SECTION 40 96 45.13 – PROCESS CONTROL SOFTWARE FOR LMCS

1.01 SUMMARY:

A. [A17]**Scope**: This Section covers the performance requirements, design, supply, development, installation, training, testing, commissioning, and technical support for software of complete process control systems (PCSs) based locks machinery control systems as part of the Works.[A17] This Section of the Employer's Requirements shall be read in conjunction with the Sections listed in Table 40 96 45.13-1.

B. **Related Sections**:

TABLE 40 96 45.13 - 1: [A9]Related Sections [A9]			
1.	Section 01 81 26	-	Communications, Control, Safety, and Security Systems.
2.	Section 28 16 46	-	Vehicular Control Systems.
3.	Section 35 10 00	-	Waterway and Marine Signaling and Control Equipment.
4.	Section 40 00 00	-	Process Systems Integration.
5.	Section 40 95 13	-	Process Control Hardware.
6.	Section 40 96 45	-	Process Control Software.
7.	Section 48 19 16	-	Inverters.
[A9]8.	Section 01 92 00.13	-	Dry Outages. [A9]

1.02 REFERENCES:

A. **Applicable Publications**: Refer to Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), Paragraph 1.02.

1.03 REQUIREMENTS:

A. **General**: The Contractor shall meet the requirements of Section 40 96 45 (*Process Control Software*), Paragraph 1.03.

B. **Locks Machinery Control System Operation**: This PCS shall be designed using the human-machine interface (HMI), master programmable logic controller (PLC) to input / output (I/O) concentrator configuration. The following shall be the system's key features:

1. The locks machinery-control system (LMCS) shall have full automation, semi-automation, and manual modes of operation.

2. A network communications failure shall only affect the related machinery operation.

3. **Remote Reset**: In the event of a breaker trip or a motor starter trip, the system shall be capable of resetting them remotely by means of user request. Remote reset feature on a particular device shall be attempted up to three instances per hour. If limit is exceeded, feature shall be disabled until user physically presses the reset button on the related machinery local control panel.

1.04 DESIGN CRITERIA / SYSTEM PERFORMANCE:

A. **General**:

1. **Problem to be Solved**: The systems shall solve the following business needs:

a. To produce software emulating the standards and "look and feel" of the existing HMI and PLC software to leverage the familiarity of the Employer's Personnel (Locks operators and maintenance personnel) with the existing control system.

b. To provide new software that improves the performance of existing software in old locks with more useful features and macros, user friendliness, and quick response, for better overall user experience.

c. Report when equalization is achieved for all pairs of adjacent bodies of water.

d. Measure and report the following for the filling and emptying system:

1) Start time beginning with valve opening signal upon open command.

2) Stop time ending upon achieving equalization.

e. Measure and report the following for RG operations:

1) Opening times, beginning with the open command time stamp, including machine startup time which ends with application of force onto moving body, and moving body time which ends with a full open indication.

2) Closing times, beginning with the close command time stamp, including machine startup time which ends with application of force onto moving body, and moving body time which ends with a full closed indication.

2. **Restrictions to be Considered**:

a. The [A9]Contractor[A9] shall gather information from the Employer's Personnel (operators) to ensure end user satisfaction.

b. All features and improvements to implemented software shall be evaluated and approved by the Employer.

c. Water levels in two adjacent chambers shall be considered as "equalized" whenever the calculated difference of levels and pressure are such that it is safe to move the corresponding rolling gate(s). This depends on the RG design and level difference is expected to be somewhere between 50 mm (2 in) and 254 mm (10").

B. **Machinery Control Station (MCS)**: The MCS is an interactive HMI application used exclusively to operate the Locks machinery to execute Lockages. The MCS shall exhibit a bird's eye view of the Locks, showing the relative machinery position (not to scale). The machinery shown shall be animated in real time and mimic actual position and events. This application shall be capable of operating in the following modes: manual, semi-automatic and full automatic.

1. **General**:

a. The main display shall simultaneously show and animate all Lockage related machinery. No multiple page-displays or scrolling displays shall be acceptable. Special care shall be taken to avoid as much as possible, pop-up windows or dialogs that cover machinery animation during the Lockage process, because it may negatively impact Employer's Personnel (operator) response. Application configuration dialogs that are not required to be accessed during the lockage process may cover the main display when invoked.

b. Where an Active-X object for a device or function is expected, and such object is not available for the device or function, the pop-up display shall be developed in its place to allow display of device variables and configuration or to do the required function.

c. No command confirmation dialog windows shall be necessary.

d. Depending on the number of animated machinery versus screen layout space, the MCS desktop size may require up to three side by side monitors, one per lock level.

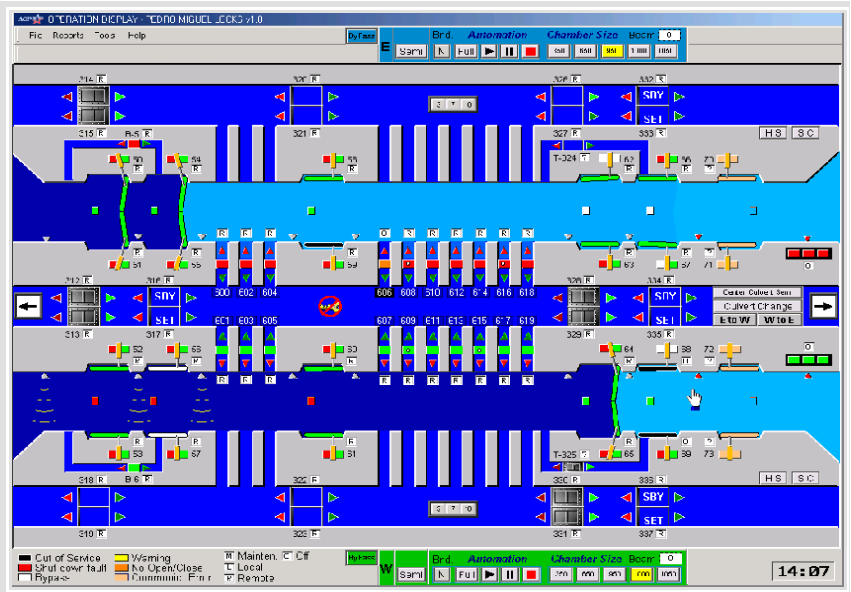


Figure 40 96 45.13–1: MCS display example from Existing Locks (1 Chamber)

2. **Water Level Graphics**:

   a. Graphics shall be animated in real-time. In normal operation, depth shall be portrayed in degrading color from dark (deep) to light blue (shallow), with a minimum of 96 colors total per Locks facility, 32 colors per Chamber. See example in Figure 40 96 45.13–1. An empty chamber shall be shown in white instead of shades of blue.

   b. If a water level transducer (WLT) is faulted, HMI shall use the value of a complementary WLT in its place, provided that the WLT measures the same level, depending on the status of gates open.

3. **Culvert Graphics**:

   a. The layout shall have "see through" lock walls and floors for the purpose of showing culverts underneath.

   b. Culverts shall be animated, for example with small bubbles or lines, to show water movement within. Water movement shall be inferred by the position of gates, valves and water head.

   c. Culverts shall also be animated to match the water level color of the body of water connected to it. In the case a culvert is connected to multiple bodies of water, the culvert color shall match the highest level of water.

4. **Control Commands**: The display shall have controls and indication for the following:

   a. Open and close commands for operating machinery. Theses commands shall be animated push buttons on opposite sides (in line with machinery motion) of the rolling gate or valve. Moving machinery shall stop when the user clicks on the control button for the opposite direction the machinery is moving. The example in Figure 40 96 45.13–2 uses small square buttons and small triangles to the left and to the right of each miter gate, culvert or a Means of Equalization, see Section 01 81 13 (*Filling and Emptying Systems*), as open and close commands. For other valves moving vertically, small triangles above and below are used as open and close commands. Other command buttons shall be available as required to control and display other commands and indications (see Subparagraph 1.04 A.7.).

   b. In the case of the fire-fighting equipment, each quadrant shall have a start and a cancel button. Once start is activated, an adjustable timer shall start and while timing, an HMI animation and an automated voice warning shall announce both locally in the control room and through the public address (PA) system, that the fire-fighting control system (FFCS) is about to start and which station activated it. Before the timer timeout, the cancel button shall be able to cancel the start of the FFCS. If cancelled, an HMI animation and an automated voice warning shall

announce both locally in the control room and through the PA system, that the FFCS start has been cancelled, and which station cancelled it. Once started, the FFCS shall be stoppable remotely and locally at the pump room. More FFCS details shall only be available through the machinery diagnostics station (MDS) HMI. A test menu item or toolbar button shall be available for FFCS operation with water only.

c. All control command buttons also show position status indication through color animation as in Table 40 96 45.13–2.

Table 40 96 45.13–2: Status and Alarm Indication Animation

Status For LMCS	Status For FFCS	Color	State
Fully Opened	Started or Active	Red	Steady
Opening	Start in Progress	Red	Blinking
Fully Closed	Stopped	Green	Steady
Closing	Stop in Progress	Green	Blinking
Bypass Active	Does not Apply	White	Steady
Stopped, not fully Opened or Closed	Does not Apply	Light last color	Steady
Shutdown Fault	Shutdown Fault	Yellow	Steady
No Communications	No Communications	Orange	Steady
System Powered Off	System Powered Off	Black	Steady

d. Status and alarm indication shall be shown on the actuated machinery body, such as a gate, valve body or monitor tower and nozzle, by means of color coded animation as in Table 40 96 45.13–2, with the exception of the blinking states. No blinking shall be acceptable on machinery bodies. For actuated and moving machinery bodies, the color animation shall be steady as for "Full Open" or "Full Closed", according to the active operation command, "Open" or "Closed". If communications are lost, or system is powered off, or "Shutdown Fault" is present, then the color animation for theses states shall override the status color animation in this order.

5. [A17]**Machinery Graphics**: Shall use great detail to show the rolling gates and auxiliary vehicle / pedestrian safety equipment or valve bodies as applicable to culvert, or Water Savings Basin (WSB) valves or Means of Equalization. Graphic details shall include object shape and look based on rendered final design Contract drawings (not to scale) and texture. [A17] Each machinery shall be labeled with an identification (ID) code, see Figure 40 96 45.13–2.

6. **Machinery Indication**: The machinery shall indicate position and movement by means of real-time animation of gate, valve body or other auxiliary equipment moving parts. [A17]See example in Figure 40 96 45.13–2. In the case of rolling gates, the gates shall be animated moving as they are extended or retracted, out or into Recess. [A17] In the case of culvert or Means of Equalization, the full valve body shall be depicted while valve is fully closed and as it is opening, the valve body shall disappear into the outlining left or right graphic border, leaving only a small part of the valve visible when fully open. Other machinery shall animate as closely as possible how it moves in reality. When the valve body or moving

machinery is physically removed for maintenance, the valve body or moving machinery shall be not visible at all. Same shall occur in the case of WSB valves, except moving vertically.

a. A small text box next to the machinery shall display a code letter representing the current machinery mode, where "R" indicates remote mode, "L" for local mode, "M" for maintenance mode, "O" for off mode, and "E" for emergency mode.

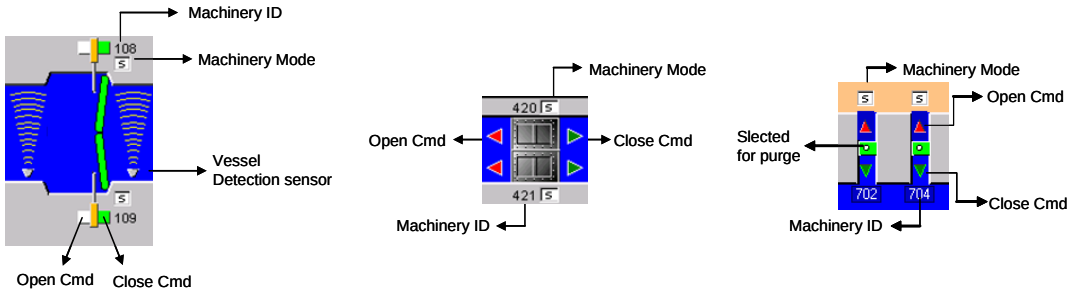


Figure 40 96 45.13–2: Machinery Graphic Examples from Existing Locks

7. **Other Indications for LMCS**:

a. **Debris Light**: The Employer's Personnel (lockmasters) shall have available to pulse, a field pushbutton to warn about floating debris that may interfere with Lockage operation. It shall be a configurable signal that shall be usable as only a warning or as an interlock that will stop gate operation.

b. **Hot Ship**: With the schedule of vessel arrivals, the Employer's Personnel (operators) shall have available to activate, for dangerous cargo vessels, a revolving light and simultaneously play over the PA system a recorded message for "Hot Ship" warning.

c. **Low or High Water Alarms**: The Employer's Personnel (Locks operator) shall have an automated voice announcement and visual indication lights warning of low or high water alarms. The operations HMI shall provide both the audio warning and the visual indication at the control console.

d. **Single Culvert Indication**: There shall be an animation of the single culvert button indicating it is active and hence the Lockage operation will result with the use of a single culvert. There shall be button label and function cycles between single east (1E), single west (1W), and double (D).

e. **Culvert Valve Standby Set**: Once configured through the operation properties menu, culvert valves option, the culvert valves designated as the standby set shall have an overlaying text indication, similar to Figure 40 96 45.13-3. Standby valves shall be excluded from macro

operation but remain active for manual operation. In case of failure of the active culvert valves, the active set shall be available for manual operation.

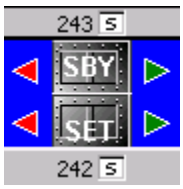


Figure 40 96 45.13-3: MCS Culvert Valve Standby Indication (Example from Existing Locks)

f. **Detected Vessel in Lock**: Vessel detection system (VDS) shall be indicated as waves or light screens traveling across the Chamber from the sensor location, depending on the technology sensor used. When the vessel is detected, the animation shall depict reflection from a Vessel. A standard vessel graphic for each approximate vessel size shall animate vessel position within Chamber.

g. **Detected Vessel Entering / Exiting Speed in Lock**: Calculated speed shall be displayed where indication does not interfere with animations, in or near the Chamber where the vessel is detected entering / exiting.

h. **Current Lane Direction**: An arrow on the display at the Locks approach structure shall indicate to approaching vessels, the lane availability for passage (pointing down), tie up and wait for turn (pointing sideways) or wrong direction indication (pointing up). [A17]Wrong direction indication notifies approaching vessels that other ships are leaving the Locks through this approach. [A17]

i. **Other**:

1) Operational alarms shall be available to the Employer's Personnel (Locks operator) through the operations HMI.

