CITY OF AURORA, COLORADO

SCADA DESIGN AND ENGINEERING GUIDELINES

REVISION 1

March 2019

SCADA DESIGN AND ENGINEERING GUIDELINES

<u>HISTORY OF CHANGES</u>

A. 11 NOV 16: Major technical updates to existing Draft version. By Douglas Zalewski (City of Aurora)

B. 23 JAN 17: Major technical and formatting updates. By Mat Hollerbach (Carollo Engineers).

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E. 28 APR 17: Final version delivered to City for project use. By Mat Hollerbach (Carollo Engineers).

F. 21 MAR 19: Review meeting with Technical Operations (William "Philip" Mendenhall, Chris Bliden and Brian Matthews) and COA SCADA Engineer (Douglas Zalewski) to go over update comments to move DEGs from Rev 0 to Rev 1.

G. 28 MAR 19: Revision 1 produced / delivered to Technical Operations. By Douglas Zalewski (City of Aurora SCADA Engineer)

END OF HISTORY OF CHANGES

CITY OF AURORA, COLORADO

SCADA DESIGN AND ENGINEERING GUIDELINES

REV. 1

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ABBREVIATIONS AND DEFINITIONS

ACS: Automation Control System: A general name for the computerized system that gathers and processes data from equipment and sensors and applies operational controls to the process equipment. It includes PLCs, RIOs, OITs, HMIs, LCPs, VCPs, and data management systems accessible to staff. (See: PCS)

AOI: Add-On-Instruction: Tool used for Function Block PLC Programming

BOM: Bill of Material: A detailed list that provides specific manufacturer and quantity of individual components of a system. Numbers on BOM will correspond to individual devices on a design drawing.

COA: City of Aurora

CCS: The Process Control System's (PCS) central computer system (CCS) consisting of computers and software. The personal computer-based hardware and software system that includes the operator interface, data storage, data retrieval, archiving, alarming, historian, reports, trending, and other higher-level control system software and functions.

DCS: Distributed Control System: A general name for the computerized system, similar to an ACS or PCS, where the vast majority of hardware and software is provided by a single manufacturer as a complete package. It includes the PLCs and/or RIOs, HMIs, LCPs, VCPs, and all control and data management systems accessible to staff.

DEG: Design and Engineering Guidelines

DMZ: Demilitarized Zone: A secure subset of a network or potentially a dedicated server to which multiple parties may have access. The DMZ permits one-way data transfer. For example, the SCADA system could provide historical usage data to a city's planning department without exposing itself to an external threat.

DPDT: Double-pole, double-throw.

ES: Enterprise System: Computer based communications or data sharing system utilized for non-process control functions such as e-mail, sharing files, creating documents, etc.

FAT: Factory Acceptance Test: Testing to occur at the manufacturer factory and witnessed by City / Owner prior to equipment being shipped to the project site. The FAT shall include the entire ACS/PCS (each PLC panel, RIO panel, headend, OIT, and HMI) and testing shall include each I/O (including spares) point on terminal blocks from terminal blocks to PLC to OIT to/from HMI.

HART: Highway Addressable Remote Transducer: Means of calibration communication for HART capable field instruments.

HOA: Hand-Off-Auto: Type of switch that provides different means of equipment control. In the Hand mode, equipment is directly started or stopped, valves are opened or closed by the operator based on hardwired control circuits completely independent of the PLC with minimum interlocks and permissive conditions. In the Auto mode, equipment can be started or stopped, and valves are opened or closed through a control algorithm / programming within the PLC software. In the Off mode, the equipment is prohibited from responding to PLC control, and existing hand operation is terminated.

HMI: Human Machine Interface: A software application that presents information to an operator or user about the state of a process, and to accept and implement the operators control instructions. Typically, information is displayed in a graphical format. For COA, HMI is one half of the SCADA Maintenance team that resides within the Technical Operations group of the City and maintains the network, server and control nodes of the ACS/PCS.

ICSC: Instrumentation and Control System Contractor: Entity who specializes in the design, construction, fabrication, software development, installation, testing, and commissioning of industrial instrumentation and control systems. Also known as an Integrator or Systems Integrator.

IJB: Instrument Junction Boxes: A panel designed with cord sets to easily remove, replace, or relocate instrument signals.

I/O: Input & Output. Specific signals that are either coming from field equipment INTO the PLC or being OUTPUT from the PLC to field equipment. These can be discrete (ON/OFF) or analog (VARIABLE) signals.

IP: Internet Protocol: A type of network addressing.

I&C: Instrumentation and Controls: The field portion of the ACS/PCS that typically includes process equipment, associated instruments, PLC, LCPs, and OITs. For COA, I&C is one half of the SCADA maintenance team that resides within the Technical Operations group of the City.

LCP: Local Control Panel: Operator interface panel that may contain an OIT, pilot type control devices, operator interface devices, control relays, etc.

LAN: Local Area Network: A control or communications network that is limited to the physical boundaries of the facility or a defined area.

LOR: Local-Off-Remote: Type of switch that provides the operator a means to select location of control. In the Remote mode, equipment is started or stopped, and valves are opened or closed through the PLC (possibly based upon the selection of an associated HOA switch). In the Local mode, equipment is started or stopped, valves are opened or closed based upon hardwired control circuits completely independent of the PLC with minimum interlocks and permissive conditions. In the Off mode, the equipment is prohibited from responding to any control commands.

NJB: Network Junction Box: An enclosure that contains multiple access points to various networks within the facility. Networks could be Ethernet, Ethernet/IP, Fieldbus, RIO, etc.

O&M: Operations and Maintenance.

OIT Operator Interface Terminal: A display used to view and control process equipment, generally mounted in the field or process area.

P&ID: Process and Instrumentation Diagram.

PCIS: Process Control and Instrumentation System: Includes the entire instrumentation system, the entire control system, and encompasses the work specified in the Instrumentation and Control Specifications and depicted on the design drawings. This includes the entire PCS, associated instruments and networking components including the various servers, workstations, etc.

