the multiplexer will divide this among 2, 3, or 4 camera pictures, depending upon how many cameras are being displayed. If all 16 cameras are displayed on the monitor, each camera display will only have ¼ the horizontal resolution of its original display. Another use of a multiplexer is for documentation purposes. A 16-input multiplexer can store 16 camera signals to video tape. During playback, the multiplexer can display all 16 camera or just the frames for a particular camera. Note that the playback from the tape will not be real-time because the multiplexer is dividing the recording time among all 16 inputs.

4.3.6.11 Quad Unit. A quad unit is similar in operation to a multiplexer but is limited to four inputs and one output. This unit will display four cameras on a single monitor

4.3.6.12 Video Monitor.

4.3.6.12.1 CRT. The most common video monitor is the Cathode Ray Tube or CRT. The designer must determine the size and mounting of the video monitors in addition to the number required. Monitors are available in 9”, 13”, 14”, and 20” sizes. A common approach is to use multiple 9” monitors. It may vary by manufacturer, but two 9” monitors can be mounted side by side in a standard 19” rack. Mounting of the monitors should minimize the strain on the lock operators. Commercial enclosures with many different configurations are available. Most often it is more cost effective to use commercially available consoles and avoid specially constructed consoles. A modular approach also reduces impacts from upgrades and equipment repair. Another approach is to use a larger monitor in combination with a quad unit. This allows the single monitor to display multiple views. This method may ease installation and maintenance, but if the monitor fails, four views are lost instead of just one. Also, this may not be the cheapest approach and is only included as an option to the designer for certain applications.

4.3.6.12.2 LCD/Plasma. Flat screen technology has improved in recent years, eliminating the requirement of the user to be directly in front of the screen. Viewing angles have increased to 160°+. These monitors require a much smaller footprint than the CRT monitors. The LCD/Plasma monitors are available in various sizes. While prices of these monitors are dropping, they are currently considerably more costly than the CRTs.

4.3.6.13 Keypad Controller. This device allows the user to control which camera is displayed on a monitor and sends pan, tilt, and zoom commands to the camera. All commands from the controller are directed to the matrix switcher.

4.3.6.13.1 Keyboard/Joystick. This type of controller is available in a desk-top or rack-mount version and can be considered the industry standard. The controller contains a small keyboard and pushbuttons for camera and monitor selection, zoom, focus, auto-iris, etc. The joystick provides pan and tilt commands to the currently selected camera.

4.3.6.13.2 Computer-based. Some manufacturers provide computer-based control through a graphical user interface (GUI). A serial connection provides the communications between the matrix switcher and the PC. With the manufacturer-supplied software, the user can develop a site plan showing the camera and monitor layout. Camera and monitor selections can be made using the “drag and drop” operation common in Microsoft Windows operating systems. Windows may contain PTZ controls to replace the joystick and buttons to replace the zoom and focus controls. Using a video overlay card in a expansion slot, the PC can be connected to the matrix switcher as a video monitor.

4.3.6.14 Receiver. Typically, a receiver is required for each camera in the CCTV system, but some manufacturers produce receivers to drive multiple cameras. The connections between the receiver and camera should be kept as short as possible, so a multiple-camera receiver should only be used when cameras are adjacent to each other. The receiver decodes the serial (RS-422) commands from the matrix switcher and sends them to the camera. The receiver or its accessories may offer “preset” capabilities. The user can set the position and zoom for a camera and store it in memory where it can be recalled. The receiver will require 24VAC or 120VAC power, dependent upon the manufacturer. The receiver provides power to the camera and the pan/tilt drive. The output to the pan/tilt drive may be 24 or 120VAC dependent upon the drive’s requirements.

4.3.6.15 Interconnection Methods. Each camera receiver requires multiple connections to the matrix switcher. The video signal from the camera is transmitted to the matrix switcher over a cable separate from the receiver’s serial connections.

4.3.6.15.1 Copper. The receiver serial connections are made using a dual twisted-pair cable and the video connection to the camera is made using coaxial cable. Both connections are distance limited. While distance may not be a problem with the lock and dam, the designer must consider other problems. Lightning and noise can cause major problems with the CCTV system, including equipment loss. Camera receivers, especially the serial connection, are very susceptible to damage.

4.3.6.15.2 “Up the Coax.” CCTV system manufacturers have developed methods of transmitting the camera commands (PTZ) over the coaxial connection to the receiver. While this method does not offer complete immunity to noise and surges, it does simplify installation and eliminate the need to route dual twisted-pair cable all over the facility.

4.3.6.15.3 Fiber Optic Receivers/Transmitters. While more expensive to implement, use of fiber optic transmission offers immunity to noise and the greatest isolation between the receivers. These factors will reduce and limit equipment damage. Use of fiber optics can also increase the distances between equipment. The maximum distance is related to the losses associated with the fiber. These may be splices, connectors, etc. Multi-mode fiber can be used for distances between 3.2 to 4 kilometers (2 to 2.5 miles). Single mode fiber (more expensive than multi-mode) can provide distances from 10 to13 kilometers (6 to 8 miles). The standard optical connection is the ST type and most units are configured for 62.5/125 micron fiber optic cable. The most basic transmission system provides the transfer of one composite video signal over a single fiber optic cable. Some systems offer multi-channel options allowing the transfer of 2-4 composite video signals. Again, the copper connection between the camera and transmitter should be kept as short as possible. Other systems go one step further by including the transmission of data with the composite video. The data is the pan, tilt, zoom, focus, etc. commands for the cameras. The video is transmitted from the receiver to the switcher and the data is in the opposite direction. This simplifies installation by eliminating the need for the dual twisted-pair cable. This is considered the most reliable solution for networking CCTV receivers. Other units may include audio.

4.3.6.16 Pan/Tilt Drive. This unit provides the pan and tilt movement for the camera. It receives 24 or 120VAC signals from the camera receiver. Drives are available for loads up to 100 pounds. Drives should also be equipped with travel limits and adequate braking to prevent coast.

4.3.6.17 Camera Mounting. Manufacturers providing equipment to wall mount, corner mount, parapet mount, and pole mount camera equipment should be consulted. The designer must insure that the hole pattern in the mounting equipment is compatible with the pan/tilt drive. In a lock and dam application, pole mounting is used most often. Pole mounting provides the heights needed to obtain a good view down in the lock chamber. Parapet mounting may be used on a dam structure to provide camera coverage of either the lock or dam.

4.3.6.18 Camera Housing. Camera housings protect the camera and lens from tampering when used indoors and also from the elements when used outdoors. Accessories may be available for the housing to control the inside temperature, block the sun, and a wiper to keep the viewing window clear. A thermostat controls the heater inside the housing. Heating the unit keeps the viewing window clear and prevents condensation. Sun visors eliminate some of the problems associated with the glare produced by the sun. The visor also helps keep the rain off the viewing window. When selecting a housing, choose a unit with a wiper available. If rain becomes a problem in the future, the wiper can be added. Some units can be pressurized with dry nitrogen to eliminate air from the unit. This will reduce problems with moisture and condensation.

4.3.6.19 Camera. Outdoor cameras, should be ½-inch, high-resolution, color charge-coupled device (CCD) cameras equipped with suitable wide-angle zoom lens. Cameras should be enclosed in a pressurized environmental housing mounted on a heavy-duty pan and tilt drive. Refer to Army Technical Manual TM 5-853-4 for camera and lens application guidelines.

4.3.6.20 Integrated Dome Camera. Indoor cameras, typically housed in a dome unit with an integral pan/tilt and receiver, should be ¼-inch, high-resolution, color CCD cameras equipped with a suitable zoom lens.

4.3.6.21 Recording Devices. As a minimum, video recordability should be a feature of any CCTV system. The idea of providing this capability is to capture accidents on video tape to help settle law suits. With sophisticated remote control systems, additional capabilities such as recording of audio and radio communication should be considered.