2) Other maintenance alarms shall be available to the Employer's Personnel (Locks operator) through the maintenance HMI.

3) Other power distribution alarms shall be available to the Employer's Personnel (Locks operator) through the power distribution HMI.

4) Other fire-fighting system alarms shall be available to the Employer's Personnel (Locks operator) through the fire-fighting HMI.

8. **Other Indication for FFCS**:

   a. **Flushing Procedure**: When a flushing procedure is active, an animation relative to the quadrant shall indicate this status.

9. **HMI Application Title Bar**: Shall display the HMI application icon and name. Title bar shall only display the application close command button at the far right.

10. **HMI Application Menu Bar**: Shall at least include a) File, b) Reports, c) Tools, and d) Help. Sub menus shall include a menu icon to the left of the option text.

    a. **File**: Shall at least include a) Edit Telephones List, b) User Management and Security, c) HMI Preferences (a dialog to configure auto and manual selection of which HMI application server to use, and configure file locations), and d) Exit.

    b. **Reports**: Shall at least include a) Print Screen(s), and given a from/to date filter and other applicable filters such as Employer's Personnel (operator) ID and machinery ID, shall at least include the printing and emailing of b) login and logout date and times per operator, c) the out of service and removed machinery date, time and duration, and d) Time stamped operator activity and events log.

       1) Operator activity shall be defined as all HMI application operation interaction, for example login and logout, open, close, stop, bypass commands, using automation macros, and changing parameters and configuration.

       2) Events shall be defined as all HMI application responses to operator commands or machinery status, for example machine mode (R, L, O, E), shutdown faults, opening, closing, stop, full open, full closed, water levels, vessel detection, and active parameters and configuration.

11. **Tools**: Shall at least include a) Operation Properties Menu, b) Out of Service Dialog, c) Remove Machinery Dialog, and d) Bypass Interlock Dialog.

    a. **Operation Properties Menu**: Shall provide access to the rolling gate, culvert valves, WSB valves, Means Of Equalization, sensor operation configuration, vehicular, and pedestrian safety equipment (open / close times, and warning lights and sound duration), central control alarm, warning lights and sound duration, configurations such as the example Figure 40 96 45.13–5.

       1) Figure 40 96 45.13-4 shows an example of how to configure staggered operation of gate machinery. Other configuration dialogs, such as for culvert valves WSB or Means Of Equalization, shall have other configuration settings as required, for example:

a) Setting the automatic logic to be used to select the standby culvert valve set of a redundant pair, and to adjust the time interval of alternating the active pair. Standby culvert valves shall remain open in a Lockage process and typically become the actively used pair every other week.

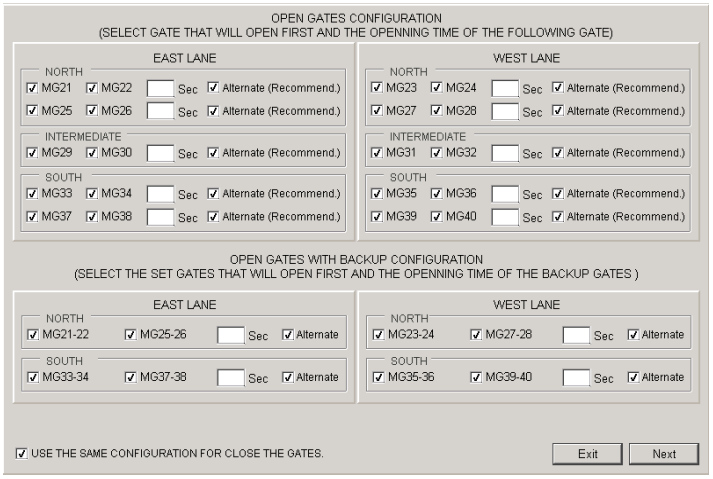


Figure 40 96 45.13–4: MCS Configuration Dialog Example from Existing Locks

b) Machinery macro configuration parameters.

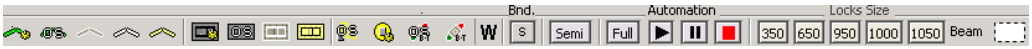
c) Setting the reference WLT, from which all other WLT shall be compared with to ensure proper value readings.

d) Other systems, machinery, devices or sensors configuration parameters as required.

12. **Help**: Shall at least include a) Help (running the Windows HELP.EXE application with the HMI help document in HLP format), b) System Statistics (to include hard drive space, memory available, number of tags, number of displays, and other statistics), c) Critical Telephone Numbers List, and d) About, containing Employer and Contractor credits.

13. **Tool Bar**: Shall include an access button for all frequently used functions such as example in Figure 40 96 45.13–5. Tool bar shall be divided in at least 2 sections: a) Machine Parameters and Configuration, and b) Lockage Operation Control, Parameters and Configuration.

Tool Bar:



Icons:


Valve Config


V. Out of service


Valve Removed

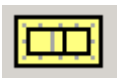

Valve bypass

Figure 40 96 45.13–5: MCS Toolbar Example from Existing Locks

14. **Machine Parameters and Configuration**: Shall include at least tool buttons related to each operation behavior configuration menu item, bypass, out of service, and removed.

    a. **Lockage Operation Control, Parameters and Configuration**: Shall include at least the following buttons:

        1) Button for selecting Lockage direction parameter, North or South bound.

        2) Button for selecting Lockage size parameters: normal, long, and extra long.

        3) Button for selecting single or double culvert Lockage. Button label and function cycles between single east (1E), single west (1W), and double (D).

        4) Button for activating the "Hot Ship" warning lights a PA annunciation.

    b. **Lockage Timing and Sequences Configuration Dialog**: Shall include at least the following buttons:

        1) Selector button for displaying either semi-automation controls or automation controls.

        2) Semi-automation control buttons for each macro.

        3) Automation control buttons for play, pause, and stop.

        4) Button for calling the automation configuration dialog, where lockage optimization method may be selected, as well as other parameters and configuration.

15. **Status Bar**: The left side of the status bar shall always be reserved for the color code legend. The middle and right side of the status bar shall get updated with machinery specific information, every time it gets focus, see Figure 40 96 45.13-6. The status bar shall have four sections, a) Color Code

Legend, b) Selected Machinery Status, c) Interlock Status, and d) Official Date and Time.

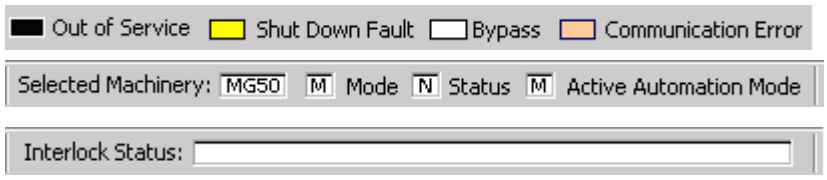


Figure 40 96 45.13–6: MCS Status Bar Example from Existing Locks

a. **Color Legend**: See Table 40 96 45.13–2 (Status and Alarm Indication Animation)

b. **Machinery Status**:

1) Last manually selected or the last macro selected machinery ID.

2) Mode – remote (R), local (L), maintenance (M), off (O), emergency (E).

3) Status – normal (N), bypassed (B), out of service (O), removed (R), standby (S), and selected as throttle valve (T), where applicable.

4) Active automation mode – shall indicate which command control the machinery is operating under. This field shall be blank when idle, have an "M" when operating by manual command, an "S" when operating by macro command in semi mode, and an "A" when operating by macro command in automatic mode. When auto mode is in "Pause" and the selected machinery was part of the running macro, this field shall display an "A".

c. **Interlock Requirements**:

1) Interlocks shall be based on the machinery indication information. If the machinery indication information is not available, the interlock shall assume an "Open" condition for gates and valves.

2) Interlocks shall always prevent any forbidden operations. Control outputs shall be interlocked with logic rules such that control outputs shall not be issued if the necessary criteria is not met.

3) The selection of control function interlocks shall be configurable only by those with adequate access privileges.

4) An attempt by Employer's Personnel (an operator) to issue a control output to a device that is so interlocked, shall result in an

appropriate message being displayed in this status bar, and if selected in the configuration dialog, in a pop-up window.

d. **Interlock Status**:

1) Every time machinery gets focus by touching the machinery, not the command buttons, the interlock status display shall be updated to display availability of further actions. For example, "Gate enabled for Open Cmd, Locked for Close Cmd".

2) If a command was issued, and the command is in progress, the result shall be displayed. For example: "Valve Open Cmd accepted". When the command is completed, the interlock status display shall be updated to display availability of further actions again.

3) If the issued command was rejected, additional information shall be required about the general reason the action failed: "Gate Open Cmd Rejected, water head too high" or "Gate Close Cmd Rejected, vessel detected" or "Valve Open Rejected, Gates are Open".

C. **Navigating the MCS HMI Application under Normal Conditions**:

1. **Manual Mode**:

a. Clicking on the machinery (not the command buttons) for all machinery involved in the first steps of the Lockage procedure, shall verify the availability of the machinery, which should be in remote mode and unlocked by the interlock. If not, the application shall troubleshoot and resolve.

b. Clicking on one or more command buttons of the machinery shall operate it, and display animation response, as machinery begins to move.

c. Note that the machinery to operate in the next step shall not be unlocked by the interlock until the machinery in the first step have completed their operation cycles, since the interlocks operate with machinery full open or full closed input signals.

d. The process shall be repeated with the next step in the Lockage procedure until complete.

2. **Semi-Automatic Mode**:

a. Clicking on the controls selector until its label changes to "Semi" shall bring forth the semi-automation controls and hide the automation controls on the toolbar. The controls selector shall toggle between semi and auto only.

b. The "Semi" tool bar shall appear with all the macros sorted in order of use.

c. Clicking on the desired macro button, the macro shall validate all operation requirements first, before operating the machinery and if the machinery or related alternative machinery involved is not available, or an interlock restriction is active, the macro shall end. The application shall display the results on the status bar, troubleshoot and resolve. If no restriction is active, the macro operation shall begin.

d. Note that the machinery to operate in the next step shall not be unlocked by the interlock until the machinery in the first step has completed their operation cycles.

e. The process shall be repeated with the next step in the Lockage procedure until complete.

f. Note that manual commands shall still be active while semi-automation macros are ongoing. Using manual commands shall only override the individual machinery operation where it was applied. Other macro operated machinery shall complete the active command request, and exit the macro. Using manual commands on machinery not involved in the macro operation shall act as regular manual commands.

3. **Automatic Mode**:

a. Clicking on the controls selector until its label changes to "Auto" shall bring forth the automation controls and to hide the semi-automation controls on the toolbar.

b. The application shall verify the active Lockage type settings, and if changes are required, apply the following steps as needed: a) Choose the Lockage direction by clicking on the direction button, wherein button label and function shall toggle between "N" and "S" only; b) Choose the Lockage length by clicking on the Lockage length button, wherein button label and function shall cycle through "1400", "1500" and "1600" only (assuming distances in feet); c) Choose the filling capacity by clicking on the culvert selection button, wherein button label and function shall cycle through "1E", "1W" and "2C" only; d) Choose to activate the "Hot Ship" warning, this setting shall reset to no warning after every Lockage.

c. Clicking on the "Play" button shall result in the automation sequencer first validating the automation point of entry in the Lockage procedure and continue from there, applying the corresponding semi-automation macros until completing a Lockage. If the automation sequence is at the starting point, the system shall begin by activating the appropriate open gates macro, opening the gates for vessel entry.

d. Clicking on "Pause" shall pause the automation sequencer, but it shall not stop the machinery operation in progress. "Pause" shall not end the

active macro. When "Play" is resumed, any active macros shall complete, and the sequence of macros shall also resume.

e. Note that manual commands shall still be active while automation sequence of macros is ongoing. Using manual commands shall only override the individual machinery operation where it was applied. Other macro operated machinery shall complete the active command request, and exit the macro. If a macro exits, the automation sequencer shall exit. The application shall allow using manual commands on machinery not involved in the macro operation act as regular manual commands and not interfere with sequencer unless an interlock is unexpectedly activated.

f. As the Vessel enters the Lock, Vessel detection sensors shall monitor the progress of the Vessel until they determine that the Vessel is safely inside the Chamber and clear of all gates. After an adjustable delay, the sequencer shall activate the appropriate close gates macro, making the gates behind the Vessel close.

g. [A17]As soon as the gates close, the sequencer shall activate the appropriate Equalization macro and move the Vessel to the correct water level.[A17] As soon as the levels are equalized to an adjustable tolerance, the sequencer shall activate the appropriate open gates macro, and the gates in front of the Vessel opened.

h. The process shall repeat itself until the complete lockdown is complete and the Locks have reassumed starting position, waiting for another "Play" action. At this point Lockage settings may be adjusted again.

i. To lock downstream or upstream, an automated Lockage sequence shall begin with the upper level equalized with the lake or normal high; middle level shall be normal low; and lower level shall be equalized with the sea, or normal low. All gates shall be closed, and all valves shall be closed except one upper level intake culvert valve and one lower level discharge culvert valve.

D. **Machinery Diagnostics Station (MDS)**: The MDS shall be an interactive HMI application used exclusively to monitor process values, generate alarms, reset faults, datalog and trend process values, analyze data, diagnose problems, suggest solutions, output reports and data, and access and generate work orders to external computerized maintenance management system (CMMS) application, see Figure 40 96 45.13-7.

1. **General**:

a. The main display shall be designed to run on the largest desktop possible without requiring a second monitor. Multiple page-displays or scrolling displays shall be acceptable. It shall consist of a title bar, a menu bar, a tool bar and a status bar, always visible and consistent throughout the application.