PCM: Process Control Module: An enclosure containing any of the following devices: PLC, RTU, or RIO.

PCS: Process Control System: A general name for the computerized system that gathers and processes data from equipment and sensors and applies operational controls to the process equipment. It includes PLCs, RIOs, OITs, HMIs, LCPs, VCPs, and data management systems accessible to staff. (See: ACS)

PDS: Project Delivery Services: COA Engineers that provide project management and SCADA review / implementation.

PJB: Power Junction Box: An enclosure with terminal blocks that distribute power to multiple instruments.

PLC: Programmable Logic Controller:

RIO: Remote I/O device for the PLC consisting of remote I/O racks, or remote I/O blocks.

SAT: Site Acceptance Test: Testing conducted once the FAT approved panels have been shipped to site and installed. The SAT shall mimic the FAT except utilize actual field devices to provide I/O. The SAT shall be witnessed by City / Owner.

SCADA: Supervisory Control and Data Acquisition system: A general name for the computerized system that gathers and processes data from instrumentation, sensors, process equipment and HMI to provide supervisory control of process systems and provide the resulting data and automated control to operators.

SMP: SCADA Master Plan.

SPDT: Single-pole, double-throw.

SPST: Single-pole, single-throw.

UDT: User Defined Tag: Feature used in ControlLogix PLC Programming

UPS: Uninterruptible Power Supply: Means to provide power to control equipment in the event of a utility power outage.

VCP: Vendor Control Panel: Control panels that are furnished with equipment provided by a specific Vendor other than the ICSC. These panels may contain PLCs, RIO, OIT, network devices, etc.

VFD: Variable Frequency Drive: A specialty motor drive that varies motor speed via frequency and voltage to maintain a process variable.

WAN: Wide Area Network: A control or communications network that extends beyond the physical boundaries of the facility.

1.0 INTRODUCTION

The Supervisory Control and Data Acquisition (SCADA) system manages devices that measure or monitor process conditions along with the equipment that permits automatic and manual (operator-initiated) action to occur in order to vary the status of process equipment. In addition to control, the SCADA system allows operators to remotely monitor processes to verify that they are performing as intended. The components of the SCADA system are divided into either the instrumentation or controls category.

Instrumentation refers to the group of field devices that includes but not limited to: flow meters, pressure transmitters, pressure switches, differential pressure transmitters, analytical measuring transmitters, level transmitters, level switches, and other devices associated with control panels like hand-off-auto (HOA) switches, variable frequency drives (VFDs), valve actuators and pilot devices.

The devices described by the term “controls” include but not limited to: local control devices, programmable logic controllers (PLCs), remote telemetry units (RTUs), human machine interface (HMI) hardware, and operator interface terminals (OITs).

The intent of this SCADA Design and Engineering Guidelines (DEG) document is to ensure the City of Aurora's (COA’s) standardized conventions are used for instrumentation, equipment, wiring, panels, controllers, PLC programming, network communications, OITs, and HMIs. Conformance to these conventions shall be uniform and will result in the systematic reference and representation of equipment and instrumentation between varying documentation and drawings. For projects involving existing facilities, these DEGs take precedence. If it is deemed necessary to deviate from certain DEG requirements, such deviations must be reviewed and approved by the COA SCADA Engineer on an individual basis.

The DEGs are intended to be utilized by the design engineer during all project designs that include any SCADA aspect. The most recent version of the DEGs should be included as a reference to the contract specifications. The DEGs are not intended to be a legally binding portion of the contract documents, however, the contract documents should incorporate the requirements set herein. It is the responsibility of the design engineer to review the requirements of the DEG and incorporate those requirements into the specifications and design drawings.

1.1 CODES AND STANDARDS

SCADA design should conform to the standards specific to the water and wastewater industry, as well as to nationally-recognized standards for Instrumentation and Control systems. Design shall conform to the following codes, standards, and recommended practices shown in Table 1.1.

Table 1.1 Instrumentation & Control and Electrical Codes and Standards	
Organization	**Code/Standard Title**
International Society of Automation (ISA)	Develops standards, certifies professionals, provides education and training, publishes books and technical articles, and hosts conferences and exhibitions for automation professionals.
National Fire Protection Association (NFPA)	National Electric Code (NFPA 70E)
National Electrical Manufacturers Association (NEMA)	Enclosures for Electrical Equipment (1000 Volts Maximum) (NEMA 250)
UL 508	Underwriters Laboratories Safety Standards for Industrial Control Equipment
National Electric Code (NEC)	Electrical and Industrial Code

1.2 ABBREVIATIONS AND DEFINITIONS

A list of Acronyms and Abbreviations is included at the beginning of these Design and Engineering Guidelines following the Table of Contents. All additional symbology and identification shall be in accordance with ANSI/ISA-5.1-2009[(1)] unless otherwise noted.

1.3 PROGRAMMABLE LOGIC CONTROLLERS

For projects involving the addition of PLCs, the designer and integrator shall provide the Allen-Bradley ControlLogix series of processors, racks, power supplies, and I/O modules. PLC programming is to be performed with Rockwell Software's RSLogix 5000 / Studio. Version 20[(1)] is the only permitted version for L7 series processors and version 28[(1)] is the only permitted version for L8 series processors. Any versioning conflicts or recommendations must be brought to the attention of the City and any deviations approved by the COA SCADA Engineer prior to the procurement or programming of PLCs. The following protocols are to be used for specific instructions:

- Function Block style for process control that utilizes standardized custom AOI and UDT functions where applicable.
- Ladder Logic style for I/O mapping and alarming only.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

- Structured text for complex math calculations. No logic, including If Then statements, are to be utilized in structured text.

Specific programming requirements are listed in subsequent sections.

For Capital Improvements Projects, the Contractor shall be responsible for all PLC and HMI programming.

1.4 PROGRAMMING WORKSHOP

For projects involving the addition of new PLCs and/or modifications to existing PLC code, the designer, integrator, and programmer shall schedule a programming workshop with the City of Aurora SCADA Team. All required parties, regardless of prior experience programming COA PLCs, must attend. This programming workshop needs to be scheduled and held prior to initiation of any programming performed by the ICSC.