4.3.6.21.1 Analog. Video recording can easily be accomplished with traditional time-lapse analog VCRs. One VCR should be considered for each lock. With a single, stand-alone VCR the operator is responsible for switching the appropriate camera onto the monitor being recorded. If the operator forgets, an accident may not get recorded. Also, with time-lapse VCRs, unless the operator removes the tape containing the accident recording, it will get overwritten after the time set for restarting the record cycle.

4.3.6.21.2 Digital. Digital recording systems offer several advantages over traditional analog VCRs. A digital recording unit converts an analog video signal to digital data for storage on its internal hard drive. The internal hard drive can store 2-6 hours of video. For longer periods of storage, the video is transferred to digital audio tape (DAT). A jukebox is used to change the DAT as they fill with data. The use of the jukebox eliminates the need for an operator to change the video tape in a VCR. The jukebox is sized to provide the needed length of time before the data is over written. Many of the digital recording units can record the video from multiple cameras. Digital recordings can be real-time at thirty frames per second (fps), or time-lapse. Time-lapse recording rates range from 1 to 7.5 fps. Some time-lapse units can record as many as 32 separate cameras. Some units can vary the recording rate based upon a discrete input of the recording unit. Retrieval of information is also much quicker and convenient, typically done with desktop PCs. Video can be retrieved by camera, date, and time. Also, DATs, because of their smaller physical size, can be archived using much less storage space than VHS tapes. There is a high price to pay for this flexibility because digital recording systems are currently many times as expensive as traditional analog recording systems.

4.3.6.22 Motion Detector. Cameras dedicated to security monitoring around a lock and dam can benefit from motion sensing technology. Motion detectors have become sophisticated enough that they should be considered when designing a CCTV system. Current models can be configured to filter out rain, snow, cloud shadows, small animals, and so forth. They can also be configured to display intruder paths for later viewing, should the operator not immediately notice the intruder. Detectors can also be connected to audible alarms for immediate notification of a security problem. Motion detectors may also have application at low-volume locks to detect small vessels in the lock approaches.

4.3.6.23 Upgrade Frequency. Generally, the upgrade frequency of a CCTV system depends on the type of device or component to be upgraded. CCTV cameras and monitors will usually need to be upgraded most frequently in a CCTV system. Ultimately, equipment serviceability and availability of spare parts will determine the upgrade frequency of CCTV system components. See Table 4-3 for recommended CCTV system upgrade frequencies. Note that the frequencies listed are the maximum recommended and should be used strictly as a guideline. Depending on the type of hardware, its day-to-day use, and its environmental stress, the upgrade frequency may be lower or higher. The frequencies listed are for planned upgrades and not routine maintenance, such as replacement of failed or damaged components.

4.3.7 Auxiliary Equipment. Selection and installation of a quality PLC/IPC/CCTV control system is only part of the work necessary to complete a successful lock control system. The input/output devices that provide information to the computerized control system are just as critical in the overall success of a lock and dam control system as the PLC itself. Failure to specify quality materials and proper installation and testing of field devices will diminish the operators' confidence in the whole system, regardless of how good the PLC/IPC system may be. Also, consider that these devices often serve a dual purpose when they are used in the emergency back-up system. Redundancy and spare parts are an important part of the auxiliary equipment design process.

4.3.7.1 Limit Switches. The most common PLC input device is a dry-contact limit switch. Different switches are used for different applications. These devices are particularly useful for end-of-travel or overtravel limit switches because they are absolute, passive, and require no

Table 4-3 Recommended CCTV System Upgrade Frequencies

Description	Notes	Upgrade Frequency (years)
CCTV System		
Switcher		15
Alarm Interface		15
Control Distribution Unit		15
Control Keypad		10
Computer Control Module		10
Monitor		5
Quad Combiner		10
Camera	CCD type, B&W or color	10
Power Supply		10
Lens		10
Housing		15
Pan/Tilt Drive		15
Dome Camera	Integrated type	10
Receiver		10
Fiber Optic Transmitter		15
Power Supply, Fiber Optic Transmitter		15
Fiber Optic Receiver	Rack-mounted type	15
Fiber Optic Rack		15
Power Supply, Fiber Optic Rack		15
Recording System		
Analog VCR		10
Digital Recorder		10
Digital Recorder Software		5
Digital Recorder Option Board		10
Digital Archiving System	Hard Drive/DAT Drive	5-7

electronic calibration. Limit switches of this type can also be provided with auxiliary contacts for a hardwired back-up system. In this day of not using brand name and “or equal” specifications, carefully specifying all of the important features is essential to insure that the contractor provides a quality product. Limit switches are as critical, if not more so, than any other feature of the control system, and time should be taken to write sound specifications for procuring, installing, and testing them.

4.3.7.1.1 Vein/Roller/Lever Operated. Simple vein or roller operated dry contact limit switches are used for all types of moving machinery. It is a good idea to specify these with extra contacts for hardwired applications. Addressable limit switches, which can be connected directly to the PLC network, eliminating the need for I/O racks, are becoming increasingly popular and are a good consideration for non-critical applications where there are few limit switches and great distances between them. Their usage on locks and dams has been limited generally because lock operating machinery is grouped together and has enough limit switches in one location to justify an I/O rack. Specifications should include heavy duty, oiltight, corrosion ratings, number, rating, and type of contacts, NEMA 4X or 6P rating, UL listing, operator lever type, and operating temperature range.

4.3.7.1.2 Magnetic/Proximity/Photo Electric. By eliminating moving parts and providing a degree of submergibility, magnetic and proximity limit switches have replaced the vein operated switches for use on the end of miter gate leaves for indication of proper miter, and in the miter gate recesses for indication of a fully recessed gate. Headquarters, to avoid damage to miter gates, has mandated positive indication of the miter and recess positions. These switches must be installed and used in the control system as interlocks to prevent filling of the chamber (improper miter) or changing the traffic light to green (improper recess). The use of these type of switches is a good consideration in other areas where ice can hinder the operation of vein operated switches. When procuring magnetic or proximity switches specifications should include number, type and rating of contacts, NEMA 4X or 6P rating, UL listing, temperature range, copper or fiber optic leads, side or top mount, standard and extended operating ranges, and surge protection. The extra time it takes to properly specify a good switch is well spent.

4.3.7.2 Encoders. Position and level measurement require the installation of an electronic encoder such as those included below. Encoders should be specified without the need for external or third party converters, decoders, linearizers, or signal conditioners. These devices have much higher failure rates than PLC I/O cards and cannot always be diagnosed for problems through the PLC system. Encoder signals should be fed directly into a PLC intelligent input card. It is usually not a good idea to use electronic encoders in a hardwired back-up system. The need for scaling and offsetting factors, easily accomplished in the PLC software, coupled with the distances that the signal must travel will often cause reliability, noise, and calibration problems when used without a PLC system. These problems could, depending on how the system is wired, interfere with the normal PLC control system. Electronic encoders require special installation, wiring, and shielding in order to provide long-term reliability and accuracy. Large electrical contractors often will not provide this type of detailed quality installation unless specifications are written tight enough to force them.

4.3.7.2.1 Pressure Transducers. Pressure transducers are used to measure the level of water in and around the lock and dam. A pressure transducer produces an analog signal directly proportional to the amount of water in which it is submersed. Typically, a designer should put at least two (2) transducers in the upstream pool, two (2) in each lock chamber, and two (2) in the downstream tailwater. Such transducers can also be used to measure the amount of leakage in manholes and crossover tunnels. Placing two transducers in areas of critical applications allows for reliability and accuracy checks in the PLC software. In an automated system, the pressure transducers become one of the most critical control components because each automated sequence depends on determination of equal water levels without visual check from an operator. In this case it is essential to have good reliability checks and failover programming built into the PLC program. When specifying submersible pressure transmitters, design engineers should take the time to consider transmitter construction (titanium provides excellent corrosion control), unique pressure rating, excitation power supply level, output signal and wiring, accuracy, repeatability, electrical connection (should include molded integral cable of sufficient length for each application), resolution, and installation instructions. It is important to note that merely stating that the transducer shall be installed in accordance with manufacturer’s recommendations may not be sufficient. There are many different applications for such transducers in industry and many are not in as harsh an environment as a river near a lock and dam. The installation should provide protection from ice, debris, and zebra muscles, should facilitate easy maintenance and replacement, and should provide unobstructed atmospheric reference pressure to the breather tube.