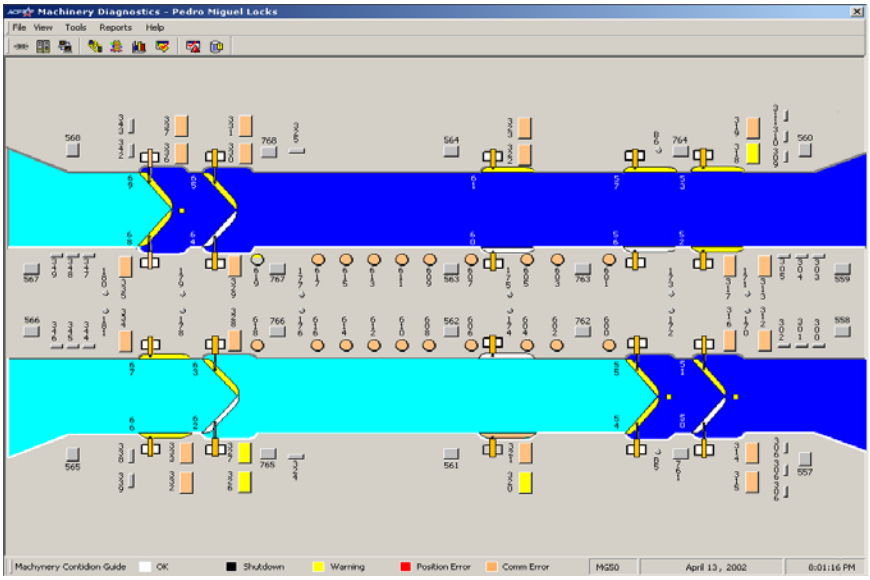


Figure 40 96 45.13-7: MDS LMCS Overview Display Example from Existing Locks (1 lift)

b. Where an Active-X object for a device or function is expected, and such object is not available for the device or function, the pop-up display shall be developed in its place to allow display of device variables and configuration or to do the required function.

c. No command confirmation dialog windows shall be necessary.

2. [A16]**Title Bar**: Shall be per requirements for MCS.[A16]

3. **Menu Bar**: Shall at least include a) File, b) View, c) Tools, d) Reports and e) Help. Sub menus shall include a menu icon to the left of the option text.

a. **File**: Shall at least include a) Expert Help input, b) User Management and Security, c) HMI Preferences (a dialog to configure auto and manual selection of which HMI application server to use, and configure file locations), and d) Exit.

b. **View**: Shall at least include a) lock overview display, b) foam fire-fighting control system, c) elevators d) air-compressor system, e) DC power systems, and f) other machinery (other control systems as applicable including those listed in Section 40 95 13 (*Process Control Hardware*). Selecting view options shall hide the current control system's tool bar and display, and bring forth the selected control system's toolbar, and default display. The menu bar shall remain unchanged.

c. **Tools**: Shall at least include a) Overview, b) Equipment Room, c) Fiber Optics, [A9]d) PLC network topology, e) Ladder, f) Factory Floor Data, Trend, [A9] g) Tag Monitor, h) Alarms i) Operation data tables.

1) **Overview**: Shall call the control system's default display, see Figure 40 96 45.13-7.

2) **Equipment Room**: Shall call the display that shows the equipment room layout of the front view of equipment racks, where the condition monitoring information related to each equipment and other technical data useful for trouble shooting is available (via pop-up when clicked.) Examples of available data are the PLCs health status variables, the power supply status, the breaker status, the fiber optic modem banks indicating each modem's health, and terminal blocks wiring. See Figure 40 96 45.13–8.

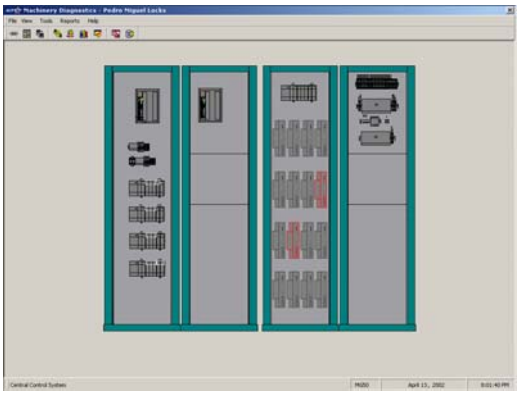


Figure 40 96 45.13 –8: LMCS Equipment Room Racks Example from Existing Locks

3) **Fiber Optics**: Shall call the display that shows all the self-healing rings of the fiber optic network. The display shall also show tool tips for each cable represented indicating the cable ID. Nodes shown on the ring shall include patch panels (with ID) and fiber optic modems (with ID) separately indicating health (as "OK", "Weak" or "Fail") and RSS attenuation (in db) for A and B channels. See Figure 40 96 45.13–9.

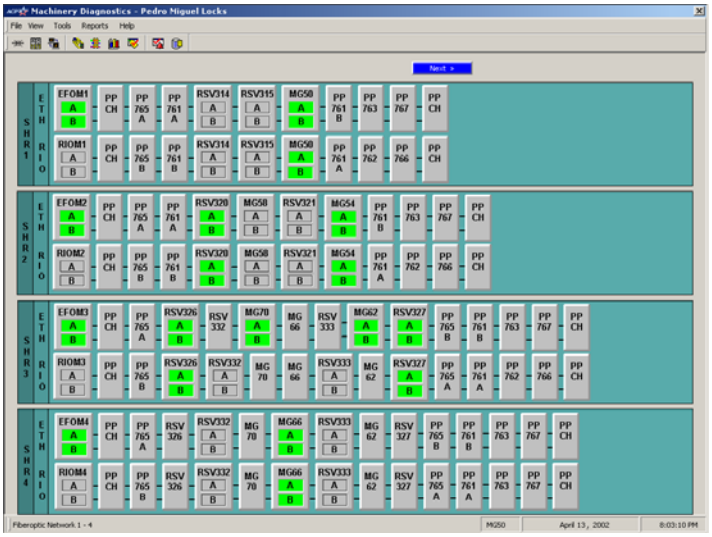


Figure 40 96 45.13–9: LMCS Self Healing Rings Example from Existing Locks

4) [A9]**PCS Network Topology**: Shall call the PCS Network Topology Active–X (or similar tool), from PLC Programming Software. [A9] See Figure 40 96 45.13–10.

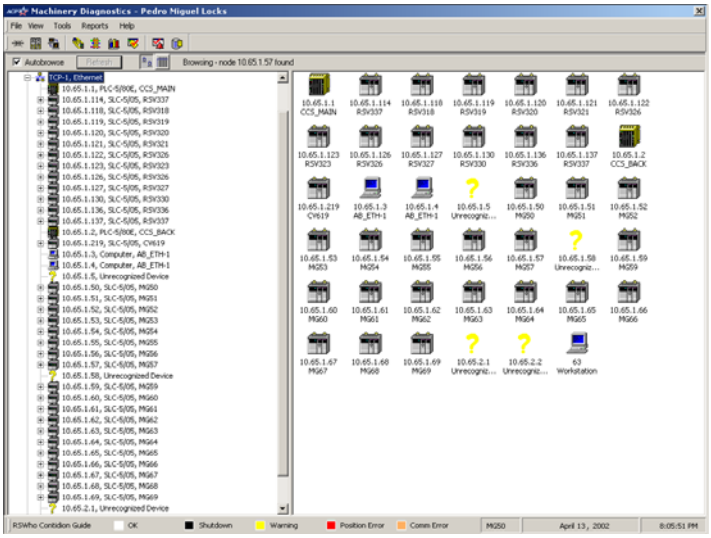


Figure 40 96 45.13–10: LMCS [A9]PCS Network Topology Software [A9] Display Example from Existing Locks

5) [A9]**Ladder Logic Software**: Shall call a specific Active–X or similar application. PLC program file locations shall be configurable through Tools or File >HMI Preferences. [A9] See Figure 40 96 45.13–11.

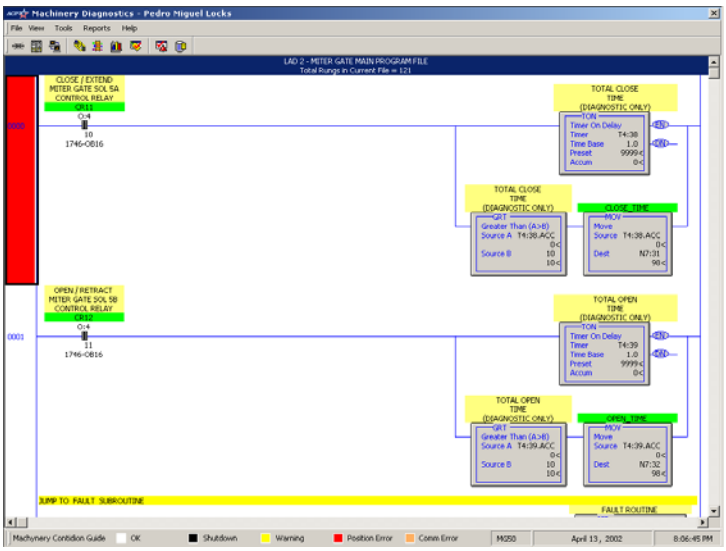


Figure 40 96 45.13–11: LMCS [A9]Ladder Logic Software[A9] Display Example from Existing Locks

6) [A9]**Business Data Server Software**: Shall call a specific Active–X or similar application.[A9] Reports list available shall be configurable though separate authoring client. See Figure 40 96 45.13–12.

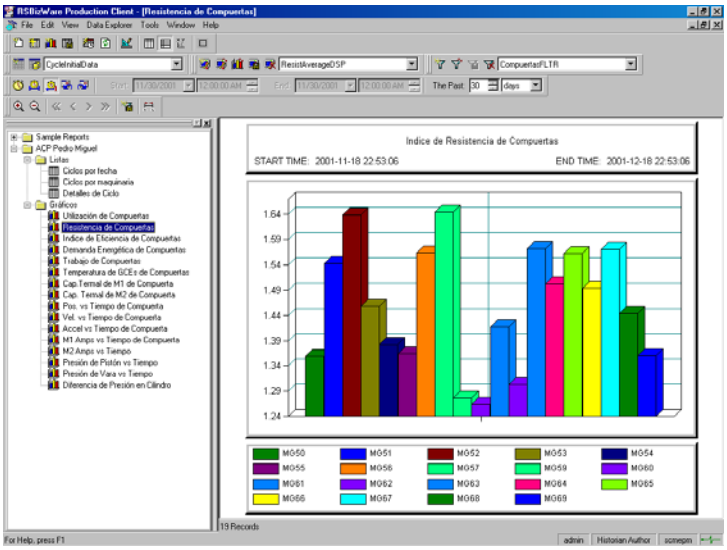


Figure 40 96 45.13–12: LMCS [A9]Business Data Server Software[A9] Display Example from Existing Locks

7) [A9]**Trend Software**: Shall call a specific Active–X or similar application. [A9] Depending on the last selected machinery, the user shall be allowed to select from preset trend types such as position vs. pressure, position vs. vibration, or customizing a trend.

8) **Expert Help**: A red textbox shall show expert help information indicating a description of a) each fault code and brief description, b) a brief narrative describing the alarm logic and its triggers, and c) a list of possible solutions, each rated statistically to show problem solving success in the past instances of each fault.

9) **Tag Monitor**: Shall be a read-only customized display that groups related process values of a machine and displays them side by side with other machines for comparison on a spreadsheet like background. Those values out of range shall be colored red. Communications status of process values shall be displayed on a column next to the tags. The machine tag group shall be properly labeled to distinguish them form other machine tag groups. A combo box control shall allow for selecting multiple pages and comparison themes. At least the following groups shall be available: a) position sensor and limit switches per machine, b) control cabinet temperature per machine type, c) WLTs per level, d) ship detection equipment (SDEs), e) vibration per machine type (where applicable), f) motion resistance index per machine type.

10) **Alarms**: See the Figure 40 96 45.13 – 13 example. Alarms shall have a menu item containing the following sub menu items that call the following alarm displays.

a) Information management errors and alarms

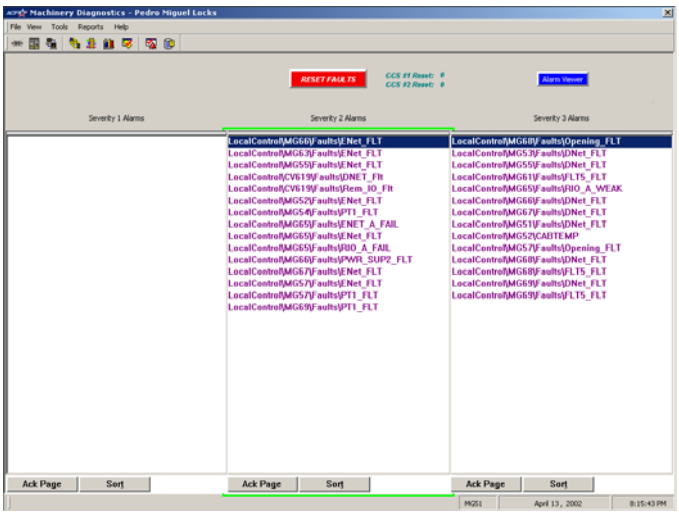


Figure 40 96 45.13–13: LMCS Alarm Display Example from Existing Locks

b) [A9]PCS[A9] servers and open process control (OPC) servers errors and alarms

c) Communication protocol errors and alarms

d) Communication media errors and alarms

e) PLC errors and alarms

f) **Control Panel and Machinery Specific Errors and Alarms**: Shall be a customized display showing three levels of alarm severity per machine, per machine group, and per Lock facility. On the same display, if the user selects an alarm, the user shall be allowed to choose to reset it or to get expert help on it. Resetting the alarm shall send a reset signal to the PLC who in turn shall handle a reset request, which may or may not clear the fault. Choosing expert help shall call another display that shows the following: a) how the alarm logic works and what triggers it, b) a list of possible causes, c) a percentage statistic on prior successful fixes per possible cause. See example Figure 40 96 45.13–13.

11) Water level transducer and Vessel detection system errors and alarms.