This workshop will be led by the City of Aurora's SCADA Team. Being these DEGs are a "living document," the purpose of the programming workshop is to ensure the ICSC utilizes the most recent AOI and UDT that exist within the COA SCADA programming library. The COA SCADA Team shall determine the length of the programming workshop.

COA SCADA personnel will walk-through template examples of PLC, OIT/HMI programs and screens and highlight the specific programming standard requirements. COA SCADA will provide the ICSC a copy of the programs that were reviewed at the conclusion of the workshop. See §12.0 for additional requirements.

1.5 DELIVERABLES FOR DESIGN

For projects containing instrumentation and control components, the designer and integrator shall provide the following deliverables to COA SCADA for review:

- Process and Instrumentation Diagrams, complete with process, PLC, OIT, and HMI bands in a bottom-to-top direction.

- Loop Drawings that completely define and document the path and terminations of each monitoring, alarming, interlock, and control loop.

- Instrumentation and SCADA installation details, specifically indicating required calibration manifolds, installation locations (to demonstrate accessibility to perform future maintenance / calibrations), security devices, grounding, lightning protection, etc.

- Security layout drawings, complete with Lenel Panel, card reader, specific security device(s) locations and associated bill of materials (BOM).

- Final Control Narratives that have been reviewed, revised, and approved, by the Site or future Site Owner.

- Specifications for instrumentation, field control equipment, process controllers, control panels, computers, security and network equipment.
- Network or Control System Block Diagram for projects containing process controllers. The Control System Block Diagram shall show all controllers connected to a network or that are part of the control system. All computers, networking equipment, and communication equipment that are part of the project shall be shown on the Control System Block Diagram. If making modifications to an existing control network, the new equipment shall be added to the existing version of the block diagram.
- Instrumentation Device Schedule or Instrument Data Sheets and Calibration Data Sheets.
- Control Panel Layout, Wiring Drawings ad associated bill of materials (BOM).
- SCADA System Control and Programming Descriptions.
- Complete I/O List, inclusive of, but not limited to, PLC, OIT, Head End, and HMI tags.
- PLC programs (including PLC, OIT and Headend (if applicable) programs) and HMI Screens / associated database.

The standards and formats for each of these deliverables are discussed in subsequent sections in these guidelines.

1.6 FACTORY ACCEPTANCE TESTING (FAT)

The Factory Acceptance Test demonstrates all SCADA and controller software, hardware, and panel components are working properly and all software configurations match the requirements identified within the design, including detailed process narratives, operating manuals, and logic flow chart diagrams. The goal is to identify and resolve any problems in the control system (Field Device → PLC → OIT → HMI) before it arrives at the installation site.

All equipment shown on the network architecture drawings shall be connected and tested for interoperability, including equipment address, I/O mapping, and any failover measures. If the project involves multiple components that communicate with one another as a system, those components shall be set up together (i.e. ten new recovery well panels, or three filter panels) at the factory or other location if the integrator's facility does not suffice. The Contractor shall also demonstrate network operation of all network switches, media converters, and servers. A sourcing device will be used to ensure field terminals are correctly mapped to the PLC and HMI and to confirm control panels are wired per shop drawings. See §13.0 for additional requirements.

1.7 SITE ACCEPTANCE TESTING (SAT)

After the FAT and following commissioning of the control system, Aurora Water works with the Vendor to provide the Site Acceptance Testing in accordance with Aurora Water's plan. Site Acceptance Testing is identical to the Factory Acceptance Testing, but includes testing of actual field devices and foreign device interfaces.

Site Acceptance Testing is performed to prove the delivered system is interfaced to the site I/O correctly and wired the same as the system tested at the factory, and performs in accordance with the project specifications. Site Acceptance Testing consists of repeating the Factory Acceptance Testing using the actual site instruments, I/O, and service connections once all site equipment has been installed and successfully tested at the factory. See §14.0 for additional requirements.

1.8 TRAINING

After City acceptance of the SAT, the Contractor shall provide specific training to the Aurora Water teams:

- Site operations and maintenance training shall be provide to all personnel in department that owns the new or upgraded facility as well as the SCADA team. Operation and Maintenance manuals appropriate to the operations shall be provided.

- Site programming training shall be provide to all personnel in the SCADA. Operation and Maintenance manuals appropriate to the operations shall be provided.

The duration and breadth of training shall be agreed upon by the City and Contractor, but shall be no less than two days.

2.0 CONTROL NARRATIVES

2.1 INTRODUCTION

This section of the DEG provides the minimum requirements for the Control Narrative submittals required for new system installations or existing system control modifications. The control narrative shall not only include a written description of the system controls, but provide a concise, step-by-step process of how the I/O interacts to provide control and alarms for the system.

2.2 FORMAT REQUIREMENTS

Control Narratives shall have the following minimum format requirements:

1. Introduction: The introduction shall provide a brief text description of how the entire system functions as a general overview.

2. I/O Table: The I/O Table shall provide each I/O point to be utilized for control of the system. The table shall provide the complete tag name, instrument or location from which the I/O is generated, and a brief description of how that I/O is used in control of the system.

3. Control Loop List: The control loop list shall include a list of control loops being utilized in programming the controls for the system. This list should be provided in an order to disseminate control steps for programming the control of the station or system.

4. Detailed Control Description: This text description shall provide a detailed, step-wise description of how the I/O interacts to provide control and alarms for the system.

5. Alarm List: This list shall provide the I/O or Control tag name, the condition that activates this tag, and the associated alarm. This table shall also provide the response associated with the individual alarm, like a pump shut down, warning alarm, or callout.

6. Indicators List: The list shall include any indicators specific to the control loop that are to be displayed on any OITs or HMIs.

7. Failure Mode Description: List any specific responses to failures in the control loop. Failures can include, but are not limited to: loss of power, loss of communication, or out-of-range values.