4.3.7.2.2 Rotating Encoders. Angular position of rotating machinery, such as cable spools, gears, chain sprockets and miter gate machinery is accomplished through the use of rotating angle encoders. Typically these are mounted adjacent to the machinery and attached via shaft couplings. Shaft couplings should be one-piece flexible stainless steel and sized to exactly match the encoder shaft and adapt it to the machinery shaft. Installation details should include provisions for making the machinery shaft extension absolutely true and aligning the shafts as true as possible through the use of properly installed stainless steel shims. Details to include in the specifications are NEMA 4 or 6P housing, output signal and wiring, power supply and excitation requirements, number of turns needed to resolve entire travel of machinery, repeatability, accuracy, resolution, lightning and surge protection for primary and secondary windings, shaft size, operating temperature range, and installation instructions. Also, it is important to insure that the rotation of the shaft extension to which the encoder is coupled is linear with the movement of the machinery. If not, programming must be added to the software to correct this. Note: Wire cable wound on a drum is not a linear application because the length of cable unreeled each rotation varies with the amount left on the drum. Each successive wrap of cable on the drum is shorter than the previous one by the cable diameter multiplied by 2B.

4.3.7.2.3 Inclinometers. Inclinometers are used to track angular tilt of the machinery or structural member on which they are mounted. A good application for such a device at a lock and dam project is the position of the tainter gates. Angular rotating encoders do not work as well in this application because the rotation of the cable drum or chain sprocket is not linear with the change in opening between the gate and the sill. Also, because a tainter gate can become frozen in place during times of heavy ice and because drift can be lodged under the gate, the rotation of the machinery is not necessarily indicative of gate movement. A submersible inclinometer mounted on the tainter gate strut will give an accurate indication of gate movement. By programming simple interlocks in the PLC software, slacking of the hoist cables or chains can be avoided in the event the gate does “hang up”. As stated above the signal from the inclinometer should be fed directly into the PLC control system as a “raw” electronic signal. All scaling, trigonometry, and linear and angular offsetting should be done in the PLC software. It is very important that this type of device be thoroughly engineered in a design document. Some parameters to determine in a specification are housing construction, NEMA 6P (may require separate purged enclosure), angular operating range, resolution, accuracy, repeatability, vibration sensitivity, axis of measure (to insure proper mounting), excitation power supply requirements, output signal and wiring, temperature operating range, and detailed installation requirements.

4.3.7.2.4 Hydraulic Cylinder Position Transducer. With the increasing popularity of hydraulic cylinders in navigation lock equipment design, several manufacturers offer position sensing transducers integral to the cylinder construction. The type of transducer and the output signal vary by manufacturer and a design engineer should consider this and specify the type of position sensing system that is best for their equipment. The output signal should be directly compatible with the PLC system I/O cards available. As stated above, it is not a good idea to use third party converters and signal conditioners to “massage” the signal before it is read by the PLC.

4.4 Safety and Security Considerations.

4.4.1 Personnel. Safety for our lock personnel, commercial vessel crew members, pleasure craft occupants, and public visitors is the single most important consideration when designing a quality operating system for a lock and dam facility. This should be considered in every aspect of the electrical system design including the features discussed below. It is strongly recommended that designers of such systems spend sufficient time observing the day-to-day operations at a lock and dam project. While this will not qualify a designer to operate a lock and dam, it may give him/her a better idea of some safety concerns to consider when designing a replacement electrical system or that for a new lock and dam. There are numerous procedures at each lock such as tow cuts and ice maneuvers that, while not obvious to the casual observer, can place the operators in serious danger if the equipment is not located strategically, fails to function properly, or interlocks and safety features do not operate in timely and correct fashion. All of these have to be considered at each step of the design.

4.4.1.1 Accessibility. All electrical and electronic equipment has to be installed in a way that it is safely accessible by lock maintenance personnel. All equipment that has energized circuits should be properly marked. At times it will be necessary to perform maintenance on this equipment in the energized state. Equipment for which entry will cause a shutdown of the lock control system should also be marked with such a warning. All machinery and electrical gear that is controlled from a remote location should have warning labels and a means for disabling the remote control. Also, it is a good idea to provide a means for authorized personnel to operate the machinery from local controls in the event of emergency, or at times during routine maintenance.

4.4.1.2 Operating Locations. When locating lock operating stations, designers must provide visibility to all aspects of the project as necessary to safely control the project. This can be done with direct visibility or with Closed Circuit Television cameras. Only experienced lock operators will be able to determine exactly what features of the project require constant, periodic or occasional surveillance during a lockage. Other areas may require surveillance for security reasons.

4.4.1.3 Machinery Safety Interlocks. All operating machinery should be provided with safe access to the portions that require maintenance. In addition interlocks should be in place to insure that machinery cannot be remotely started while being serviced. Interlocks can consist of machinery room door switches used as inputs to the PLC system. Auxiliary contacts on these switches can be used as hardwired interlocks. It is a good idea to have PLC inputs from these switches because of the flexibility and remote indication that can be provided.

4.4.1.4 Emergency Stop/Hardwired Backup. All lock control systems should have emergency stop pushbuttons at various points around the lock. These areas include but are not limited to all lock control consoles, at each miter gate machinery area, along the lock walls in areas frequented by lock personnel, at motor control centers and switchgear locations, and in galleries where electrical and mechanical machinery is located. The emergency stop pushbuttons should be large, red, mushroom head type, clearly marked, and hardwired directly to motor starters. Consider an auxiliary MCC starter bucket with relays for use in each gate and valve starter circuit.

4.4.1.5 Motion Detectors. Some locks have submersible walkway bridges, walkways across miter gates, or other traffic areas that can be compromised by operation of lock equipment. In these locations, particularly if the lock is automated or remotely operated, motion detectors can provide important safety interlocks to prevent movement of machinery when lock personnel are passing through these areas. It is also a good idea to have some type of visual and/or audio indication prior to actual movement of lock equipment to allow personnel to stay clear of these areas.

4.4.2 Computer System. With so much of the control system integrated with the IPC/PLC system, computer system security is a major concern. In general, access to the lock operating IPCs should be limited to qualified lock operating personnel. Access to the computer hardware as well as the ability to alter programming should be limited to the lock electrician and to district electrical engineers assigned to assist the lock personnel in maintaining and providing training for new computerized control systems.

4.4.2.1 Hardware. The biggest threat to the security of computer hardware is unauthorized use and the introduction of foreign software opening the system up to computer viruses and hardware compatibility problems. Industrial personal computers have an optional locking cover over the floppy and CD-ROM drives to prevent foreign software from being used on the system. While features such as dial-up routers, modems, and internet connections offer greater flexibility in maintaining and trouble-shooting the lock control network, they also are means for external "break-ins" to the system. Firewalls and switches to disconnect the phone lines are ways to combat this problem.

4.4.2.2 Software. The lock operating system should be equipped with a password security system that only allows qualified personnel to access the lock operating screens. Administrative tools and development software privileges should be limited to the system administrator account of which only qualified personnel should have access. Back-up directories should exist on each IPC so that databases on any of the machines can be re-built quickly and correctly in the event of failure. Back-up directories should be updated automatically anytime there are changes to the database. As stated above, external means of access to the network also creates a way for software "hackers" to access the system and corrupt software. Secure passwords and network firewalls can help this problem but they are not guarantees against system intrusion.

4.4.3 Communications. Most of the communications between the IPC system and the machinery PLC I/O racks is via fiber optic cable. Therefore noise and outside interference with the communication signal is not an issue. The fiber optic communication cable will be run in most cases in secure areas around the project. Remote communication and access via the dial-up router, modem, or district intranet as stated above is more likely the method for compromise or security breech of the lock control communications systems. Isolation of the lock control net as stated above will keep the system secure from would-be intruders.