12) Main power and DC power system alarms.

13) **Applicable Alarms to be Managed by MDS**: Shall include warnings and shutdown faults for:

a) Windows servers

b) [A9]Security software[A9] servers

c) [A9]PLC programming software[A9] servers

d) [A9]SQL[A9] server

e) [A9]Historical business data[A9] server / [A9]Business data server[A9] client

f) [A9]Operator HMI software[A9] server warnings and faults

g) Other open process control (OPC) link servers (if applicable) warnings and faults

h) All applicable IEC 61158 type 2 fieldbus warnings and faults

i) All EtherNet/IP protocol warnings and faults

j) All detectable fiber optic modem warnings and faults

k) All detectable PLC warnings and fault

l) All main power, Uninterruptible Power Supply (UPS) and DC power system warnings and faults

m) All control panel warnings and faults, per machinery

n) All machinery warnings and faults, per machinery

o) All water level sensors warnings and faults

p) All vessel detection sensors warnings and faults

q) Other equipment and sensor systems if I/O is available on them.

14) **Operation Data Tables**: Shall call a tag monitor like display that shows in the same fashion operation data from the MCS, such as out of service list, removed, and standby settings, and all other operational parameters and configuration.

d. **Reports**: Shall at least include a) Print screen(s), b) [A9]Business data server software. Business data server software[A9] shall handle all reporting requirements such as expert help database inputs (raw and approved) and statistics, the condition monitoring reports, process variable monthly trends, and the operation data tables (from the MCS HMI).

e. **Help**: Shall at least include a) Help (running the Windows HELP.EXE application with the HMI help document in HLP format), b) System statistics (to include hard drive space, memory available, number of tags, number of displays, and other statistics), c) Critical Telephone Numbers List, and d) About, containing Employer and Contractor credits.

4. **Tool Bar**: Shall include an access button for all frequently used functions such as example in Figure 40 96 45.13–14. Tool bar shall be divided in at least 3 sections, a) Display Navigation, b) Diagnostics and Analysis c) Navigation to other Diagnostic Displays of Equipment

a. **Display Navigation**: Shall include at least tool buttons related to each viewing displays, such as overview, fiber optics, [A9]PCS network topology software[A9], and schematics.

b. **Diagnostics and Analysis**: [A9]Shall include at least the buttons for calling Active X objects or similar applications for ladder logic, business data server, trend, alarms, and report software.[A9]

c. [A17]**Navigation to Other Diagnostic Displays**: Shall include at least the toolbar buttons for displaying diagnostic information of equipment such

as fire-fighting equipment, Crossunder elevators, compressed air systems, and UPS status, see Figure 40 96 45.13 – 14. [A17]

Figure 40 96 45.13–14: MCS Toolbar Example from Existing Locks

5. **Status Bar**: The left side of the status bar shall always be reserved for the color code legend. The middle of the status bar shall get updated with machinery specific information, every time it gets focus. The status bar has three sections, a) Color Code Legend, b) Selected Machinery Status, and c) Official Date and Time.

   a. **Color Legend**: See Table 40 96 45.13–2 (Status and Alarm Indication Animation). Color legend shall include warning fault – yellow blinking. In the case of warning fault indication, blinking animation on machinery actuated body will be acceptable for MDS status and alarms.

   b. **Machinery Status**: Shall include:

      1) Last manually selected or the last macro selected machinery ID mode – remote (R), local (L), maintenance (M), off (O), emergency (E).

      2) Status – normal (N), bypassed (B), out of service (O), removed (R), standby (S), and selected as throttle valve (T), where applicable.

      3) **Official Date and Time**: Standard time display whose source is the workstation's system time. System time shall be updated via NTP.

6. **The LMCS Overview Display**: In the middle portion of the screen, between the tool bar and the status bar, the main LMCS display shall appear by application default. It shall exhibit a bird's eye view of the Locks, showing the relative machinery position (not to scale). The machinery shown shall be animated in real time and mimic actual position and events.

   a. **Water Level Graphics**: Shall be animated real-time with degrading color from dark to light blue to portray deep and shallow respectively, with a minimum of 96 colors total per Locks facility, 32 colors per Chamber. See example in Figure 40 96 45.13–1.

   b. **Culvert Graphics**: Is not needed in the overview display.

   c. **Control Commands**: No operation control commands available, only application navigation controls.

d. **Machinery Graphics**: Shall use great detail to show the rolling gates and auxiliary vehicle / pedestrian safety equipment or valve bodies as applicable to culvert, WSB or Means Of Equalization. [A17]Graphic details shall include object shape and look based on rendered final design Contract drawings (not to scale) and texture. Every machinery shall be labeled with an ID code, see Figure 40 96 45.13–2, of the MCS HMI. [A17]

e. **Machinery Indication**: The machinery shall indicate position and movement by means of real-time animation of gate, valve body or other auxiliary equipment moving parts. See example in Figure 40 96 45.13–2. The machinery indication shall be as in the MCS HMI, except that the command buttons shall be disabled, yet retain indication properties. For status and alarm color codes see Table 40 96 45.13–2 (Status and Alarm Indication Animation) and include warning fault – yellow blinking shall be included. In the case of warning fault indication, blinking animation on machinery actuated body is acceptable for MDS status and alarms.

f. **Other Indication**: See descriptions under "MCS".

1) Debris light

2) Hot ship

3) Single culvert indication

4) Culvert valve standby set

g. **Special Navigation Available to all Displays**:

1) The last machinery to have focus, as indicated in the status bar, shall be the target machinery when the following tool bar buttons are used: [A9]Ladder logic, Trend,[A9] TagMonitor, alarms, and others as needed.

2) For example, if the user selects a machine, the status bar shall update the selected machinery name on the selected machinery field. Next, if the user clicks on the alarm button on the toolbar, you get specific alarms related to the selected machinery. If the user uses the menu bar selection, he shall get the full range of alarm reporting. Given a selected machine and the user clicks on the [A9]Ladder logic [A9] button on the toolbar, he shall get the ladder logic display for that machinery. Given a selected machine and the user clicks on the [A9]Trend [A9] button on the toolbar, he shall get the trending display with the last trend settings used for this type of machinery running with the selected machinery.

h. **Navigating the Overview Display**:

1) By right clicking on a machinery the user shall get a selection menu as in Figure 40 96 45.13-15. The selection menu shall

include a reset command or submenu, used to remotely reset breakers, motor starters, variable frequency drives (VFDs), or other devices, whichever the case, with the intention to normalize machine operation.

2) All displays that are accessible from the selection menu in Figure 40 96 45.13–15, shall have "Previous" and "Next" buttons to cycle through each display without having to return to the LMCS overview display.

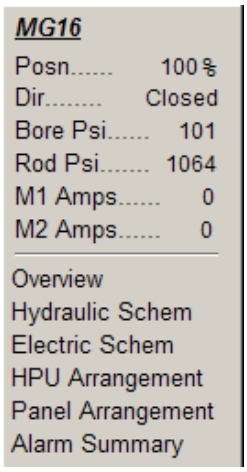


Figure 40 96 45.13–15: Overview Machinery View Selection Menu Example from Existing Locks

3) **The Machinery Overview Display**: Shall only be accessible from the LMCS overview display, by right-clicking a machine and selecting overview, this display shall allow editing field adjustable parameters that affect performance of the machinery such as closing time, and ramp-up and ramp down profiles. A restore defaults button shall restore machine performance if editing results in inadequate performance. See Figure 40 96 45.13–16. [A17]The display shall show all key process values of the machinery and a real-time animation of the machinery based on rendered final design Contract drawings.[A17] The categories of data displayed shall be (see Figure 40 96 45.13–16):

a) **Operation**: Shall show active mode (R, L, M, O, E), alarm condition (ok, warning, or shutdown present), status (off, idle, opening or closing), last cycle time to open, last cycle time to close.

b) **Position Process Values**: Shall include analog position sensor data in terms of stroke in mm and percent closed, related travel limit switches status (detecting, not detecting, faulted), maximum and minimum analog rate of change values.

c) **Hydraulic Systems Process Values**:

i. **Pressures**: Shall include pump #1 and #2 pressure output pressure (analog or pressure switch status), pilot pump output pressure (analog or pressure switch status), and extend and retract cylinder pressure (analog and if available pressure switch status).

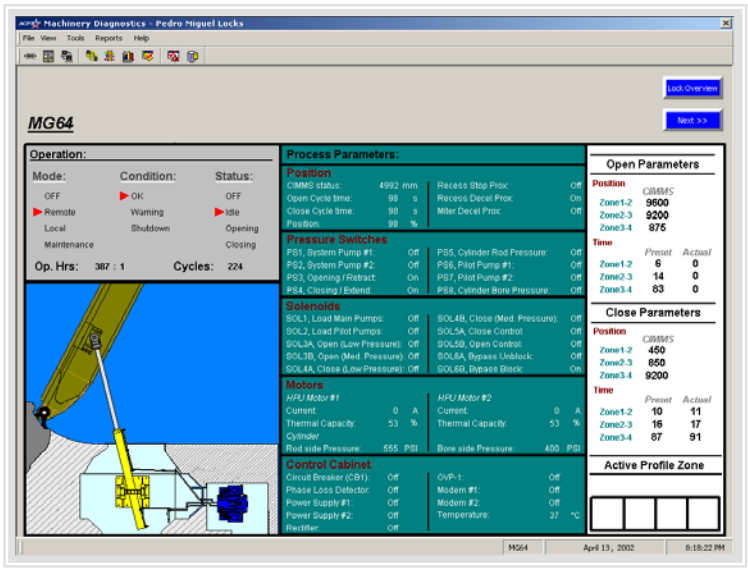


Figure 40 96 45.13–16: MDS Machine Overview Display Example from Existing Locks

ii. **Hydraulic Valve Solenoids**: Shall include indication of energized solenoids and hydraulic spool valve limit switches.

iii. Other process values as listed in Section 40 91 00 (*Primary Process Devices*).

d) **Mechanical Systems Process Values**:

i. **Vibration**: Shall include average at different locations as needed.

ii. **Limit Switches**: Shall include indication as needed.

iii. Shall include other process values as listed in Section 40 91 00 (*Primary Process Devices*).

e) **Motor Process Values**: Shall include for each motor, indication of analog rms current signal in amps, motor

thermal capacity, maximum levels of analog current signal, and overall current average in last cycle.

f) **Open / Close Cycle Operation Parameters**: This display category shall show field adjustable parameters that affect performance of the machinery such as closing time, ramp-up and ramp down profiles, and end of cycle positioning parameters. Parameters shall be editable on this display. A restore defaults button shall restore machine performance if editing results in inadequate performance.

7. **Hydraulic / Mechanical Schematic Display**:

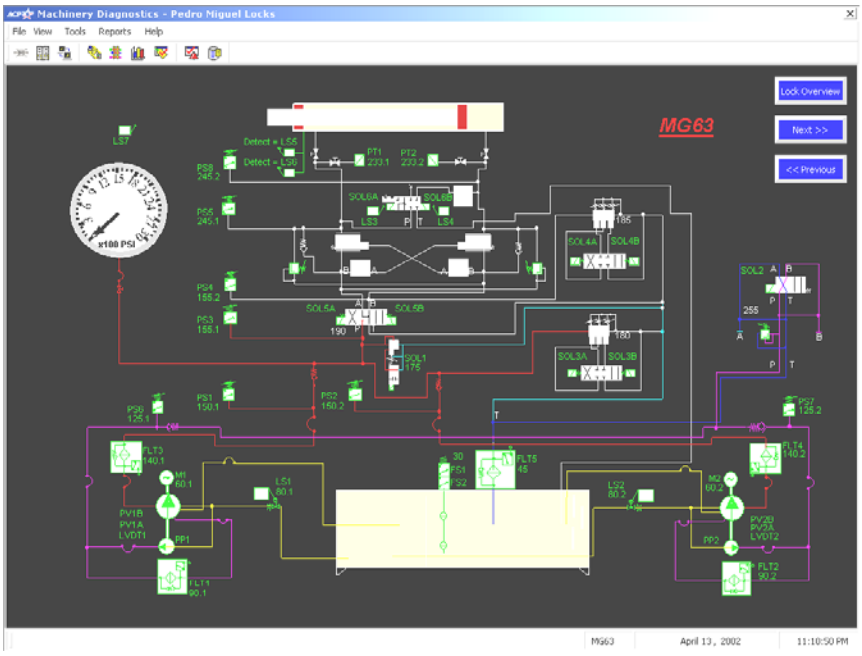


Figure 40 96 45.13–17: MDS Machine Hydraulic / Mechanical Schematic Display Example from Existing Locks

a. This display shall show in the case of a hydraulic machine, the animated hydraulic schematic represented by pressure lines (red) and connection to tank lines (blue) as well as pilot pressure (light red) and pilot tank lines (light blue). Pump suction lines (yellow) shall also show. Lines shall be light gray or white if excluded from pressure side or tank connection, by valves. One or more pressure gauges shall show the rod side and bore side pressures and the reservoir oil level shall also be animated to reflect the proportional level in relation to cylinder extension. In the case of variable flow pumps, the arrow in the pump symbol shall be animated to reflect real-time pump flow. In the case of proportional valves, the analog position of the valve shall be animated in the schematic symbol. All solenoid valves shall be animated to shift in real-time and pressure /

tank lines shall change in color to reflect hydraulic circuit state. Pressure and limit switches shall also be animated, see Figure 40 96 45.13–17.

b. In the case of a mechanical machine, the animated schematic shall show the moving mechanical drive components and the rotation ratios between them.

8. **Power Unit Arrangement with Expert Help**:

a. This display graphically shall show all hardware components that have an alarm associated to it with blinking animation. This shall allow for direct physical location of a fault on the power unit.

Figure 40 96 45.13–18: MDS Power Unit Arrangement Example from Existing Locks, with Expert Help Display

b. All components shall have tool tip captions that appear when the mouse pointer moves over the item. Captions include ID name, and Employer storehouse part number (when available). Component examples are motors, motor starters, junction box components, valves, testing points, filters, and any other assembly accessory.

c. A red textbox shall show filtered expert help information related to the power unit indicating a) active fault codes and brief description for each, b) if selected a fault code, display a brief narrative describing the alarm logic and its triggers, and c) a list of possible solutions, each rated statistically to show problem solving success in the past instances of the selected fault.