2.3 REQUIRED MEETINGS

The following minimum meetings shall be scheduled with the City for development of the control narrative. All programming parties, regardless of past projects or experience with the City, are required to participate in these meetings.

1. Preliminary Control Meeting: For new installations, this meeting with be held to address the specifics of how the station is to be controlled with focus on unique or critical control components. For existing installations, this meeting will review existing I/O and controls of each station or system, and discuss modifications to the existing controls and any I/O that may be needed.

2. Draft Control Narrative Meeting: This meeting will review the draft control narrative submitted in accordance with the minimum format requirements. The City will provide comments or clarify control requirements. The City requires two weeks to review the draft control narrative submittal prior to scheduling this meeting.

3. Final Control Narrative Meeting: This meeting will finalize the control narrative. If comments or modifications are substantial, an additional final control narrative meeting shall be held. The City requires two weeks to review the final control narrative submittal prior to holding this meeting.

In addition to the aforementioned control narrative meetings, the following minimum meetings shall be scheduled with the City for production of the OIT/HMI screens. All parties responsible for developing screens, including Vendors, are required to participate in these meetings, regardless of past projects or experience with the City.

1. Preliminary Screens Meeting: Held before any configuration work is begun. The developer must bring to this meeting example of displays, display symbols, reports, etc. to show the capabilities of the system software. Coordinate with the City to review City SCADA screens and standards. These standards are included in later chapters, but it is the responsibility of the developer to provide screens in accordance with the most current version of these standards.

2. Intermediate Screens Meeting: Held after the initial database is entered and typical screens and reports have been entered. The City will provide comments for submitted screens. The City requires two weeks to review the screens submittal prior to holding this meeting. If multiple screen developers and/or PLC programmers are involved on a project, a second intermediate screens meeting is required to discuss, at a minimum:

    a. Tag Naming Conventions.

    b. PLC to PLC global data mapping.

    c. All PLC to HMI tags mapping.

    d. OIT screen colors and navigation.

    e. Interlock and Permissive definitions.

    f. Communication Methods.

    g. Standard code blocks for common control functionality.

    h. Alarms: Clearing, formats, colors, and status.

3. Final Screens Meeting: Held after initial completion of all configuration work. This meeting is to discuss all HMI/OIT interface submittals. Make final format revisions after this review.

3.0 SCADA SYSTEM ARCHITECTURE

3.1 INTRODUCTION

The goal of the City of Aurora's SCADA architecture is to provide a consistent, highly reliable system that minimizes disruption in the collection and dissemination of information and control.

3.2 CONTROL SYSTEM ARCHITECTURE

The City of Aurora's SCADA architecture is based on configuration control for both hardware and software. This includes a minimum requirement of 20 percent spares of conductors, slots, channels, types of I/O, etc. for each panel.

3.2.1 Programmable Logic Controller Criteria

The City of Aurora's SCADA processing hardware utilizes Allen-Bradley ControlLogix series of processors, racks, power supplies, and modules hardware. Rockwell Software RSLogix 5000 Version 20(1) is the current minimum software standard.

There are Allen-Bradley SLC processors in service at various facilities within the City. When modifications to these PLCs are necessary, RSLogix 500(1) shall be used. All other programming shall performed in RSLogix 5000.

Attempts are made to maintain these standards as versions and updates become available, however it is the Vendor or Contractor's responsibility to verify the City's current specifications prior to installation. Verification of current hardware specifications is performed at the programming workshop at the beginning of the project. See §7.0 for details.

3.2.2 Human Machine Interface Criteria

The City of Aurora's SCADA information and command processing is distributed across multiple stations which are connected through communication protocols via a LAN/WAN. Information is shared in near real time. Each station is responsible for a particular task.

Attempts are made to maintain these standards as versions and updates become available, however it is the Contractor's/Vendor's responsibility to verify City of Aurora SCADA current specifications prior to installation. Verification of City of Aurora SCADA current hardware specifications is performed at the SCADA workshop at the onset of the project. See §11.0 for details

3.2.3 Operator Interface Terminal Criteria

The City of Aurora's SCADA information and command processing utilize Allen-Bradley Panelview Plus 7(1) as the current minimum hardware standard. Rockwell Software FactoryTalk View ME Version 7.1(1) is the current minimum software standard.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.
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Attempts are made to maintain these standards as versions and updates become available, however it is the Contractor's/Vendor's responsibility to verify City of Aurora SCADA current specifications prior to installation. Verification of City of Aurora SCADA current hardware specifications is performed at the SCADA workshop at the beginning of the project. See §9.0 for details

3.3 NETWORK COMPONENTS

The City of Aurora SCADA network utilizes specific hardware including routers, switches, fiber modules/transceivers, and patch panels for its infrastructure.

It is the Vendor or Contractor's responsibility to verify City of Aurora SCADA current hardware specifications prior to installation.

3.3.1 Routers

The City of Aurora uses Layer 3 - Open Systems Interconnection (OSI) model (ISO/IEC 7498-1) - Cisco Catalyst 3850 Ethernet switches[(1)] as routers.

3.3.2 Switches

The City of Aurora uses Cisco Catalyst 3850 Ethernet switches with Power-Over-Ethernet (PoE) and SFP modules for network rack applications. See §3.3.3 for detailed SFP module/transceiver information.

The number of Ethernet ports required is dependent on how many connections are utilized on the switch.

Models:

- WS-C3850-24P-S is for a 24-port switch.
- WS-C3850-48P-S is for a 48-port switch.

The City of Aurora uses Hirschmann MS-series Ethernet switches[(1)] for panel mounted, process floor applications. The exact model shall depend on network communication requirements.