4.5 Procurement Considerations.

4.5.1 Computer Hardware. One of the most difficult tasks when putting together a computerized lock control system, whether automated or not, is the acquisition of quality state-of-the-art computer hardware. Often large construction contracts have too long of a construction period to write specifications around state-of-the art computer equipment. Even PLC components can be superceded in design during major construction of a new lock and dam. Government furnished equipment is not always a good idea because of the issue of responsibility. In theory, GFE is a good idea but in practice many agencies have had trouble administering contracts with a large amount of GFE. Optional bid items and change orders are usually difficult to negotiate and prove costly when issued near the end of a large contract. Following are some guidelines and ideas for procurement of such equipment.

4.5.1.1 Industrial Personal Computers. Computer Hardware will usually only stay “state-of-the-art” for about 1 year and somewhat current for 1-3 years. Therefore, it is not recommended to specify PC type hardware in a contract of duration more than nine months. Even at that with reproduction, advertisement, contract award, notice to proceed, and shop drawing phases the equipment model design will likely be well over a year old when the Government assumes ownership of the control system. Contracts of duration longer than 9 months should be looked at with the possibility of doing a small follow-up contract to install, configure, and program the computer network. When upgrading the PC hardware and software use purchase orders with hired labor for installation or write small contracts with a system integrator. Trying to incorporate computer upgrades into another contract is usually not a good idea because of the different trades involved and the contract duration time. An important part of the successful procurement of a quality system is complete engineered plans and specifications that do not allow a contractor much room to substitute cheaper components or installation methods.

4.5.1.2 Programmable Logic Controllers. Having better stability than PC components, Programmable Logic Controller equipment will generally stay current on the market for 5-10 years. Once installed a PLC system should be expected to require complete upgrade every 10-15 years. However, it is critical at the time of project start-up to have a state-of-the-art PLC system. Therefore, if the construction contract exceeds one year in length, it may be worthwhile to leave the PLC system out of the contract and write a follow-up contract to install and program just the PLC system. In the big construction contract items such as raceways, cable trays, field devices, and even some field wiring can be put in place to minimize the effort of the PLC system installer. The first contract must be managed well to insure that everything is in place. Too often we rely on operational tests to tell us that the Contractor has completed all of his work and in this case the first Contractor may be long gone when the operational tests are performed. It is important to develop some in-house expertise on PLC systems to assist in administering both contracts and providing start-up, assistance, and long term maintenance to the lock. This will prove to be the key whether the control system is successful or not. Down the road, it will be mostly forgotten what problems occurred with administering the contract, but the reliability of the PLC system will always be an issue.

4.5.2 Computer Software. Not unlike computer hardware, software does not stay current for more than 3 years in most cases, and often is superceded by new versions within one year. It can be written in the specifications that the contractor has to provide the latest release of a particular software, but at some point the contractor has to purchase the software and that needs to be written in the specifications so that there is no dispute as to which revision is the latest at the time of purchase.

4.5.2.1 Operating System. The operating system software should be purchased at the same time as and by the same contractor as the computer system hardware. This will alleviate any compatibility problems between the operating system software and other software or hardware.

4.5.2.1 Man-Machine Interface Software. Man-Machine-Interface software should be purchased, the latest revision, at the same time that the PLC system is purchased. Upgrades should probably take place on a three-year basis with most MMI packages. Problems arise when operating systems, such as Windows NT, are revised to the degree that a plant's current version of the MMI software will not run on the new operating system software. These are times when a design engineer or software maintenance personnel have to be careful when upgrading software. Usually databases can be transferred when the MMI software is upgraded but not always. Before writing plans and specifications or a purchase order it is recommended that the designer have a thorough understanding of the marriage between the operating system software and the MMI as well as a thorough knowledge of what is available on the market at the time. All projects should program monies to upgrade the MMI software on a three-year basis.

4.5.3 Sensors. Non-electronic sensors such as dry contact vein operated limit switches, traveling nut limit switches, and magnetic limit switches can be purchased and installed in a large construction contract. However, if your construction contract exceeds one year in duration, consider purchasing encoders, pressure transducers, inclinometers, hydraulic cylinder position tracking devices, and other solid state sensors in a separate follow-up contract perhaps with the PLC/IPC system hardware. Again raceway and wiring can be put in place for these items but to insure that the latest revisions are acquired it may be best to purchase the sensors later.

4.5.4 Training. Training should be provided in all contracts and purchase orders. Generally a contractor will not raise his bid price too much to cover training, so consider putting a generous amount of training in your specifications package. Having said that, it is a good idea to put enough training, stressing quality and qualifications of instructor, to force the Contractor to put some extra money in his bid. This will ensure better training when the time comes. If you find the system is easier to operate and maintain you can always delete some training or reserve it for cross training personnel from other locks or projects. In as much as possible all training should be provided well in advance of equipment installation. It is a good idea to video tape all training to be used later as a reference and a training tool.

4.5.4.1 PLC/IPC System Training. The contractor's system integrator should provide the PLC/IPC system training. Schedule enough sessions for enough personnel to more than ensure that everyone gets sufficient training. Three things to include in the contract are number and length of training sessions, qualifications of instructors, and material to cover as well as training aids to furnish.

4.5.4.1.1 Hardware. The PLC hardware training should cover everything from simple I/O card installation and removal to termination of fiber optic and copper communication cables. Discussion should cover hardware diagnostics, interpretation of system LED indicators, automatic failover of communication channels, power supply connections, fuses, line conditioners, lightning protection and all other hardware located in the PLC I/O racks. The instructor should provide hardware similar to that used on the project and complete with power supplies, I/O cards, communication cards, and all equipment necessary to allow trainees to assemble a small PLC system ready to program as stated below. The IPC system hardware training should cover all connections to the chassis including network, printer, mouse, keyboard, and power. The discussions should cover the installation and removal of CPU, video, and network cards. The contractor should thoroughly discuss all connections to equipment such as routers, modems, printers, hubs, and back-up tape drives.

4.5.4.1.2 Software. Software training should be included with the hardware training and accomplished on the same hardware during the same training sessions. This will help bridge the gap between the hardware and software.

4.5.4.1.3 Operating System Software. The software training should start with a thorough review of how to navigate the system operating software. Particular attention should be paid to how the system operating software interacts with the PLC programming software and the MMI software. System log-in and boot-up procedures should be shown. Passwords and restricted access should be discussed and explained. Location of directories and file storage folders for the PLC programming software and the MMI should be addressed in the training. Things such as operating screen file transfers and file back-up procedures should be discussed. Any special custom icons used to short-cut loading of the PLC or MMI software should be reviewed. The contractor should show how to re-load and configure the system operating software in the event of failure. This is usually a good time for government personnel to point out some features that they would like to see changed such as passwords, initial loading screens, profiles, etc. At this point a system integrator will usually make these changes at no additional cost because it does not impact the schedule. Sometimes these changes can be made during the training session, which enhances the quality of the training.

4.5.4.1.4 PLC Programming Software. The contractor should demonstrate how to install and configure the PLC programming software package. The training should cover complete I/O rack and slot addressing as well as communication software installation and configuration. PLC ladder logic should be developed for the mock PLC system developed as stated above. All common programming features such as coils, contacts, timers, counters, shift registers, LET, IF, and compare statements, GOTOs, and other common ladder logic notations. Documentation of the program should also be covered. An application should be developed for the training PLC system, loaded to the processor, and shown to be working.

4.5.4.1.5 Man-Machine-Interface Software. The same procedure should be followed for the MMI software training. After demonstrating how to navigate through the package an application should be developed for the training IPC/PLC system and shown to function properly.

4.5.4.2 Sensors Training. The contractor should provide training on all of the field devices including limit switches, pressure transducers, encoders, inclinometers and other input/output devices. The training should cover the installation and replacement of these devices as well as their respective interfaces to the PLC/IPC system.