9. **Electrical Schematic**:

a. The display of Figure 40 96 45.13–19 shows the animated electrical schematic represented by positive 24 DC voltage lines (yellow) and reference voltage lines (light gray) as well as switched and energized voltage (return) lines (light red) and ground lines (dark gray).

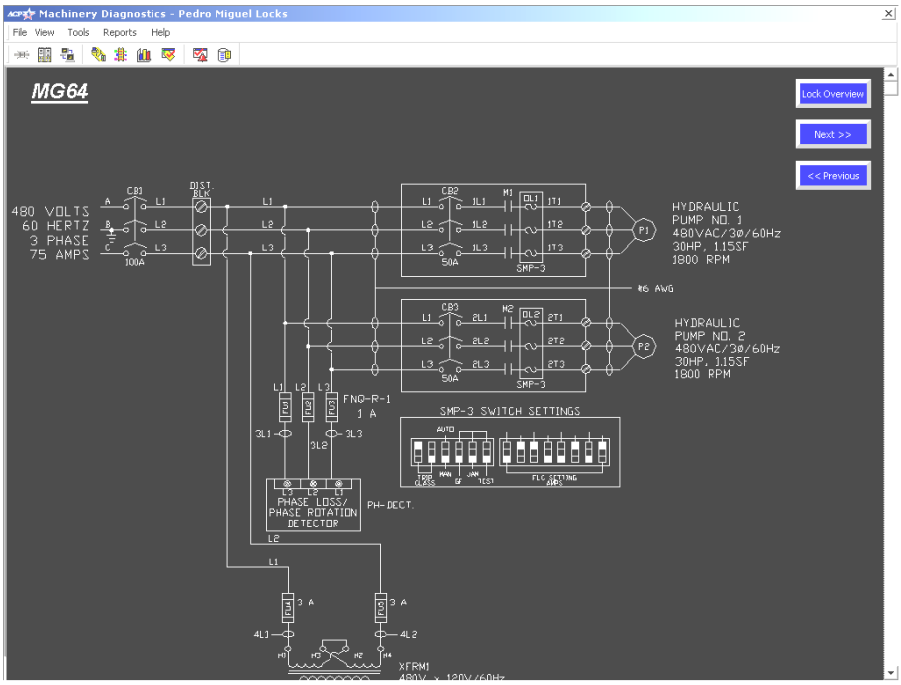


Figure 40 96 45.13–19: MDS Electrical Schematic Display Example from Existing Locks (note that this is in development, not in production, so colors have not been implemented yet)

b. When energized, AC lines shall be animated as follows: A, B, C as black, blue, and red, respectively, where black shall be surrounded by white contrast lines due to black background. Lines shall be white if open or not energized.

c. Analog signals, discrete signals, bridge rectifiers, and breakers shall also be animated.

d. Motor run signal shall be represented by continuous rotation animation of the motor symbol.

10. **Control Cabinet Arrangement**:

a. Figure 40 96 45.13–20 graphically shows all hardware components that have an alarm associated to it with blinking animation. This allows for direct physical location of a fault on the electrical control panel.

b. All components shall have tool tip captions that appear when the mouse pointer moves over the item. Captions shall include ID name, and Employer storehouse part number (when available). Component examples are: PLC modules, power supply, fiber optic components, relays, power strips, terminal blocks, ground bars, over-voltage protection, rectifiers, breakers, light bulbs or LEDs, and any other assembly accessory.

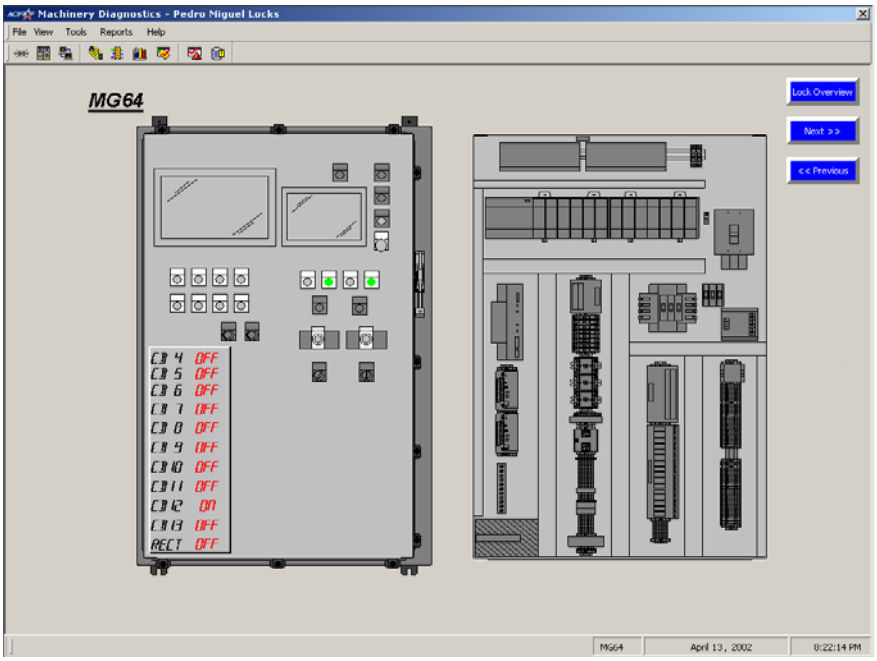


Figure 40 96 45.13–20: MDS Control Cabinet Arrangement Display Example from Existing Locks

c. Breaker on / off levers shall be animated by color and position animation.

d. When a phase loss relay is clicked, a pop-up window shall appear over it with correct settings information.

e. When a terminal block strip is clicked, a pop-up window shall appear with connection diagram information.

f. A red textbox shall show filtered expert help information related to the control panel indicating a) active fault codes and brief description for each, b) if a fault code is selected, display a brief narrative describing the alarm logic and its triggers, and c) a list of possible solutions, each rated statistically to show problem solving success in the past instances of the selected fault.

11. **Water Level Displays (WLD)**: The WLD shall be a fixed display HMI application used to monitor water level values and sensor health and generate alarms, see Figure 40 96 45.13-21.

a. **General**:

1) This single display application shall be designed to run on the largest desktop possible without requiring a second monitor. Multiple page-displays or scrolling displays shall not be acceptable. The display shall have a title bar, but no menu bar nor tool bar. The title and status bar shall always be visible.

2) No operator commands shall be available within this application. WLD shall be visible at all times to the Employer's Personnel (operator).

b. [A16]**WLD Title Bar**: Shall be per requirements for MCS.[A16]

c. **WLD Menu Bar**: No menu bar required.

d. **WLD Tool Bar**: No tool bar required.

e. **WLD Graphics**: The graphics shall be an isometric view of the Locks, showing all water pools (Chamber, between gates and WSBs) as variable height cubes, according to WLT process values, in an approximated scale size arrangement of the Locks, see Figure 40 96 45.13–21.

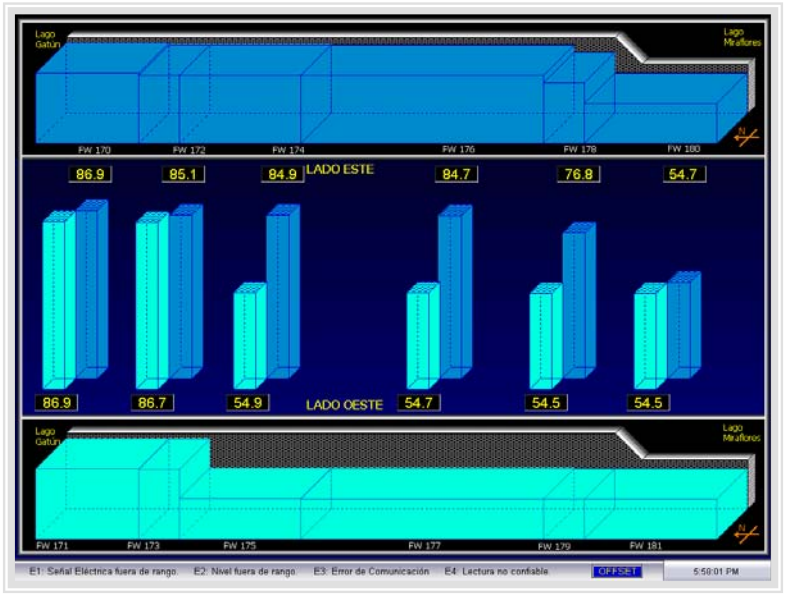


Figure 40 96 45.13-21: WLD Display Example from Existing Locks

1) All bodies of water shall have tool tip captions that appear when the mouse pointer moves over the item. Captions shall include WLT ID name.

2) All bodies of water shall have water levels color animation and high or low water alarm color animation.

3) If a WLT is faulted, HMI shall use the value of a complementary WLT in its place, provided that the WLT measures the same level, depending on the status of gates open.

4) WLT error codes and error code descriptions shall be shown on the status bar of the HMI Application.

f. **Main Display Status Bar**: The left side of the status bar shall always be reserved for the error code legend. The middle of the status bar shall get updated with WLT specific information, every time it gets focus. The status bar has three sections, a) Error Code Legend, b) Selected WLT Status, d) Official Date and Time.

1) **Error Code Legend**:

a) E1 – Electrical signal out of range

b) E2 – Process value out of range

c) E3 – Communications error

d) E4 – Redundant data tolerance error

E. [A16]**PLC Software**: The software for all PLCs shall meet the following requirements:[A16]

1. **Tags, Symbols, and Descriptions**:

a. All tags to be imported or exported from the PLC to other PLCs or used by HMIs, shall have a symbol (variable name) assigned. If tag is not used elsewhere other than the source PLC, no symbol shall be required.

b. Symbols shall employ standard acronyms throughout the program. Symbols shall be constructed by a prefix, body and suffix, and each part is separated by an underscore. The prefix shall always be the machine ID acronym, such as G1 (gate 1), or V1 (valve 1). The symbol body, shall be the variable function, followed by a qualifier suffix, such as OPEN_CMD, OPEN_REQ, or a variable name, followed by a qualifier suffix, such as POS_IN (raw position input), POS_100 (position percent), and POS_FLT (position fault). Additional suffixes may be added as codes or numbers for faults.

c. Description of all tags shall consist of 3 lines, where first line shall be the machine Employer ID, the second line shall be the variable function

description, and the third line shall be the operation mode or a specific qualifier description that differentiates tags with same first two description lines.

2. **Program Structure**: This structure shall be a standard programs structure applicable to all PLC programs provided for the Third Set of Locks Project.

   a. **Main Program**: This file shall consist mainly of jump to subroutine (JSR) instructions which shall be conditioned by manual enable bits. Status of these enable bits shall only be changed by online program editing. Other few rungs such as arithmetic error traps may be included in this file.

   b. **Admin (for non–Redundant PLC configuration)**: This file shall manage general program functions relative general overhead logic, for example, variable scaling, calculations, and default value setting for parameters.

   c. **Primary Admin (for Redundant PLC configuration)**: This file shall manage general program functions relative to duties of the primary PLC, for example, the logic that determines which PLC is primary, mirroring data tables to the secondary PLC, variable scaling, calculations, default value setting for parameters and monitoring and diagnostics logic of the secondary PLC performance. To have the primary PLC monitor and diagnose the secondary PLC is a requirement for PCS system.

   d. **Secondary Admin (for Redundant PLC configuration)**: This file shall manage general program functions relative to duties of the secondary standby PLC, for example, the logic that determines which PLC is primary and, monitoring and diagnostics logic of the primary PLC performance. To have the secondary PLC monitor and diagnose the primary PLC is a requirement for PCS system.

   e. **Command Control**: This file shall contain the logic that handles the output commands that shall operate the Locks machinery. It shall read the memory data table written by the HMI with each operator command request, and condition the request to the corresponding interlock permissive found in a memory data table written by the interlock logic. Next, it shall condition the request with the corresponding conditions found in other memory data tables set by HMI such as, interlock bypass states, out of service or machinery removed, other conditions as required, and outputs results to a command memory data table. The commands shall then be used by the machinery operation file and the command executed.

   f. **Interlocking**: This file shall contain the machinery interlocking logic. The inputs shall be a memory data table written by the machinery actual position indication. These inputs shall be conditioned by the interlock logic and the outputs shall be written to an interlock memory data table.

g. **Operation Sequencer**: This file shall contain the logic that tracks operation sequences and determines which part of the process is currently active, and what is required to complete each sequence. Once started, the operation sequencer shall continuously cycle through the operation process unless paused or stopped as per the automation memory data table written to by the HMI.

h. **Gate Macros (applicable only to LMCS)**: This file shall contain the logic necessary to operate the gates in semi or full automation modes.