3.3.3 Fiber Modules/Transceivers

The City of Aurora uses Cisco Small Form-factor Pluggable (SFP) fiber transceivers, model GLC-LH-SMD[(1)]. The SFP expansion module C3850-NM-4-1G[(1)] shall be used.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Table 3.1 SFP Transceiver Port Cabling Specifications						
SFP Transceiver Product Number	**SFP Transceiver Type**	**Wavelength (nm)**	**Fiber Type**	**Core Size (micron)**	**Modal Bandwidth**	**Cable Distance (ft)**
GLC-LH-SMD	1000BASE-LX/LH	1310	MMF	62.5	500	1,804
		1310	MMF	50	400	1,804
		1310	MMF	50	500	1,804
		1310	SMF	ITU-T G.652	N/A	32,821

3.3.4 Patch Panels

The City of Aurora uses Corning Patch Panels. See §3.3.5 and §3.3.6 for detailed information. Note that the Patch Panel models listed are generic and not a one-size-fits-all option. Provide Patch Panels that are specific to the needs of the site.

3.3.5 Wall-Mountable Closet Housings

Corning Cable Systems' Wall-Mountable Closet Housings (WCH) provide interconnect or cross-connect capabilities between the outside plant, riser or distribution cables and the opto-electronics.

These units can be wall-mounted in Main Cross-Connects (MCs) or Telecommunication Rooms (TRs) and are available in different versions; two panels, four panels and six panels.

Models:

- WCH-02P (up to 24 fibers).
- WCH-04P (up to 48 fibers).
- WCH-06P (up to 72 fibers).
- WCH-012P (up to 144 fibers).

Optional products:

- Wall-Mountable Jumper Storage Guide Kit - WJG-02R.
- Cable Strain-Relief Kit - WCH-STRNRLF-KIT.
- Standoff Bracket - WCH - STDOFF-BKT.
  - Extends the WCH housing from the wall so that cable can be routed behind the units.

Wall-Mountable Closet Housings can be ordered with connector panels for both multi-mode and single-mode applications. The same connector panel is used on the rack-mountable version.

Units accept standard Closet Connector Housing (CCH) connector panels and modules and options include jumper routing guides and a bracket for securing buffer tube fan-out kits.

3.3.6 Closet Connector Housing

Corning Cable Systems Closet Connector Housing Panels (CCH-CP) are offered in a variety of fiber counts for use with LANscape Solutions hardware products for a one-size-fits-all approach. Used with factory-installed or field-installable connectors, these panels provide interconnect or cross-connect capability in a housing at main cross-connects, intermediate cross-connects, telecommunication rooms or work areas. Available with a variety of industry-standard adapter types, the CCH-CP provides an efficient way to secure mate two connectors and offers multi-mode and single-mode applications in 6-, 8-, 12-, 16- and 24-fiber count options, plus 36-, 72-, 96- and 144- fiber count options with MTP Connector adapters. It is the Contractor's responsibility to verify the number of fibers needed, the fiber type, and the adapter type needed for the project.

Figure 3.2 and Figure 3.3 shows part number information that includes both the fiber count and the corresponding adapter/connector.

Figure 3.1 CCH Panel Ordering Information

CCH	-	CP	☐ ☐1	-	☐ ☐2
			1		**2**
			Select fiber count 06 = 6 fibers 08 = 8 fibers 12 = 12 fibers 16 = 16 fibers 24 = 24 fibers 36 = 36 fibers 72 = 72 fibers 96 = 96 fibers E4 = 144 fibers		Select adapter code (See Adapter/Connector Code table on following page).

Figure 3.2 CCH Adapter/Connector Code Options

Adapter Code	Fiber Type	Alignment	Housing	Fiber/ Adapter	Available Fiber/Panel Counts								
					6	8	12	16	24	36	72	96	144
LC Duplex													
A7	62.5 µm multi-mode	Metal	Composite	2		X	X	X	X				
D3	50 µm multi-mode	Ceramic	Composite	2		X	X	X	X				
E4	50 µM LOMMF*	Ceramic	Composite	2		X	X	X	X				
A9	Single-mode, UPC	Ceramic	Composite	2		X	X	X	X				
SC Duplex													
91	62.5 µm multi-mode	Metal	Composite	2	X	X	X						
G7	50 µm multi-mode	Ceramic	Composite	2	X	X	X						
E7	50 µM LOMMF*	Ceramic	Composite	2	X	X	X						
59	Single-mode, UPC	Ceramic	Composite	2	X	X	X						
SC													
56	62.5 µm multi-mode	Metal	Composite	1	X	X	X						
G6	50 µm multi-mode	Ceramic	Composite	1	X	X	X						
E6	50 µM LOMMF*	Ceramic	Composite	1	X	X	X						
3C	Single-mode, UPC	Ceramic	Composite	1	X	X	X						
6C	Single-mode, APC	Ceramic	Composite	1	X	X	X						
ST® Compatible Connector													
25T	62.5 µm multi-mode	Metal	Metal	1	X	X	X						
15T	50 µm multi-mode	Ceramic	Metal	1	X	X	X						
G5	50 µM LOMMF*	Ceramic	Metal	1	X	X	X						
H3	Single-mode, UPC	Ceramic	Metal	1	X	X	X						
19T	Single-mode, APC	Ceramic	Metal	1	X	X	X						
FC													
11	Single-mode, UPC	Metal	Metal	1	X	X	X						
21	Single-mode, APC	Metal	Metal	1	X	X	X						
MTP® Connector													
69	62.5 µm multi-mode	N/A	Composite	12						X	X	X	X
G3	50 µm multi-mode	N/A	Composite	12						X	X	X	X
E3	50 µM LOMMF*	N/A	Composite	12						X	X	X	X
89	Single-mode, UPC	N/A	Composite	12						X	X	X	X
90	Single-mode, APC	N/A	Composite	12						X	X	X	X
MT-RJ													
97	62.5 µm multi-mode	N/A	Composite	2		X	X	X	X				
G1	50 µm multi-mode	N/A	Composite	2		X	X	X	X				
E1	50 µM LOMMF*	N/A	Composite	2		X	X	X	X				
98	Single-mode, UPC	N/A	Composite	2		X	X	X	X				

Fiber Type	**Housing**
62.5µm multi-mode	Beige
50 µm multi-mode	Black
50µM LOMMF*	Aqua
Single-mode, UPC	Blue
Single-mode, APC	Green

*LOMMF = Laser optimized multi-mode fiber.