4.5.4.3 CCTV System Training. It is very important to include in a construction contract sufficient training on the CCTV system. As with the IPC/PLC training the specifications should include three things, the qualifications of the instructor(s), the amount of training, and the topics to cover. The instructor should be an integrator who has commissioned CCTV systems at other projects with the same components. The instructor need not be a representative of the hardware manufacturer and in fact, the quality of training will probably improve if the instructor is an integrator who actually makes the equipment function rather than a manufacturer’s representative. Specify enough training in the contract to force the CCTV supplier to build sufficient monies into his bid. This is because large manufacturers will often tell electrical contractors during the bid process that they will provide the training at no cost if they use their equipment. In this case a salesman will come to the site and read from an operating manual. This is not quality training. If a supplier has to build some cost into his bid he will be more flexible in providing the training and, after award of the contract, quality rather than quantity can be stressed. Topics should cover everything from installation and configuration of all hardware and software to long term access and maintenance of the equipment. Constructing a mock system as part of the training is always a good way for maintenance personnel to learn the new equipment.

4.5.4.4 CCTV System. Closed Circuit Television equipment does not evolve as fast as computer hardware and software. However, if your contract duration is more than two years, it is best to furnish and install the CCTV equipment with a follow-up contract to ensure procurement of the latest technology. In all cases it is probably best to have a CCTV system supplier and integrator do the work. They should be a firm regularly engaged in providing, installing, and performing start-up and long term maintenance of CCTV systems. As with the IPC/PLC equipment, thoroughly engineered plans and specifications are the key to the procurement of a successful CCTV system.

4.5.5 Warranties and Service Contracts. Troubleshooting, repair, and long term maintenance of computerized control equipment is a critical part of a successful lock control system implementation. It is recommended that a plan for such action be in place prior to procurement of such equipment. Some things to consider are as follows.

4.5.5.1 Warranties. Most construction contracts include a one-year warranty on labor and materials. It is a good idea to have the contractor make written transfer to the Government of any manufacturer warranty on equipment covered by this manual. Some of these warranties may exceed one-year. Procure additional years of extended warranty with caution because there is a point of diminishing returns. Namely, some equipment will become outdated before it fails. Also, it has been shown that a majority of equipment failures occur within the first year or so of operation. Once the “wrinkles” are worked out of a system many of the components can be expected to last a reasonable amount of time relative to the time it takes for their obsolescence to drive replacement.

4.5.5.2 Service Contracts. Generally speaking it is better to provide in the construction contract a service agreement with the contractor’s system integrator as opposed to searching for a low bid third party to service the system. Limit this agreement to one year with the Government’s option to renew for a second year. By doing this the district will have a chance to evaluate the contractor’s performance. Specify in the service contract that it shall be the responsibility of the contractor to furnish spare parts, as he feels is necessary, above and beyond that specified in the original contract. Also, specify response and repair times as well as a list of Government points of contact to avoid confusion when problems arise. Require that the contractor make a full report of changes and procedures that were made to correct the problem, both temporary and permanent. This report should include all parts that were replaced.

4.5.5.3 In-house Maintenance. The best way to maintain systems such as these is through the use of well-trained in-house electricians and electronic technicians supplemented with help from district engineers when required. When personnel and budget restrictions allow, a district should have at its disposal a crew of such personnel that can perform routine maintenance as well as emergency repairs at all of the districts locks. Busy locks may be able to justify a highly trained electrician/electronics mechanic dedicated to that lock. This is the best way to maintain the system. Keep in mind that in addition to the high skill level necessary to service computerized control systems, this person must have a thorough knowledge of fundamental electrical principles. This is important because the computerized control system is only a convenient “front end” to make operations and maintenance safer, more reliable, and more flexible. Beneath all of this is still the basic concept of electrical power transmission and conversion into mechanical work via a motor or solenoid. For this reason it is generally better to put a sound electrician through the proper training and upgrade them to an electronics technician, than to take a computer programmer and try to teach them fundamental electrical principles.

4.5.6 Testing and Startup. All construction projects should have testing and start-up procedures well defined in the contract requirements. All testing should be witnessed by Government representatives from engineering, construction, and operations. This will insure that the test procedures are correct, relevant, and that all hardware and software pass the test. Each system should be tested individually and then as a total lock control system.

4.5.6.1 PLC System. Require the contractor, prior to installation, to assemble a small system using their proposed PLC components to demonstrate how the system will work. This will also be a good training tool for district personnel. This should be done off site at the system integrator’s shop to enhance the training aspects of the testing. Mixing training with testing at his point can be a good thing as long as there are clear requirements for each, as stated herein and above, provided for in the contract.

Once the system is in place at the lock, the contractor should be required to test each and every I/O point on the system, making a chart to verify that each point has been tested. This test should be done independent of field devices using dry contact switches and pilot lights for digital inputs/outputs, and function generators and meters for analog I/O. This will test the entire PLC communication network. The test should be performed using each of the redundant PLC communication channels. The Contractor should be responsible for correcting any and all deficiencies shown by the test. Field devices, such as limit switches, encoders, and transducers can be now be tested using the PLC system with confidence that the communication and I/O rack wiring are properly in place.

4.5.6.2 IPC System. At the same time as the PLC factory test, the system integrator should be required to set up a mini version of the IPC network. The network should include the PLC processor with all appropriate software to allow programming, troubleshooting, and execution of a ladder program and an MMI application. During this test, in the presence of Government personnel, at least one IPC should be “brought on line” from the ground up including the following.

- Connect all peripherals such as monitor, mouse, modem, etc
- Install the Network Cards.
- Install and configure Windows NT operating software.

- Verify communications with all other network devices.
- Install and configure all PLC programming software.
- Install and configure all MMI programming software.

After this has been done, the system integrator should demonstrate that numerous large files and directories can be copied over the network with speed and accuracy. At the same time as the PLC factory test a mock ladder program and MMI application should be developed to insure compatibility of all hardware and software. Again this test procedure also serves as a good training exercise for Government personnel.

After the system is in place at the locks, all network communications should be verified again to check all field wiring. Knowing from the factory test that all network software parameters are configured correctly will aid in determining start-up problems at the site. While testing the PLC I/O points a test MMI application can be used. This will make the I/O testing easier as well as demonstrate further that the IPC network is properly in place.

4.5.6.3 Field Devices. Immediately after installation, the contractor should check all field devices using meters to determine that they have freedom for necessary motion, put out the correct signal when input power is applied, operate correctly with the movement of machinery, and are protected from operations, debris, and weather. After all I/O points have been checked, field devices should be wired to the I/O racks and tested using the PLC/MMI network to verify that all field device outputs are compatible with the PLC system.

4.5.6.4 Total System. After the above tests have been successfully completed and the lock machinery is ready to be moved the entire system should be checked for proper operation. All systems should be checked as follows:

4.5.6.4.1 Water Level Sensing System. Because it is used as a safety interlock, the water level sensing system should be tested prior to operation of any lock machinery. Each water level sensor should first be checked for a proper and accurate level as displayed on the MMI operating screen. Because the transducer itself has been tested previously this test should concentrate more on the decoding in the ladder logic. Require the contractor to verify that the level displayed corresponds to water level changes. In the case of a submersible pressure transducer raise each unit exactly one foot and verify that the level displayed responds accordingly. Repeat this step through several feet and back down again. While not the most accurate test, this will give a very good indication that the unit and programming are responding correctly. Fine tuning the calibration can be done when the lock chamber is filled and emptied and large changes in water level can be tested.

4.5.6.4.2 Lock Gates. Motor rotation should always be checked prior to movement of any equipment. When all limit switches and safety interlocks have been tested and verified for proper operation, the contractor should begin moving each lock gate one at a time in slow speed. Immediately check to insure that the position displayed on the MMI screen is responding correctly. The contractor should stop and restart the gate from several different positions to insure that the machinery starts in slow speed and changes speeds correctly. All limit switches, including over travels, should be checked for proper operation and indication. Each gate should be run through a minimum of ten cycles for testing purposes. Miter gates should be run together after it is shown that each leaf operates correctly. The position indication should be monitored continuously for any glitches or spikes. End-of-travel limits should be checked for proper mitering and recessing of the gates. Bubbler system compressors and solenoids should be checked for proper operation and indication.