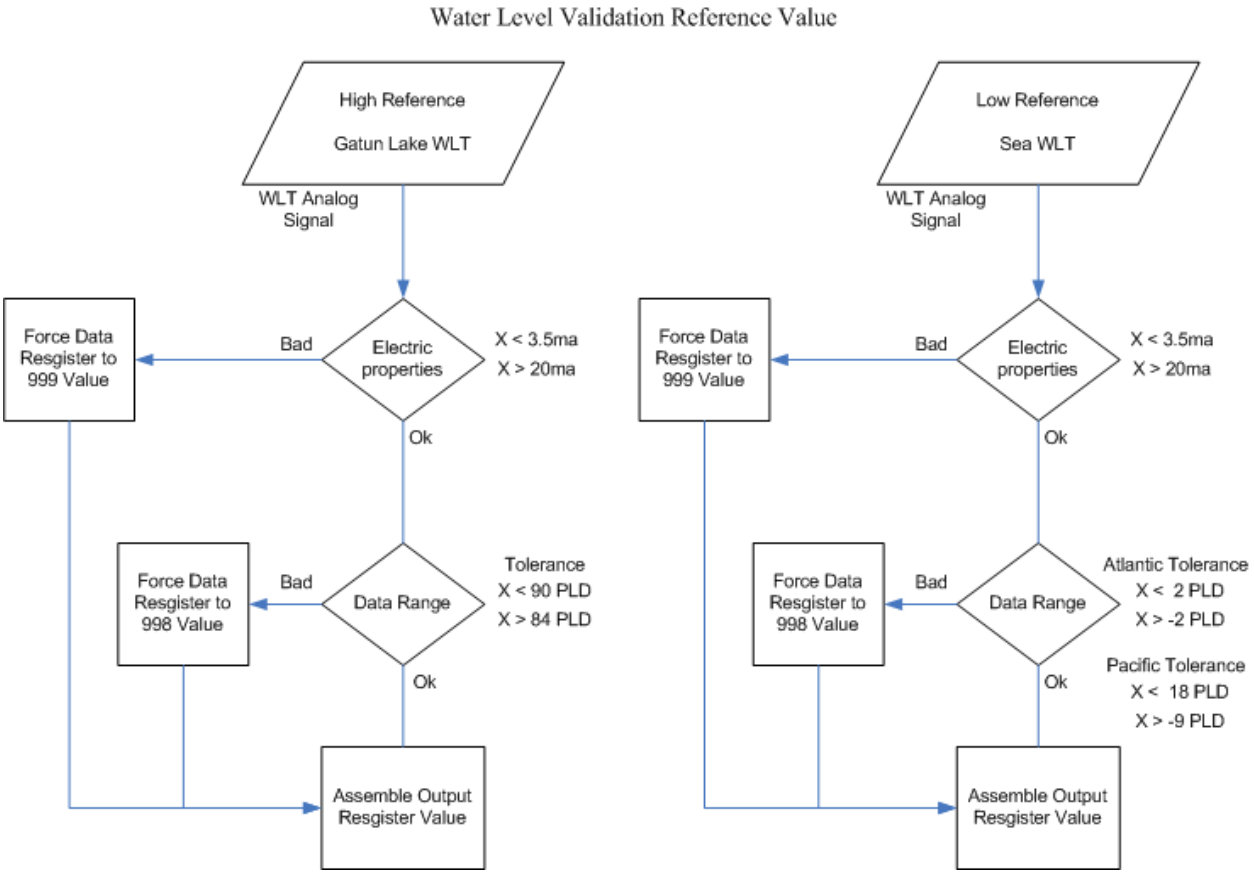


Figure 40 96 45.13–22: Conceptual WLT Validation

i. **WLT Validation (applicable only to LMCS)**: This file shall contain the logic necessary to validate the water level in the Chamber, and sensor health.

1) All WLTs shall be validated following the logic example in Figure 40 96 45.13–22.

2) The lake WLTs and the sea WLTs shall be high and low reference WLTs respectively. Using reference WLTs, logic shall also validate if Chamber is normal high or normal low. The high

reference shall be the default reference for certification of other Chamber WLTs. If high reference WLT is faulted, then certification of other Chamber WLTs shall be accomplished by using the low reference WLT.

3) [A17]Reference WLTs, high and low, shall certify measurements of Chamber WLTs, by determining which sensors should be detecting similar values, depending on the position of the gates in the Chamber and Chamber Equalization, using the logic shown in Figure 40 96 45.13–23. [A17]

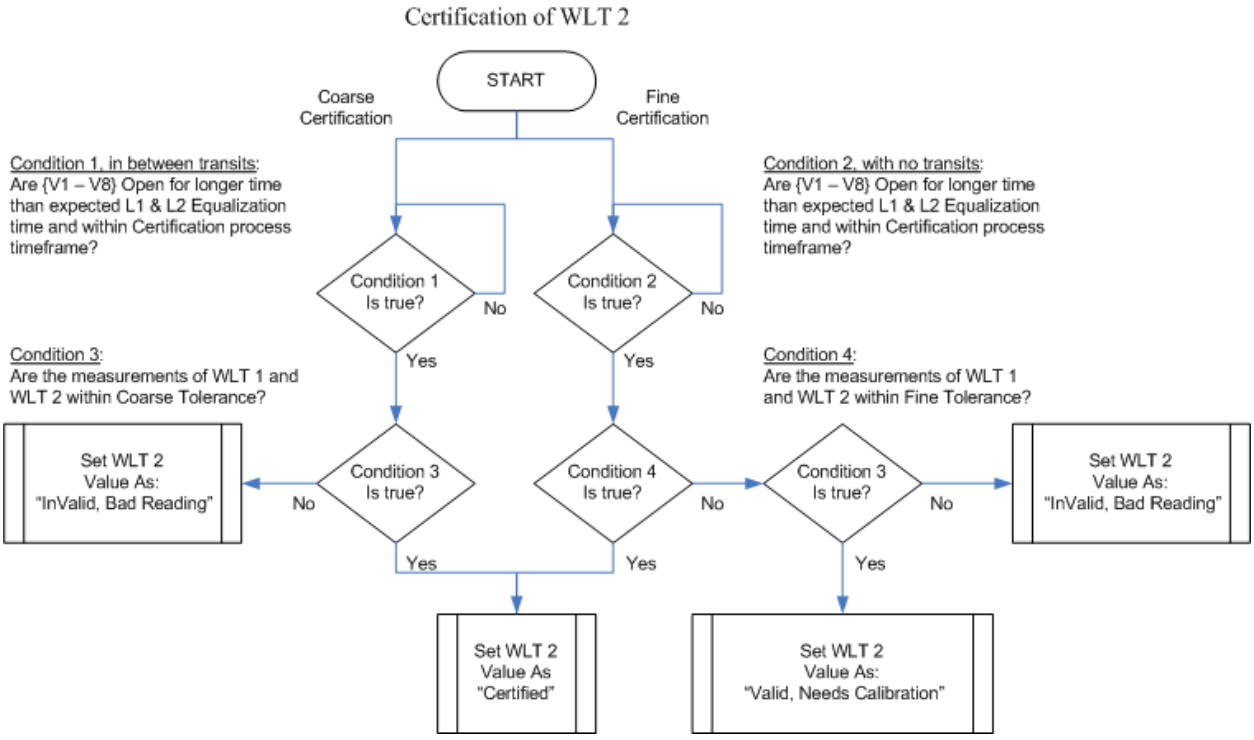


Figure 40 96 45.13–23: Conceptual WLT Certification Logic

j. **VDS Validation (applicable only to LMCS)**: This file shall contain the logic necessary to validate the presence of a Vessel in the Chamber. It shall calculate which sensors should be detecting, depending on vessel size, direction and vessel movement in the Chamber, to validate the vessel presence or absence, and sensor health, using comparison logic similar to WLT certification logic. This file shall also contain the logic that calculates the Vessel speed entering or exiting the Chamber.

k. **Equalization Macros (applicable only to LMCS)**: This file shall contain the logic necessary to operate the culvert and [A9]Means [A9] of Equalization in semi or full automation modes.

l. **WSB Macros (applicable only to LMCS)**: This file shall contain the logic necessary to operate the WSB valves in semi or full automation modes.

m. **Emergency Macros**: This file shall contain the logic necessary to perform emergency macros.

n. **Machinery Operation**: This file shall be the main machinery operation logic of the system and include machine operation related logic. Automated diagnostic tests, sensor calibration tests and step-by-step operation and other maintenance related logic shall also be included in this file.

o. **Communications**: This file shall contain ladder logic used for all communications between PCS systems, or within a PCS system between its master PLC and its slave PLCs, or between PLC and its remote I/O rack. It shall define and manage the communication word(s) structures for sending or receiving. It shall also handle the logic used to time all communications and update a communications timing table for each node.

p. **Faults**: This file shall include all fault reporting or alarm logic. It shall include as many detectable faults as possible. Faults shall be classified as warning or shutdown, where shutdowns are faults that shall inhibit operation (or machine cycle). All faults shall be stored in a designated alarms data table. The faults logic shall detect the following as a minimum:

1) **Analog Input Signal Electrical Health**: Logic shall check for analog signals at or below 3.5 mA and at or above 20.5 mA and if so, a fault alarm shall be set. This type fault shall inhibit use of signal for operation use until after proper operation is validated in a following cycle, and signal is restored. When the signal is restored, the alarm shall be reset.

2) **Analog Input Signal within Acceptable Range of Process**: Logic shall check for input outside normal operation ranges for open or close cycles and if so, a fault alarm shall be set. This type fault shall inhibit use of signal for operation use until after proper operation is validated in a following cycle, and signal is restored. When the signal is restored, the alarm shall be reset. Minimum and maximum range parameters shall be stored in a designated parameters data table.

3) **Analog Input Signal Changing in Unexpected Direction**: If analog signal is expected to increase or decrease and it decreases or increases beyond an acceptable tolerance, a fault alarm shall be set. This type fault shall inhibit use of signal for operation use until after proper operation is validated in a following cycle, and signal is restored. When the signal is restored, the alarm

shall be reset. Minimum and maximum tolerance range parameters shall be stored in a designated parameters data table.

4) **Analog Input Signal with Unexpected Rate of Change**: If analog signal is expected to increase or decrease and it decreases or increases beyond an acceptable tolerance, a fault alarm shall be set. This type fault shall inhibit use of signal for operation use until after proper operation is validated in a following cycle, and signal is restored. When the signal is restored, the alarm shall be reset. Minimum and maximum tolerance range parameters shall be stored in a designated parameters data table.

5) **Discrete and Analog Input Signal Validation Criteria**: All discrete sensing devices shall be validated only by analysis of its own behavior during operation. All analog sensing devices shall be primarily validated by analysis of its own behavior during operation. A confirmed process condition may be used to improve analog sensor behavior analysis. A confirmed process condition is defined as two positive indications of a process condition by two different signals, discrete or analog. Any discrete sensing device validated good on the previous machine cycle, may also be used to improve analog sensor behavior analysis. Any analog sensing device validated good on the previous and current machine cycle, may be used to improve sensor behavior analysis provided that the following is avoided: cyclic redundancy and a single sensor failure that creates a failure chain reaction of other sensors.

   a) **Example of Improved Analog Sensor Validation for a Failed Pressure Transducer**: After the confirmed process condition of Motor 1 running (because positive indication is available from the auxiliary motor contacts and the electronic motor starter reports motor running and both were validated good on the previous machine cycle), and after confirming the shift of the directional valve to retract position by means of a limit switch (which was validated good on the previous machine cycle), a pressure transducer on the high pressure side of the cylinder is validated bad after failing to read high pressure (as defined by minimum and maximum range parameters) for more than 4 seconds, and while the pressure switch on the high pressure side of the cylinder indicated high pressure (pressure switch was validated good on the previous machine cycle.)

6) **Discrete Input Signals**: Except operator interface inputs or discrete device alarm inputs, a fault alarm shall be set for all discrete input signals that unexpectedly change or not during a machine cycle for a particular time or condition. For example, limit switches shall be validated each machine cycle by means of

detecting at least one event of each the following: a) a 0 to 1 transition, and b) a 1 to 0 transition. This type fault shall inhibit use of signal for operation use until after proper operation is validated in a following cycle, and signal is restored. When the signal is restored, the alarm shall be reset.

7) **Discrete Device Alarms Inputs**: Fault alarm logic shall be included for all supplied devices that have alarm outputs or status feedback circuits. When the device alarm is reset, the software alarm shall also be reset.

8) **Discrete Output Signals**: Fault alarm logic shall be included for all solenoids or relays that operate directly from a PLC output, by means of sensing expected results. Only if needed input signals have been validated good in the previous cycle, shall a fault alarm be set. This type fault shall not inhibit use of output signal in operation. However, if in a following cycle the fault is not detected, the alarm shall be reset.

9) **Sensing Conflicts**: Any signal or combination of signals, discrete or analog, shall be compared with any other signal or combination of signals in cases where they may be used to measure, calculate or infer the same process condition, and if in conflict beyond an acceptable tolerance, a fault alarm shall be set. This type fault shall not inhibit use of either signal in operation. However, if in a following cycle the conflict is not detected, the alarm shall be reset. Minimum and maximum tolerance range parameters shall be stored in a designated parameters data table.

10) [A5]**Creep Alarms:** Creep alarms for hydraulic equipment shall show up in maintenance workstations, not in operator workstations.[A5]

q. **Remote Reset**: This file shall have the logic necessary to remotely reset all main breakers, motor breakers, frequency drives or motor starters. Remote reset feature on a particular device shall be allowed up to three instances per hour. If this limit is exceeded, the feature shall be disabled until user physically presses the reset button on the related machinery local control panel.

r. **Closed Circuit Video System (CCVS) Presets (applicable only to LMCS)**: As Lockage sequence develops, PLC shall set either dry contacts that active CCVS presets, or shall send ASCII commands serially to activate the presets. CCVS presets shall position camera views over the relevant lockage visuals, such as a gate roadway or walkway prior to opening the gate, or Lock wall markings to see Chamber target water level, or Chamber entry / exit.

s. **Statistics**: This file shall contain logic that calculates operations and maintenance statistics, as accrued in the last 30 days, not limited to operation hours, number of operation cycles, average cycle time extending, average cycle time retracting, overall failure rate for the machinery, and failure rate per fault and per fault type.

t. [A9]**SQL Triggers**: [A9] This files contains the logic for transaction triggers that will unload data tables produced by data logging, to the Microsoft SQL (MS-SQL) database. Triggers shall be when machinery cycle is complete.

u. **PLC Datalogging**:

1) One machine cycle shall be equal to one machine start and stop, regardless of distance traveled. Two types of cycle data shall be required, initial cycle data and run cycle data.

Table 40 96 45.13-3: Initial Cycle Data	
Machine Cycle Number	Oil Moisture Content (if Appl.)
Time	DC Power Supply Temp
Date	DC Power Supply Voltage
Operation Hours	DC Power Supply Current
Operation Minutes	[A5]CFOM CHA RSS[A5]
Motor 1 Temp. or Therm. Cap.	[A5]CFOM CHB RSS[A5]
Motor 2 Temp. or Therm. Cap.	[A5]CFOM CHA RSS[A5]
Oil Level (if applicable)	[A5]CFOM CHB RSS[A5]
Oil Temp (if applicable)	Other available process values
Oil Cleanliness (if applicable)	

2) **Initial Cycle Data**: Two machine cycles shall be stored before overwriting the first cycle's data file. For every machine cycle there shall be one time only logging of data that does not change much during the rest of the cycle. The initial cycle data file minimum data required is listed in Table 40 96 45.13-3.