3.3.7 Equipment Lockers/Boxes

Network equipment not stored in server rooms inside full equipment racks should be contained in an equipment enclosure. The City of Aurora uses the Hoffman EWMW242418(1) enclosure. Its dimensions are 24” x 24” x 18”. It is a 12U tall enclosure with a window door, center section, and a wall section. It is double-hinged for easy equipment access. The center section provides 19-inch rack mounting per EIA universal spacing and is accessed through the front door.

3.4 NETWORK CONNECTIONS

Some City of Aurora sites use multi-mode fiber, single-mode fiber or a mixture of both types. Below Table 3.2 shows optical fiber cable colors.

Table 3.2 Fiber Cable Colors

Buffer/Jacket Color	Meaning
Yellow	Single-mode optical fiber
Orange	Multi-mode optical fiber
Aqua	10 gig laser-optimized 50/125 micrometer multi-mode optical fiber
Grey	Outdated color code for multi-mode optical fiber
Blue	Sometimes used to designate polarization-maintaining optical fiber

3.4.1 Multi-mode

Multi-mode fiber has a larger diameter core and supports multiple pathways, or modes, of light. Several pathways of light are transmitted simultaneously through the fiber as they bounce off the edge of the core. Multi-mode fiber is best suited for shorter-distance applications. Multi-mode fiber sites like Griswold WPF and Wemlinger WPF utilize both multi-mode and single-mode fiber.

3.4.2 Single-mode

Single-mode fiber permits only one pathway to travel through the core. This allows data to travel greater distances than over multi-mode, potentially up to 50 times farther. Single-mode is a better solution for situations where low signal loss and high data rates are required, such as: long-haul network applications; those spread out over campuses; and longer distances. Single-mode fiber sites are Aurora Pump Station, Binney WPF, Conveyance, Intertie, North Campus, Quincy Pump Station, and SCADA WAN.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

3.4.3 Fiber Connection Types

The City of Aurora typically uses SC fiber connectors with Physical Contact (blue)[1] connector types.

Figure 3.3 shows several common fiber connection types.

Figure 3.3 Fiber Connection Types

ST	**SC**	**LC**	**MT-RU**
			
The ST connector uses a push-and-turn-to-lock system.	The SC connector has a molded plastic plug and a push/pull locking system.	The LC connector is has a small form factor connector that resembles a mini-SC connector.	The MT-RU connector has a small form factor connector with a square plastic casing that contains both fiber strands in a single polymer ferrule.

Table 3.3 shows the different connector boot types.

Table 3.3 Fiber Boot Connection Colors

Connector Boot	**Meaning**
Blue	Physical Contact (PC), 0º
Green	Angled Physical Contact (APC), 8º
Black	Physical Contact (PC), 0º
Grey/Beige	Physical Contact (PC), 0º
White	Physical Contact (PC), 0º
Red	High optical power

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

3.5 SECURITY

Security is of paramount importance to the City of Aurora ICS network and system. The following methods to maintain network and system integrity are and will be utilized:

- Restricting logical access to the ICS network and network activity. This includes using a demilitarized zone (DMZ) network architecture with firewalls to prevent network traffic from passing directly between the corporate and ICS networks, and having separate authentication mechanisms and credentials for users of the corporate and ICS networks.

- Restricting physical access to the ICS network and devices. Unauthorized physical access to components could cause serious disruption of the ICS's functionality. Several preventative methods are used, including locks, card readers, and security personnel.

- Protecting individual ICS components from exploitation. This includes: expeditiously deploying security patches after testing them under field conditions; disabling all unused ports and services; restricting ICS user privileges to only those that are required for each person's role; tracking and monitoring audit trails; and using security controls such as antivirus software and file integrity checking software where technically feasible to prevent, deter, detect, and mitigate malware.

- Maintaining functionality during adverse conditions. This involves designing the ICS so each critical component has a redundant counterpart. Additionally, if a component fails, it should fail such that it does not generate unnecessary traffic on the ICS, nor does not cause problems elsewhere, such as a cascading event.

3.5.1 Passwords

For some ICSs, automated response time or system response to human interaction is critical. Requiring password authentication and authorization on an HMI should not hamper emergency actions for industrial control systems. Information flow must not be interrupted or compromised.

3.5.2 Building Access

City of Aurora personnel will accompany Vendors and Contractors to sites for which they need access. The City requires a seven day notice before any site visits.

3.5.3 Cameras/Equipment

The City of Aurora utilizes security cameras and digital video recorders at all sites. None of this equipment is of consequence to Vendors due to the fact Vendors will be provided escort by Aurora Water personnel at all times.

3.5.4 Networks

The City of Aurora's ICS network is not permitted to access outside systems, including the Internet. When working with City of Aurora files, one must be working on a computer approved or provided by the City.

3.5.5 Panel Alarms

The City of Aurora requires door switches on control cabinets. Intrusion alarms on hatches must consist of a both a hatch door limit switch and motion detector.

3.6 REMOTE SITE CONTROLLERS

City of Aurora SCADA personnel will accompany Vendors and Contractors to remote sites as necessary. The City requires a seven day notice before any site visits. The procedure for modifying existing code is as follows:

- COA SCADA provides existing or example code to ICSC at PLC programming workshop.
- ICSC produces PLC program on their own equipment.
- ICSC provides program to COA SCADA for approval.
- Upon approval, COA SCADA loads program on SCADA laptop.
- COA SCADA personnel connect SCADA laptop to PLC processor.
- ICSC transfers approved PLC code to processor utilizing the SCADA laptop COA SCADA staff must be present.

3.7 COMMUNICATION TO REMOTE SITES

The City of Aurora utilizes several communication methods to its remote sites, including:

- Fiber optic.
- Ethernet.
- Modem.
- Radio.

The City of Aurora will provide this information to the Vendor. The Vendor is required to maintain the City of Aurora's standards.