4.5.6.4.3 Culvert Valves. The same basic procedure for the miter gates should be followed for start-up and testing of the culvert valves.

4.5.6.4.4 Dam Gates. After rotation has been checked the dam gates should be individually operated through as much of their full range of travel as pool conditions will allow. If possible, placing stop logs will give the contractor the chance to test the full range of travel of the gates. All limit switches and over travels should be checked for proper operation. Again, the position readout of the gate on the MMI should be monitored for proper response to the movement of the gate. The contractor should periodically stop the gate and verify the position against a known benchmark such as a staff gauge.

4.5.6.4.5 Lock Lighting. All PLC-controlled lighting systems should be checked for proper operation and indication. Feedback indication on the MMI screens should be from auxiliary contacts on the lighting contactors. Integrators often will use PLC output status as an indication of light operation, but this is reliable feedback. Traffic lights should also be tested for proper operation. The contractor should verify that the traffic light changes to red when the lock gates close.

4.5.6.4.6 Alarms. All alarms such as transducer failure, fire and smoke detectors, motor overload, machinery overtravel, communications fault, power failure, etc. should be simulated and checked for proper indication on the MMI screens.

4.5.6.4.7 Remote monitoring and troubleshooting capabilities of the system should be tested by the contractor for proper operation and security.

4.5.6.4.8 Miscellaneous Control Features. Miscellaneous control features unique to each lock should be checked for proper operations. When all of these systems have been verified to function properly the Contractor should run the lock through several (at least five) complete lockage cycles utilizing all of the equipment mentioned above. Pay particular attention to the position indication of the gates and valves, and the level readouts for the pool, tailwater, and chamber water level sensors. Make sure that the "pools equal" interlock is functioning correctly at each end of the lock. It is usually better to specify requirements for extra testing rather than not enough. A contractor will usually not add too much to his bid to cover testing but will always try to reduce the amount of testing when the project comes to an end. This test procedure may be the last chance to have the contractor correct some deficiency so it is important to be clear about the amount of testing the Government requires.

4.5.7 Documentation. The contractor should be required to provide complete system documentation for all hardware and software used on the system.

4.5.7.1 IPC Network. The documentation should show all network and communication parameters and should include detailed drawings showing the complete Ethernet network including all IPCs, PCs, modems, routers, fiber optic equipment, communication cables, hubs, transceivers, network cards, video and sound cards, data storage devices, uninterruptible power supplies, and other network equipment. Manufacturer names and model numbers should be shown for all devices.

4.5.7.2 PLC Network. The contractor's system integrator should provide drawings showing the complete PLC network with all I/O racks and cards, fiber optic converters and power supplies, lighting panels, adjustable frequency drives, network communication equipment, power supplies, uninterruptible power supplies, and other equipment. The drawings should show all manufacturer names and model numbers, how all devices are interconnected, and all PLC network addresses including addresses for each individual I/O rack slot. A list should be provided showing the location, address, type, designation, tag, and purpose of every I/O point in the system.

4.5.7.3 Ladder Logic and MMI Applications. The system documentation should include complete up-to-date listings of the entire ladder logic program with all I/O points, cross-referencing, and labels list. The MMI software documentation should include a cross reference of every I/O point monitored, a list of all tags showing type and designation, and a printed copy of every operating screen. All software configurations necessary to establish proper communications with the PLC processor should be included in the documentation.

4.5.7.4 Field Devices. The contractor should include a complete listing of every transducer, encoder, limit switch, photocell, motion detector, and other field devices. The documentation should include manufacturer names and model numbers, voltages, input and/or output parameters (if selectable), dip switch settings, wiring, power supplies, and all information relative to the job.

4.5.7.5 Input/Output Rack Wiring. The contractor should include as-built documentation of all equipment and wiring in each I/O rack enclosure. This information should be detailed enough to show point-to-point wiring with terminal board designations for all connections.

4.6 Power Supply.

4.6.1 General. The electrical power supplys quality will effect how efficient the lock operates and its operating available. As for most industry applications, the electrical power supply should be three-phase, rated 480/277-volt, with an ampacity rating not less than the estimated maximum demand plus 15 percent for future growth. Wye-connected systems allow the ability to quickly identify and locate a faulted circuit in a widely dispersed area. Further guidance on rights-of-way, ownership, operation, etc., of the transmission line and substation may be found in TM 5-811-1, Electric Power Supply and Distribution.

4.6.2 Configurations. Possible configurations for the lock's power supply system are radial system or network system.

4.6.2.1 Radial System. A radial distribution system has only one simultaneous power flow path to the load. This is the lowest cost system and the system with the lowest reliability. A single point failure can leave the lock without electrical service.

4.6.2.2 Network System. A network distribution system has more than one simultaneous power flow path to the load. There are several variations for network distribution systems. In general, a system with more redundancy tends to be more reliable. That is not to say that redundancy in its self will increase reliability. Single point failures do not necessary leave the lock without electrical service. Redundancy comes with a higher price. A network distribution system is more difficult to operate that of a radial distribution system.

4.6.2.3 Considerations. The loss of a station service source, either through switching operations or due to protective relay action, should not leave the lock without electrical service. In general, the usage of a radial feed should be limited to projects where either the economics or characteristics of the protected property do not justify or require a more expensive network. A fully redundant network such as a system with two full-capacity transformers, two station service busses, and a tiebreaker between the busses offers a better system. Even though each transformer is capable of carrying the locks entire load, the distribution system should be configured for normal operation with approximately one-half the load on each bus. In the event that one supply transformer fails, an automatic transfer of load via the bus tiebreaker will quickly restore electrical service to the effected bus.

4.6.2.4 Recommendations. The station service system should have a minimum of two, redundant power sources with a bus tiebreaker between them. This duo-end with bus tiebreaker power configuration dramatically improves power supply availability over a simple, radial distribution system.

4.6.3 Estimating Station Service Load.

4.6.3.1 Transformer Ratings. The station service transformer ratings should be developed from the expected maximum demand. The expected demand may be determined from a total of the feeder loads with an appropriate diversity factor, or by listing all connected loads and corresponding demand loads in kVA.

4.6.3.2 Demand Factors. Demand factors used for developing station service equipment capacities can vary widely due to the type of plant (i.e., high head stand-alone power plant versus low head power plant integrated with a dam structure and navigation lock). Development of demand factors for unit auxiliaries should account for the type of auxiliaries in the plant based on trends observed at similar plants.

4.6.3.3 Load Growth. Station service systems should be designed to anticipate load growth. Anticipated growth will depend on a number of factors including size of the lock, and location.

4.6.3.4 Capacity Deficits. Capacity deficits in station service systems have not been caused by the designers inability to predict lock auxiliary requirements. However, unforeseeable added demands from providing service for off-site facilities, which are typical of multipurpose projects, have caused problems with station service capacity. Examples of this have been the development of extensive maintenance and warehouse facilities outside the lock, or electrical requirements resulting from environmental protection issues such as fish bypass equipment. The station service design should have provisions for unanticipated load growth for multipurpose projects with navigation locks and fish ladders.