3) **Run Cycle Data**: Two machine cycles shall be stored before overwriting the first cycle's data file. All alarm categories, analog inputs and outputs shall be logged, with the exception of those listed in the initial cycle data file.

v. **PLC Error Handling**: This file shall have the logic necessary to manage PLC errors. As a minimum, the logic shall document the time and date of the error, the error code, the file and rung number, set an alarm, and attempt to pass control to secondary PLC. If pass of control is not successful, the logic shall document it and attempt to continue operation.

w. **Sensor Configuration**: This file shall contain logic to configure all Highway Addressable Remote Transducer (HART) protocol enabled

devices. The configuration shall be selectable for a single sensor, by sensor type batch, and all sensors. All parameters required for the configuration process shall be available in the designated HART parameters memory data table.

x. **Application Redundancy Logic**: This file shall contain the logic pertaining to the supported PLCs under the application redundancy scheme.

y. **Other**: Any other function required not foreseen in this structure, shall be placed here, and naming shall be relevant to the general function.

3. **Machinery Motion Profile**: Actuated machine body position indication shall be used to trigger the moment of acceleration, cruise speed, deceleration and stop functions of the machinery motion profile for each machine cycle. The machinery motion profile shall define the machinery extend (close) or retract (open) cycle time, by extending or reducing the acceleration/deceleration zones and increasing or decreasing cruise speeds.

4. **Validation Criteria for Analog Position Indication**: These requirements shall apply to all machinery that report position indication to an operator in an analog format.

a. All sensing methods shall be self-validating. This means that each signal used in the sensing method shall be validated by means of each evaluating own signal behavior, as per Subparagraph 1.04 E.2.p. (Faults).

1) **Method A**: Shall be a measured value based on an absolute analog position sensor, measuring directly the displacement of the actuated body.

2) **Method B**: Shall be an inferred value using any combination of discrete and analog signals that confirm machinery motion conditions (e.g., one or more motors running) and stages (e.g., ramp up, cruise, ramp down), and using elapsed time to establish total position given the increment or decrement ratio average provided by each condition and stage of the machinery motion profile.

3) **Supplementary Method C**: Shall be a calculated value using an absolute analog sensor to measure any part of the process in motion that is proportional to the actuated body motion.

b. The resulting analog position indication from all methods shall be used if validated, in the following order of precedence: Method A, Method C, and Method B.

c. **Example for Hydraulic Machinery**:

1) **Method A**: Using a magnetostrictive type sensor mounted on a rod attached to the valve body to measure displacement.

2) **Method B**: Provided confirmation is present that one or two motors are running (using the motor's electrical auxiliary contacts or the electronic motor starter's I/O point for motor run), that the system pressure has been reached (by means of a pressure transducer or pressure switch), and that the directional valve is shifted (using the spool valve's limit switch), use the previously calculated average position vs. time ratio for Zone 1 (initial ramp up to cruise speed), plus the calculated average position vs. time ratio for Zone 2 (cruise speed), plus the calculated average position vs. time ratio for Zone 3 (final ramp down and creep to stop) as needed for one or two motors, and with the elapsed time infer valve body displacement. Every 10 cycles new average zone position vs. time ratios are calculated for both retract (open) and extend (close) cycles.

3) **Method C**: Provided that machinery motion is confirmed as in Method B example, use the analog output to the variable axial piston pump to calculate effective pump gpm output (accounting for normal leakage) for one or two motor/pump groups, and calculate valve body displacement in elapsed time.

d. **Example for Electromechanical Machinery**:

1) **Method A**: Using a radar level gauge with a parabolic antenna, measure the horizontal distance from the sensor fixed on the lock wall to the rolling gate body as it retracts (opens) or extends (closes).

2) **Method B**: Provided confirmation is present that one or two motors are running (using the motor's electrical auxiliary contacts or the electronic motor starter's I/O point for motor run), use the previously calculated average position vs. time ratio for Zone 1 (initial ramp up to cruise speed), plus the calculated average position vs. time ratio for Zone 2 (cruise speed), plus the calculated average position vs. time ratio for Zone 3 (final ramp down and creep to stop) as needed for one or two motors, and with the elapsed time infer gate displacement. Every 10 cycles new average zone position vs. time ratios are calculated for both retract (open) and extend (close) cycles.

3) [A17]**Method C**: Using a Resolver type sensor to measure a winch's number of turns and current rotational position to calculate machinery position. [A17]

5. **Position System Redundancy**: Two parallel positioning systems shall operate concurrently. The first of the two to give a trigger signal shall trigger the motion profile to change operation zones (ramp up, cruise, ramp down, and stop).

    a. **Analog Signal Position System**: Using the validation criteria for analog position indication, the resulting position value shall trigger the motion profile zone transitions, based on transition position value setpoints that are set by coordinating them to coincide with the discrete signal position system setpoints (the physical location of each sensor's placement).

    b. **Discrete Signal Position System**: This system shall consist of four limit switches performing the following functions:

        1) Fully retracted (or full open).

        2) With motion towards fully extended (or full closed) indication of end of acceleration ramp, or with motion towards fully retracted (or full open) indication to decelerate to minimum speed.

        3) With motion towards fully extended (or full closed) indication to decelerate to minimum speed, or with motion towards fully retracted (or full open) indication of end of acceleration ramp.

        4) Fully extended (or full closed).

6. **LMCS Process Manual Operation Description**: Manual operation shall be the direct and individual selection of machinery by the Employer's Personnel (operator), operated each machine sequentially, until the Lockage process is complete.

    a. At the HMI level the operator selects machinery for operation by clicking on its open or close button.

    b. With this action the HMI shall write to the command request memory table in the PLC and the command control logic shall then condition the request to the corresponding interlock permissive found in the interlock output memory data table, in addition to other conditions set by memory data tables set by the HMI such as, interlock bypass states, out of service or machinery removed, other conditions as required, and outputs results to a command memory data table.

    c. The commands shall then be used by the machinery logic for execution.

7. **LMCS Process Semi-Automation Operation Description**: Semi-Automation shall be a limited short operation sequence, or macros, of a group of machinery with the interest of achieving a procedure and reducing the number of operator interventions. The following description details the interaction between the HMI application and the PLC program.

a. When at the HMI level, a semi-automation macro is selected, the selection shall be written to an automation request memory table in the PLC. Depending on the operation sequencer memory table values, the respective macro file in the PLC shall read in the automation request table and compute the correct machine group ID parameter which shall select the correct machine group to which the macro will apply to.

b. Macros require operational parameters that shall be based on default settings that may be modified by the Employer's Personnel (operator) at HMI level at any time. These parameters shall be read by the PLC in a macro parameters memory table. The parameters shall include but not limited to individual machine selection for operation (shall allow for a machine to be excluded from macro operation), individual operation ±offset delay, machinery sequence (for example which one operates first), individual macro timeout for two-motor operation and individual macro timeout for one motor operation.

c. The macro shall be executed only if the interlock output memory table allows it to execute.

d. The operation sequencer shall record macro progress in an operation sequencer memory table. If the macro ends incomplete, semi-automation mode ends and manual mode shall be enabled. If the macro ends complete, semi-automation mode shall remains active, waiting for the next semi-automation command.

e. Other manual or semi-automatic commands shall still be enabled for other machinery not involved in an actively executing macro, if interlock will allow it.

f. A manual command request at HMI level given to any individual machinery involved in an active macro shall be conditioned by the interlock output memory table, and given the case the action is permissible, shall override the operation macro command for that particular machinery and end the macro. All other machinery involved in the active macro shall continue to operate with the last macro command until end of travel is complete. Semi-automation mode shall also end, leaving manual mode enabled.

g. For all modes, an EStop command at the HMI shall cancel all macro operations. All open or closing valves shall be closed. All opening valves shall be stopped, and after an adjustable delay, they shall be closed. All moving rolling gates shall be stopped. Semi-automation mode or automation modes shall end and only manual mode shall be enabled.

h. [A9]Macros shall vary depending on Contractor's design, number and sizes of WSBs, and other macros may be required as per Contractor's design, as per lockage scenarios similar to those in Figure 01 92 00 – 1, and as per other requirements specified elsewhere. [A9]

i. It shall be the responsibility of the Contractor to verify these macros and ensure that all macros are error-free. The Contractor shall provide additional macros, such that maximum lockage throughput may be achieved, best functionality is provided, and best safety features are available to the end user.

[A9]j. Macros shall include, but not be limited to, the ones specified below (see Figure 40 96 45.13-25 for details). Note that Subparagraphs 7) through 17) below apply in case filling and emptying design uses 3 sets of 3 WSBs per locks complex, and shall be modified as required should WSB design be different. [A9]

1) **Opening Rolling Gates**: The scope of this macro shall include any of the selected redundant rolling gate pairs as follows, {RG1-RG2}, {RG3-RG4}, {RG5-RG6} and {RG7-RG8}.

2) **Closing Rolling Gates**: The scope of this macro shall include any of the selected redundant rolling gate pairs as follows, {RG1-RG2}, {RG3-RG4}, {RG5-RG6} and {RG7-RG8}.

3) **Opening Culvert Valves**: The scope of this macro shall include any of the selected culvert valve groups as follows, {V1-V8}, {V9-V16}, {V17-V24}, and {V25-V32}.

4) **Closing Culvert Valves**: The scope of this macro shall include any of the selected culvert valve groups as follows, {V1-V8}, {V9-V16}, {V17-V24}, and {V25-V32}.

5) **Opening Means [A9]of Equalization**: [A9] The scope of this macro shall include any of the selected Means of Equalization.

6) **Closing Means [A9]of Equalization**: [A9] The scope of this macro shall include any of the selected Means of Equalization.

7) **Opening WSB Valves**: The scope of this macro shall include any of the selected WSB valve groups as follows, {W1-W12}, {W13-W24}, and {W25-W36}.

8) **Closing WSB Valves**: The scope of this macro shall include any of the selected WSB valve groups as follows, {W1-W12}, {W13-W24}, and {W25-W36}.

9) **Active Culverts**: The scope of this macro shall include enabling or disabling any of the selected culvert valve groups as follows, {V1, V2, V5, V6, V9, V10, V13, V14}, {V3, V4, V7, V8, V11, V12, V15, V16}, {V9, V10, V13, V14, V17, V18, V21, V22}, {V11, V12, V15, V16, V19, V20, V23, V24}, {V17, V18, V21, V22, V25, V26, V29, V30}, {V19, V20, V23, V24, V27, V28, V31, V32}.

10) **Enable WSB**: The scope of this macro shall include enabling any of the selected WSB valve groups as follows, {W1-W12}, {W13-W24}, and {W25-W36}.

11) **Disable WSB**: The scope of this macro shall include closing and disabling selected WSB valve groups as follows, {W1-W12}, {W13-W24}, and {W25-W36}.

12) **Equalize L1/L2**: Each open / close WSB sequence step shall have 3 types of individual adjustable trigger parameters. Type 1 shall be based on WSB level. Type 2 shall be based on start / end delay. Type 3 shall be based on WSB overall empty / fill time. Parameter type 3 shall be used as a backup for failed WSB level sensing. Sequence step trigger shall be an adjustable logic between all three parameter types. Note that at least 1 WSB valve per WSB level shall be enabled to proceed to use each level of WSBs.

a) **Step 1**: Shall close {V9-V16, RG1-RG4}. If the WSB valve group {W1-W12} is not enabled, shall skip to Step 5.

b) **Step 2**: If L2 level is lower or equal level to L2 normal low, then shall open {W3, W6, W9, W12}, else shall skip to Step 3. Near empty, shall close {W3, W6, W9, W12}.

c) **Step 3**: If L2 is lower or equal level to lower WSB, then shall open {W2, W5, W8, W11}, else shall skip to Step 4. Near empty, shall close {W2, W5, W8, W11}.

d) **Step 4**: If L2 is lower or equal level to middle WSB, then shall open {W1, W4, W7, W10}, else shall skip to Step 5. Near empty, shall close {W1, W4, W7, W10}.

e) **Step 5**: If L2 is lower or equal level to upper WSB, then shall open {V1-V8}. Near equalized L1 and L2, shall close {V1-V8}.

13) **Equalize L2/L3**: Note that at least 1 WSB valve per WSB level shall be enabled to proceed to use each level of WSBs.

a) **Step 1**: Shall close {V17-V24, RG1-RG6}. If the WSB valve group {W13 - W24} is not enabled, shall skip to Step 5.

b) **Step 2**: If L3 level is lower or equal level to L3 normal low, then shall simultaneously open {W1, W4, W7, W10} and {W15, W18, W21, W24}, else shall skip to

Step 3. The next parallel sequences shall occur asynchronously:

On L2 WSBs:	On L3 WSBs:
Near filled, shall close {W1, W4, W7, W10} and open {W2, W5, W8, W11}. Near filled, shall close {W2, W5, W8, W1} and open {W3, W6, W9, W12}. Near filled, shall close {W3, W6, W9, W12}.	Near empty, shall close {W15, W18, W21, W24} and open {W14, W17, W20, W23}. Near empty, shall close {W14, W17, W20, W23} and open {W13, W16, W19, W22}. Near empty, shall close {W13, W16, W19, W22}.

c) **Step 3**: If L3 is lower or equal level to upper WSB, then shall open {V17-V24}. Near equalized L2 and L3, shall close {V17-V24}.

14) **Case Excess Volume on L3**:

a) The WSB valve groups {W1-W12} and {W13-W24} are disabled. Open {V9-V16} and partially open one or more valves as needed from {V17-V24}.

b) Using actual L2 and L3 levels, monitor changes in estimated final L2/L3 level.

c) When estimate drops down close to target level, close {V17-V24}. Continue to monitor the changing estimate and open/close one valve if needed from {V17-V24} until L3 and L4 are equalized at target level within adjustable tolerance parameter.

d) Open / Close valve cycle used to reduce excess water volume shall typically be 1 cycle.