4.0 PROCESS AND INSTRUMENTATION DIAGRAM GUIDELINES

4.1 INTRODUCTION

Every design project associated with a process stream must include P&IDs as a deliverable. At a minimum, the P&ID must contain:

1. Process piping that carries the main, secondary, by-pass, chemical feed, and sampling streams.
2. Connected vessels, equipment, and structures.
3. Motorized equipment, actuators, and final control devices.
4. Non-motorized isolation valves, check valves, and gates.
5. Primary measurement/analysis elements, transmitters, and indicators.
6. Control and Readout panels.
7. Electrical Inputs, Outputs, and Data signals.
8. Electrical interlocks.

It is not the intent of the P&ID to include all mechanical and piping details such as fittings, reducers, and tees as these will be shown on the process mechanical drawings. The P&IDs are to represent the process stream and all equipment and instrumentation needed to control the process in a schematic form. The P&ID will incorporate established symbology for equipment and instrumentation and show all connections and interactions between those elements.

The P&IDs shall be provided as a design deliverable in both hardcopy and electronic format on CD media. The drawings shall be provided as PDFs and an AutoDesk AutoCAD software format at the version level acceptable to the Water Department. Information contained on the P&ID should include instrument electrical connection requirements. Any equipment nameplate and manufacturer information provided on the CAD drawings should also be provided in database format on CD media.

The City requires P&IDs to be based on ANSI/ISA-5.1-2009 standards[(1)].

4.2 DRAWING SHEET LAYOUT

Although it is not the intent of the P&ID to include all details, the P&IDs are to represent all SCADA equipment and instrumentation, in a schematic form. The P&ID will incorporate

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

established symbology for equipment and instrumentation and show all connections and interactions between those elements per the following subsections.

4.2.1 General

The P&IDs should be arranged to consist of, at minimum, four distinct horizontal bands. The characteristics of these bands are described below. The bands represent the hierarchy of control ranging from the field or process level (bottom), to the PLC, OIT, and HMI levels (upper). Additional bands that provide more detail regarding control features may be provided upon approval of the Water Department project manager and I&C lead. It is the intent that the P&ID serves as a tool to show each process area and the equipment, devices, instrumentation and control locations, and features available to the operator for control. Second, for maintenance purposes, it will ensure that equipment and controls interactions are provided in enough detail to do a high level diagnosis of the process controls. It is not intended that details of programming logic be incorporated in the P&ID. Control logic text, Boolean, or other type logic coding should not be included on the P&ID. Detailed process control descriptions or narratives should be provided in the contract document specifications to supplement the P&ID.

P&IDs should be arranged so that the process flow starts on the left and proceeds to the right side of the sheet. The P&IDs shall be organized in a four level hierarchy. These levels are described in the following paragraphs.

4.2.2 HMI Band - System Interface

Located in the upper most band of the sheet, this area contains the shared display HMI and computer functions. In this band, all signal interfaces should be through data links or an Ethernet TCP/IP network.

4.2.3 OIT Band - System Interface

Located below the HMI band, the OIT band contains the SCADA features accessible from operator interface terminals.

4.2.4 PLC Band - Programmable Logic Controllers, RTUs and Operator Interface Panels

This band lies immediately below the OIT band and contains digital logic control functions, I/O signal terminations, and smart device interfaces. Hardwired signals, including analog inputs, analog outputs, discrete inputs, and discrete outputs, should be clearly identified and differentiated.

4.2.5 Field Band - Process, Instrumentation, Control Panels and Equipment

This band is located on the lower portion of the drawing sheet and contains the process piping, equipment, structures, primary elements, field instrumentation, and local equipment control and monitoring functions. The process, instrumentation, and equipment level is located at the bottom of the drawing. This level also includes Vendor package control panels, area panels and process control panels that interface with the SCADA system.

4.3 PANEL REPRESENTATION

Panels other than the Process Control or SCADA panel that encloses the PLC or RTU should be shown on the P&ID in the Field Level. These panels can include Vendor package panels, area control panels, process control panels, motor control centers, variable frequency drive controllers, local control panels, and pushbutton stations. Representing control panels on the P&IDs should follow the guidelines noted below:

1. Panels and panel devices should only be shown if they interface directly or indirectly with the SCADA system. An example would be a packaged control system that has a Hand-Off-Auto switch that allows control through the SCADA system when switched to Auto.
2. Vendor packaged panels, area control panels, and process control panels should be represented with device bubbles with a light-line weight panel border.
3. Panels must be identified on the P&ID with a designation that matches the panel's nameplate.