4.6.4 Transformers. The designer should give serious consideration to requiring the utility company own the main power transformers and maintain them. It is true that by accepting power at distribution voltage levels (i.e., 2,400, 4,160, 12,470, or 13,800 voltages) instead of at utilization voltages (120/240, 480, or 480/277 voltages), that most utilities can offer lower cost per kilowatt-hour. This is due to fact that most metering is at the utilization level and does not include the transformer losses which the utility adjusts its rates so a to pass these costs on to the customer. By accepting the power at distribution voltage levels, the utility has no need to adjust for transformer losses that they do not occur. However, if the lock owns the transformer, the lock will have to perform all maintenance on the transformer. This maintenance will require specialized tools, materials, and electrician skills level that would not otherwise be required at the lock. The utility will normally be better prepared to perform these maintenance actives over what the lock's maintenance crew could handle. In the event of major damage to a main power transformer, the utility normally should be able to replace a damaged transformer faster than the lock personnel could. Since maintaining and operating a distribution system is the utility main job, the utility would be logical choice for maintaining the main power transformers because they have the training, materials, and tools to this type of work.

4.6.5 Station Service Switchgear. Metal-enclosed switchgear with 600V, drawout, power, air circuit breakers should be used for each supply and bus tiebreaker. The switchgear should be located near the station service transformers. A complete station service supply and distribution system should be provided to furnish power for station, lock auxiliaries, lighting, and other adjacent features of the project.

4.6.5.1 Power Circuit Breakers. Each supply and bus tiebreaker should be electrically operated for remote operation from the control room in attended stations. Normally, the supply breakers should be interlocked with the bus tiebreaker so that only two breakers can be closed at any one time. This interlocking scheme is to prevent paralleling the two supply transformers. If the two supply transformers are paralleled, the result is a higher available ground fault current. This would possibly increase the maximum interrupter rating for the switchgear and would increase the cost.

4.6.5.2 Remote Control. As a minimum, bus voltage indication for each bus section should be provided at the remote point where remote plant operation is provided. Transfer between the two normal sources should be automatic. Transfer to the emergency power sources should also be automatic when both normal power sources fail. Feeder switching is performed manually except for specific applications.

4.6.5.3 Duplicate Feeders. Duplicate feeders (one feeder from each station service supply bus) should be provided to important load centers. Appropriate controls and interlocking should be incorporated in the design to ensure that critical load sources are not supplied from the same bus. Feeder interlock arrangements, and source transfer, should be made at the feeder source and not at the distribution centers. All of the auxiliary equipment for a main unit is usually fed from a motor control center reserved for that unit. Feeders should be sized based on maximum expected load, with proper allowance made for voltage drop, motor starting inrush, and to withstand short-circuit currents. Feeders that terminate in exposed locations subject to lightning should be equipped with surge arresters outside of the building.

4.6.5.4 Load Centers. The distribution system control should be thoroughly evaluated to ensure that all foreseeable contingencies are covered. The load centers should be located at accessible points for convenience of plant operation and accessibility for servicing equipment.

Allowance should be made for the possibility of additional future loads. Protective and control devices for station auxiliary equipment should be grouped and mounted in distribution centers or, preferably, motor control centers. The motor starters, circuit beakers, control switches, transfer switches, etc., should all be located in motor control centers.

4.6.5.5 Relays. An overlapping protected zone should be provided around circuit breakers. The protective system should operate to remove the minimum possible amount of equipment from service. Overcurrent relays on the supply and bus tiebreakers should be set so feeder breakers will trip on a feeder fault without tripping the source breakers. Ground overcurrent relays should be provided for wye-connected station service systems. The adjustable tripping device built into the feeder breaker is usually adequate for feeder protection on station service systems using 480V low-voltage switchgear.

4.6.5.6 Control and Metering Equipment. Indicating instruments and control should be provided on the station service switchgear for local control. A voltmeter, an ammeter, a wattmeter, and a watthour meter are usually sufficient. A station service annunciator should be provided on the switchgear for a large station service system. Contact-making devices should be provided with the watthour meters for remote indication of station service energy use. Additional auxiliary cabinets may be required for mounting breaker control, position indication, protective relays, and indicating instruments.

4.6.5.7 Emergency Switching. The station service switchgear should have a sectionalized bus, with one section for each normal station service source. Switching to connect emergency source power to one of the buses, or selectively, to either bus should be provided. If the emergency source is only connected to one bus, then the reliability of the station service source is compromised since the bus supplied from the emergency source could be out of service when an emergency occurred. It is preferable that the emergency source be capable of supplying either bus, with the breakers interlocked to prevent parallel operation of the buses from the emergency source..

4.6.6 Emergency Power. Locks should be equipped with an engine-driven generator for emergency standby service with sufficient capacity to operate the spillway gate motors and essential auxiliaries in the dam. Any emergency source should have automatic start control. The source should be started whenever station service power is lost. The emergency source control should also provide for manual start from the plant control point. It is also important to provide local control at the emergency source for non-emergency starts to test and exercise the emergency source. A load-shedding scheme may be required for any emergency source, if the source capacity is limited.

4.6.7 Other Considerations.

4.6.7.1 Electrical Room. The Electrical Room should contain adequate floor space for all electrical equipment and should be constructed for noise reduction where necessary. The designer should be fully aware of the National Electrical Code (NEC) requires for working space around electrical equipment.

4.6.7.2 Facility Considerations. The design should have adequate lighting and potable and wastewater treatment facilities. Also, the buildings should provide safe and adequate facilities for visitor access (including persons with disabilities as required by regulation) as well as the features needed for efficient lock operation.

4.6.7.3 Safety Features. Among these features, designing for safety and fire resistance is of primary importance. The design for safety should comply with EM 385-1-1, and it should satisfy local ordinances.

4.7 Onsite Wireless Control.

4.7.1 General. It is preferable to conduct lockage operations from the control room/station where the lock operator has access to all controls and communication systems. However, it may be desirable to operate certain equipment, such as a tow haulage system, from outside the control station on the lock wall to improve line of sight and safety. The Engineer Research and Development Center, Construction Engineering Research Lab (ERDC-CERL) conducted research to determine the viability of onsite wireless command, control and monitoring of lock operating equipment to operate tow haulage systems and for local operation of lock equipment during maintenance procedures. This section provides general information about the results of the research. ERDC/CERL TR-01-40 report titled "Demonstration of Onsite Wireless Control of Lock Operating Machinery" provides detailed information about the results of the research and specification information for the wireless system's components. Two types of onsite wireless control systems were investigated.

- Wireless control/feedback system transported on a motorized cart.
- Handheld wireless control system that could easily be carried by lock operators and maintenance personnel.

This technology was demonstrated at Barkley Lock and Dam in Nashville District. Barkley Lock is 800-ft long x 110-ft wide with a 57-ft lift. The vertical viewing distance is approximately 80 ft. Normally, Barkley Lock has only one operator on duty per shift, and has operated this way for the past 30 years.

4.7.2 Cart-Mounted Wireless Control. The cart-mounted wireless control system consists of a small, lightweight control panel with touchscreen operator interface (OI) control and a wireless modem that enables the transmission of control commands directly to the PLC. Headwater, tailwater and chamber water levels, and filling and emptying valve status can be monitored, and tow-haulage machinery operated. The cart provides mobility that enables the lock operator to control lock machinery from any point along the lock wall, including terminating the operation if any unsafe condition happens.

As shown in Figure 4-12, the wireless system consists of a cart-mounted master controller that contains a touchpad and screen that continuously displays the feedback information transmitted from the PLCs, and a wireless modem, operating in master configuration. It transmits lock machinery commands to a second wireless modem, operating in a slave configuration, which is connected to the PLC and provides feedback data on machinery position and performance. The carts' 12-volt batteries provide the necessary power for the modem and master controller.