15) **Equalize L3/L4**: Note that at least 1 WSB valve per WSB level shall be enabled to proceed to use each level of WSBs.

a) **Step 1**: Shall close {V25-V32, RG3-RG8}. If the WSB valve group {W25 – W36} is not enabled, shall skip to Step 5.

b) **Step 2**: If L4 level is lower or equal level to L4 normal low, then shall simultaneously open {W13, W16, W19, W22} and {W27, W30, W33, W36}, else skip to Step 3. The next parallel sequences shall occur asynchronously:

On L3 WSBs:	On L4 WSBs:
Near filled, shall close {W13, W16, W19, W22} and open {W14, W17, W20, W23}. Near filled, shall close {W14, W17, W20, W23} and open {W15, W18, W21, W24}. Near filled, shall close {W15, W18, W21, W24}.	Near empty, shall close {W27, W30, W33, W36} and open {W26, W29, W32, W35}. Near empty, shall close {W26, W29, W32, W35} and open {W25, W28, W31, W34}. Near empty, shall close {W25, W28, W31, W34}.

c) **Step 3**: If L4 is lower or equal level to upper WSB, then shall open {V25-V32}. Near equalized L3 and L4, shall close {V25-V32}.

16) **Equalize L4/L5**:

a) **Step 1**: Shall close {RG7-RG8}.

b) **Step 2**: Shall open {V25-V32}. Near equalized L4 and L5, shall close {V25-V32}.

17) **Case Excess Volume on L4**:

a) The WSB valve groups {W13-W24} and {W25-W36} are disabled. Open {V17-V24} and partially open one or more valves as needed from {V25-V32}.

b) Using actual L3 and L4 levels, monitor changes in estimated final L3/L4 level. When estimate drops down close to target level, close {V25-V32}.

c) Continue to monitor the changing estimate and open/close one valve if needed from {V25-V32} until L3 and L4 are equalized at target level within adjustable tolerance parameter.

d) Open / Close valve cycle used to reduce excess water volume shall typically be 1 cycle.

18) **Manual High Mast Lighting On/Off**: This macro shall handle the logic required to turn on/off the Locks high mast lighting.

8. **LMCS Full Automation Operation Description**:

a. To enable full automation, the system logic shall validate the availability of the following:

1) The minimum number of validated water level sensors in service

2) The minimum number of validated vessel detection sensors in service

3) The minimum number of culvert valves in service

4) The minimum number of rolling gates in service

b. If mode selection is requested during an ongoing Lockage, automation mode shall continue the ongoing process sequence. If mode selection is requested at the start/end of the lockage process, automation mode shall be selected and wait for the start process trigger.

c. Automating the Lockage shall be a concatenated series of semi-automation macros that start, process and complete the Lockage.

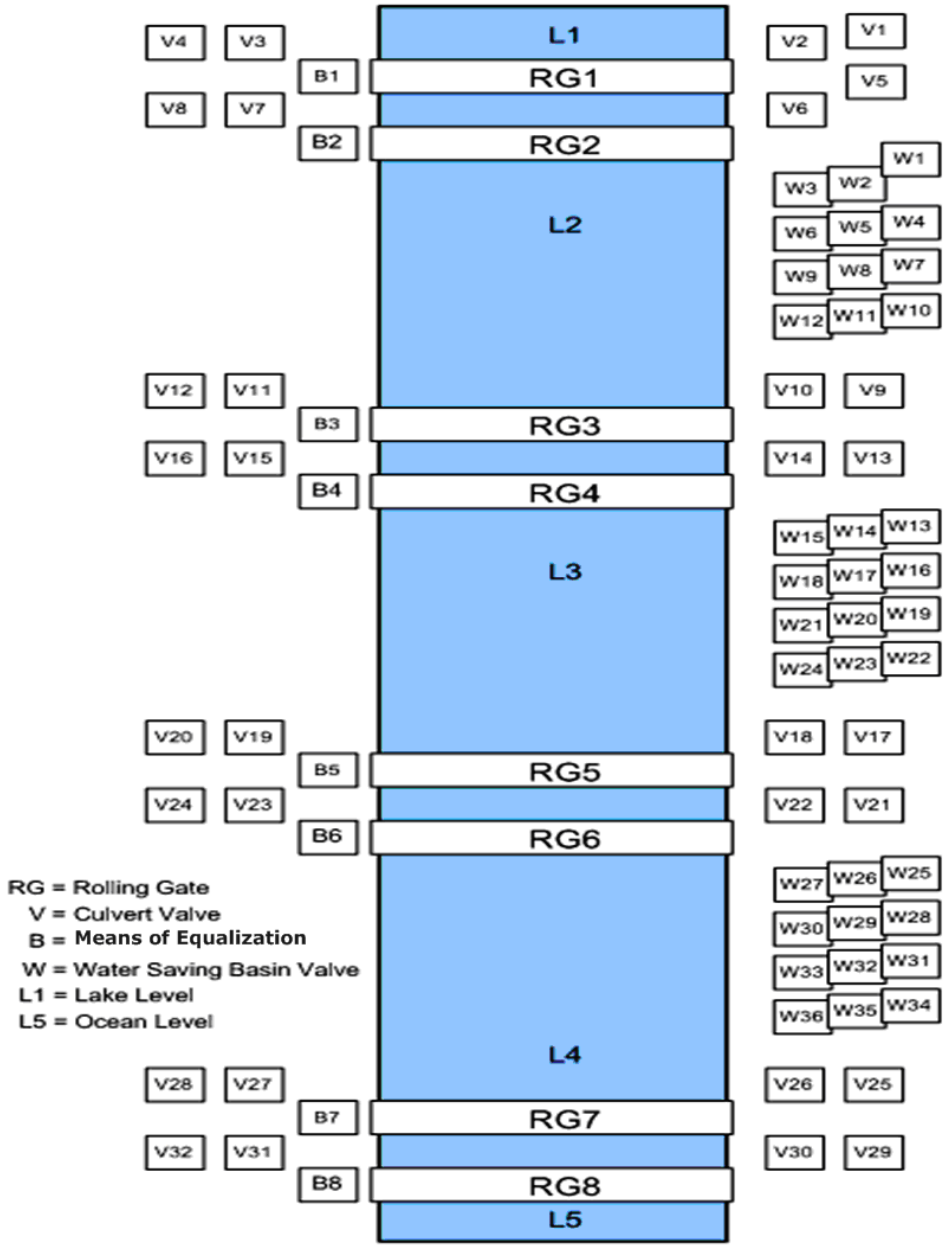
9. **LMCS Interlocks Description**:

a. Interlocks shall always prevent any forbidden operations. Control outputs shall be interlocked with tags such that control outputs shall not be issued if the necessary criteria are not met.

b. An attempt by Employer's Personnel (an operator) to issue a control output to a device that is interlock locked, shall result in a warning message indicating why the output is locked.

c. The interlocks shall be edited only by the engineers with engineering authorities area of responsibility (AOR).

A5



A5

Figure 40 96 45.13-24: Conceptual Interlock Reference Drawing.

To allow **Open**:	While **Open**:	Must be **Closed**:
RG1 + RG2	V9+V10	V13+V14
	V11+V12	V15+V16
	V13+V14	V9+V10
	V15+V16	V11+V12
		RG3+RG4
RG3 + RG4	V1+V2	V5+V6
	V3+V4	V7+V8
	V5+V6	V1+V2
	V7+V8	V3+V4
		RG1+RG2
	V17+V18	V21+V22
	V19+V20	V23+V24
	V21+V22	V17+V18
	V23+V24	V19+V20
		RG5+RG6
RG5 + RG6	V9+V10	V13+V14
	V11+V12	V15+V16
	V13+V14	V9+V10
	V15+V16	V11+V12
		RG3+RG4
	V25+V26	V29+V30
	V27+V28	V31+V32
	V29+V30	V25+V26
	V31+V32	V27+V28
		RG7+RG8
RG7 + RG8	V17+V18	V21+V22
	V19+V20	V23+V24
	V21+V22	V17+V18
	V23+V24	V19+V20
		RG5+RG6

To allow **Open**:	While **Open**:	Must be **Closed**:
[V1+V2 or V5+V6] or {V3+V4 or V7+V8}	V9+V10	V13+V14
	V13+V14	V9+V10
	V11+V12	V15+V16
	V15+V16	V11+V12
		RG3+RG4
[V9+V10 or V13+V14] or {V11+V12 or V15+V16}	V1+V2	V5+V6
	V3+V4	V7+V8
	V5+V6	V1+V2
	V7+V8	V3+V4
		RG1+RG2
	V17+V18	V21+V22
	V19+V20	V23+V24
	V21+V22	V17+V18
	V23+V24	V19+V20
		RG5+RG6
[V17+V18 or V21+V22] or {V19+V20 or V23+V24}	V9+V10	V13+V14
	V13+V14	V9+V10
	V11+V12	V15+V16
	V15+V16	V11+V12
		RG3+RG4
	V25+V26	V29+V30
	V27+V28	V31+V32
	V29+V30	V25+V26
	V31+V32	V27+V28
		RG7+RG8
[V25+V26 or V29+V30] or {V27+V28 or V31+V32}	V17+V18	V21+V22
	V19+V20	V23+V24
	V21+V22	V17+V18
	V23+V24	V19+V20
		RG5+RG6

RG Bypass Logic

All RGs have Bypass Mode. When Bypass Mode is selected for a RG, it is eliminated from the all interlock logic. Bypass is used to operate with a larger Chamber length.

Valve Bypass Logic

Only V9 through V32 have Bypass Mode. When Bypass Mode is selected for a V, it is eliminated from the all interlock logic. Bypass is used to operate filling or emptying Chambers with variable tide levels.

Figure 40 96 45.13-25: Conceptual interlock logic for rolling gates and valves

d. Interlocks shall be driven by actual operational machine position.

e. Interlocks may only be explicitly bypassed by Employer's Personnel (operators) to handle operations under emergency conditions.

f. Interlocks shall consider a valve body as closed when valve machinery is placed out of service.

g. Interlocks shall consider a rolling gate as open when valve machinery is placed out of service.

h. Figure 40 96 45.13 25 shows the general interlock logic for rolling gates and valves. In the case of culvert valves, for all duplicate pairs of valves (for example, V1+V2 and V5+V6), one pair may be left open and the second pair becomes subject to the interlock.

i. Means Of Equalization interlocks shall be designed by the Contractor. Means Of Equalization shall be used to speed the filling and emptying process, as well as for fine control of the chamber levels.

j. Figure 40 96 45.13 26 shows the general interlock logic for water saving basing valves:

To allow **Open**:	While **Open**:	Must be **Closed**:
W1 - W12	V9+V10	V13+V14
	V11+V12	V15+V16
	V13+V14	V9+V10
	V15+V16	V11+V12
		RG3+RG4
W13 - W24	V17+V18	V21+V22
	V19+V20	V23+V24
	V21+V22	V17+V18
	V23+V24	V19+V20
		RG5+RG6
W25 - W36	V25+V26	V29+V30
	V27+V28	V31+V32
	V29+V30	V25+V26
	V31+V32	V27+V28
		RG7+RG8

Notes:

- Wx –Wy refers to any valve in this range.
- The largest number of W valves that remain closed, for whichever reason and for any one culvert, must always equal the number of closed valves in the opposite culvert. A bypass shall be available to exclude individual valves from this interlock.

Figure 40 96 45.13-26: Conceptual interlock logic for water saving basin valves

k. **Ship Detection Interlocks**: Vessel detection sensors shall detect the presence of a floating object in the path of each rolling gate, regardless of the water level, as described in Section 35 12 00 (*Vessel Detection Systems*). Positive detection shall disable gate closing, and stop the gate. A sensor bypass shall also be available.

l. Water level measurement shall be available for each body of water upstream and downstream of a rolling gate. Validation of water level readings shall be as described in the PLC program structure. Gate operation shall be allowed when equal water levels upstream and downstream are present. Gates shall not be operated with differential heads, with the exception of a small head as described in

Section 01 81 19 (*Lock Gates*). Gate interlocks shall include water level inputs for allowable gate operation.

m. [A5]**Vehicular Traffic Related Interlocks**: Rolling gate open/close movements shall be disabled when one vehicle is above the RG with vehicular crossing. This shall be coordinated with vehicular control equipment of Sections 28 16 46 (*Vehicular Control Systems*) and 35 10 00 (*Waterway and Marine Signaling and Control Equipment*). [A5]

[A5]n. Rolling Gate Related Interlocks: Shall consider RG sensors to determine whether it is safe to move the RGs.[A5]

F. **Machinery Room Test and Maintenance**:

1. **General**: All tests shall be designed with software logic and hardware to maximize diagnostic capabilities, without possibility of damage to Plant (equipment) through misuse or failed equipment subcomponents.

2. **Hardware Tests**: Shall be minimum performance tests to simulate a machinery jam to test motor breaker trips, relief valve operation, and both conditions, with timeout logic to avoid actual damage.

3. **Local Maintenance Displays**: Shall be minimum operator interface maintenance data display, in accordance with Section 40 96 45 (*Process Control Software*):

   a. Time stamped active alarms

   b. Alarm history

   c. Alarm instance statistics

   d. Last motor rms current charts

   e. Last position –vs- time chart

   f. Round trip communication message times

4. **Software Tests**: Shall be minimum tests that can be toggled on/off, including the following:

   a. Software disable/enable of primary or secondary IEC 61158 type 2 fieldbus communications

   b. Software disable/enable of primary or secondary position sensing

   c. Software to disable/enable solenoids or actuators

5. **Step by Step Operation**: Minimum number of steps shall include startup of motor 1, startup of motor 2, and individual control of solenoids or other actuators.

1.05 SUBMITTALS: Shall be in accordance with Section 40 00 00 (*Process Systems Integration*), Paragraph 1.05.

1.06 QUALITY ASSURANCE:

A. QA shall be in accordance with Section 40 00 00 (*Process Systems Integration*), Paragraph 1.06.

B. During Tests on Completion, the Employer and Contractor shall independently do the following:

1. Time RG opening and closing times.

2. Time filling and emptying system, with verification of water levels on locks wall markings.

END OF SECTION