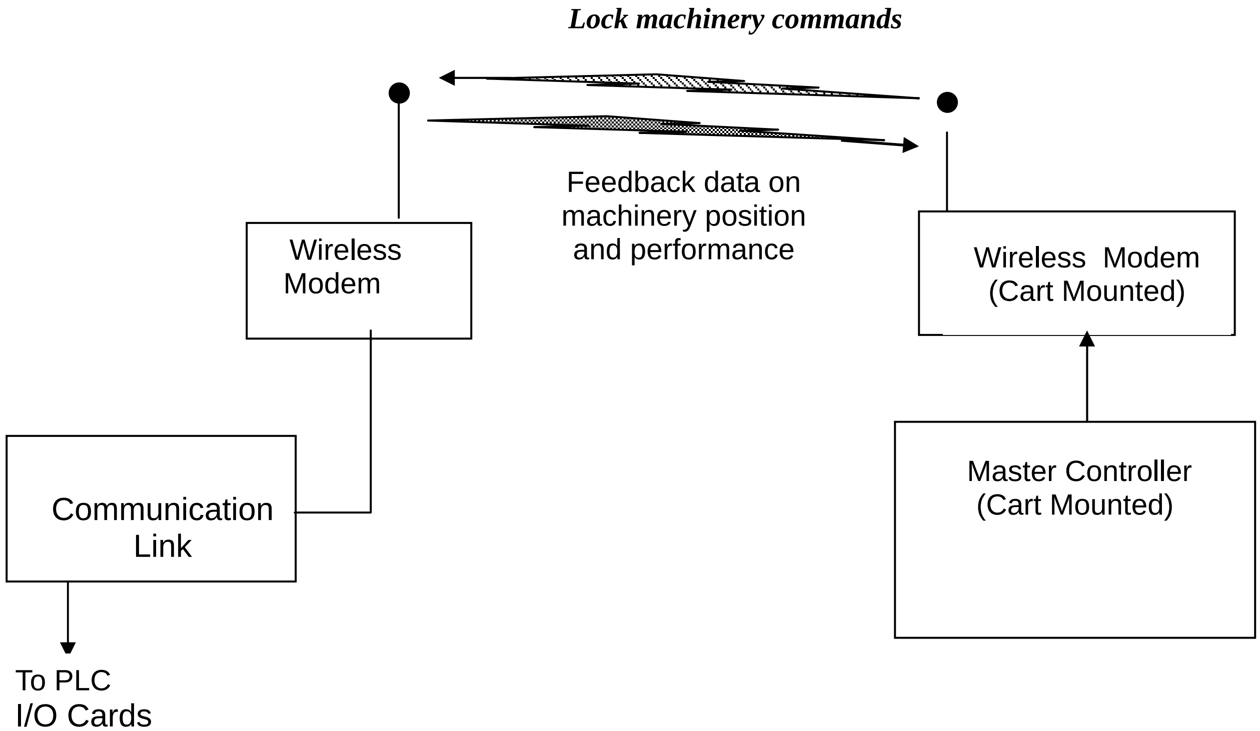


Figure 4-12. Configuration for Onsite Wireless Control

4.7.3 Handheld Wireless Control. During most maintenance procedures, the operator is close to the equipment to be controlled and needs to be able to start and stop equipment intermittently. A handheld remote controller designed to control a particular piece of equipment can provide the necessary control for such operations and it also protects the maintenance technician who is working on a piece of equipment that could be accidentally activated by someone in the control room several hundred feet away.

The handheld wireless system consists of a portable handheld transmitter and a receiver that can be mounted at some central location (e.g., in the equipment room or gallery). This system does not feed back lock data information (i.e., it provides the operator with control only and is similar to the operation of most television remote controllers in the home). When maintenance personnel are performing activities in cramped spaces, they can operate gates and tainter valves via wireless control. A schematic diagram of the control system is shown in Figure 4-13.

The receiver's relay contacts are wired to PLC input cards that communicate with the PLC processor, which in turn communicates with the PLC output cards to start or stop machinery or electronic equipment. The receiver can receive commands from the handheld transmitter and instruct the PLC's output cards to activate and de-activate equipment on command. The transmitter can be used to control equipment inside the gallery area during maintenance operations as long as the operating equipment is within 800 feet of the receiver.

This system may be used at locks where equipment is controlled through either conventional relays or PLCs. It can operate gates, valves, pumps on river or landsides, traffic signals, and control the speed of the gate or valve opening or closing (e.g., increased from slow to fast).

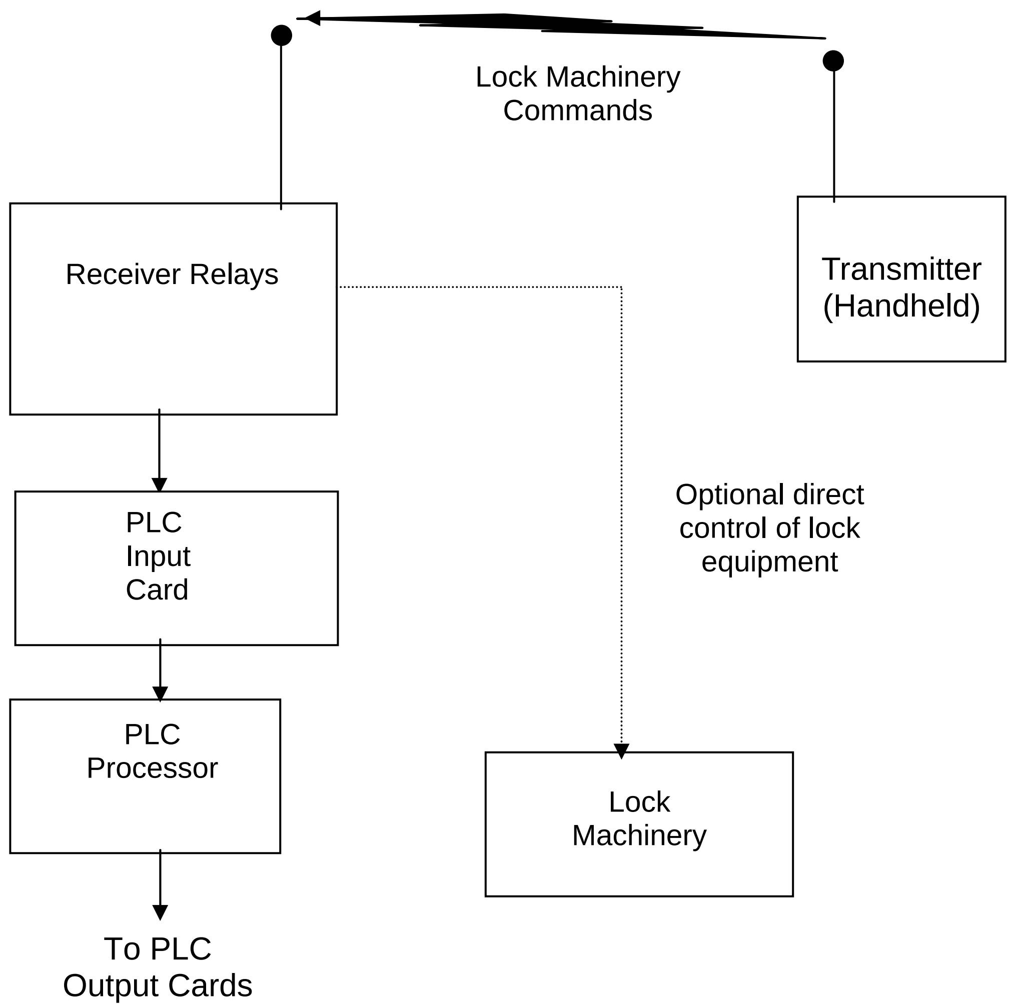


Figure 4-13. Configuration for Handheld Wireless Control

Although the size of the handheld transmitter makes it convenient and portable, it limits the unit's power capacity. This limited capacity confines the range of nominal operation to about 800 feet, and transmitter and receiver must be positioned within "line of sight" of each other. The handheld wireless control system is limited to fairly short-range operations or control, and cannot be used in situations where the signal must be transmitted from the lock wall down to the gallery area. The system is useful for maintenance operations within the lock's gallery when the receiver is positioned there. The handheld transmitter uses three 1.5-volt AA batteries as a power source.

From a practical maintenance standpoint, to ensure movement of only the desired piece of equipment, it is safer to limit the number of systems or pieces of equipment to be controllable at any one time from a single handheld remote, especially considering the lack of feedback. Functioning of existing hard-wired safety interlocks and meeting requirements of lock-out, tag-out regulations during maintenance must still be employed.