4.4 LOOP DRAWINGS

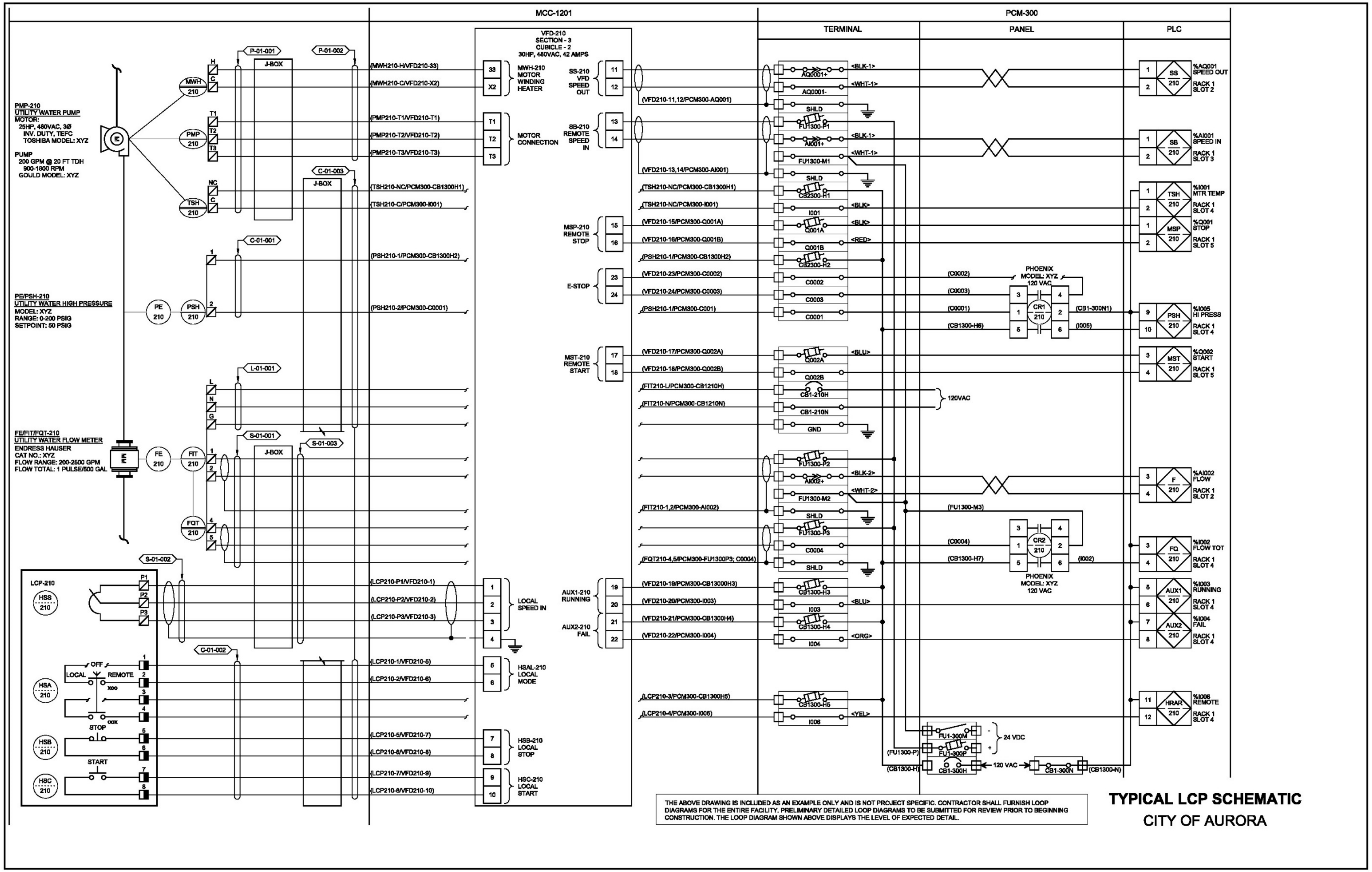
All new instrument signals shall be shown on loop drawings detailing their path from instrument to I/O module. In addition to the standards of ISA-5.4-1991(1), show the following details:

- Loop name.
- Drawing or reference name for signals continuing off the loop diagram.
- All terminal numbers.
- MCC panel, circuit, and circuit breaker numbers for power feeds to the loop and instrument.
- Tags and terminal assignments for every manhole, pullbox, junction box, and panel through which the loop passes.

Figure 4.1 shows the level of detail expected for loop drawings. It is not intended to define the specific visual format.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Figure 4.1 Sample Loop Drawing



4.5 PROCESS REPRESENTATION

Representation of the process piping, equipment and associated structures should be schematic in nature. Piping connections should be shown with arrows to denote flow directions. The layout may utilize plan or elevation views or a combination of both to clearly represent the process and equipment associations.

All process streams should be shown entering the sheet from the left side and exiting to the right. Process streams should flow from left to right and top to bottom. All process streams should be labeled and have continuation symbols that indicate sheet of origin, sheet of destination, or otherwise labeled as applicable.

Process interface letters should use letters A through Z. If additional continuations are required, two letter process interface designations should be used beginning with AA, AB, AC, etc.

The process layout should include equipment, structures, and piping. It may use either plan views or elevation views, whichever more clearly depicts the process and interaction between components. Process flow shall be generally shown left to right.

Equipment such as tanks, mixers, and conveyors should be depicted using light line weights.

Structures such as basins and wet wells should be shown using double lines in light line weight. Building boundaries are often used to indicate that a group of devices are located within a building. Building boundaries should be shown using a center dash line type.

Process lines should be drawn with a heavier line weights than other objects to help convey the information on the P&ID. Main process flow is indicated by the drawing title and is shown in the heaviest line weight. Secondary process flows such as chemical, return, water, or air are shown in a medium weight line and bypass or tertiary flows are shown in a light weight line.

4.6 INSTRUMENT AND CONTROL FUNCTION SYMBOLS

Instruments represented on P&IDs are based on the ISA standards for instrumentation symbols and identification, ISA-5.1-2009(1). The standard is suitable for use wherever any reference to an instrument or control function is required for the purpose of symbolization or identifications. The standard covers the identification of an instrument and all other instruments or control functions associated with it in a loop. As used on P&IDs, instrument symbols include lights, switches, relays, and all instruments that measure, indicate, and transmit process information. Each instrument symbol includes an instrument identifier, loop number, and additional fields for description of special instruments. Instrument identifiers, loop numbers, and description fields are described in detail in sections 4.9.1, 4.9.2, and 4.9.3, respectively.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

4.6.1 Instrument Power

Instruments that require power from external sources can optionally include an external power source identification. At a minimum, externally powered instruments should carry a flag near the instrument bubble at the 11 o'clock position that denotes the required voltage.

4.7 DISTRIBUTED CONTROL, SHARED DISPLAY AND HMI/SCADA SYMBOLS

Symbols for distributed control, shared display, logic, and computer systems are based on ISA standard ISA-5.3-1983(R1992)(1), Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic, and Computer Systems. Distributed control functions include PLCs, RTUs and other types of microprocessor-based field controllers.

Shared display function symbols should be used where systems include components identified as computers or panels and are distinct from integral processors. Shared display function symbols include preprogrammed algorithms, user-defined strategies, and software calculations.

HMI/SCADA display functions include the graphic or alphanumeric display of data on the computer control system's HMI. Digital control and shared display symbols also include function identifiers, loop numbers, and additional description fields which are defined in detail in other sections of this chapter.

4.8 INPUT & OUTPUT SYMBOLOGY

Control system I/O includes discrete inputs, discrete outputs, analog input, analog outputs, pulse inputs, and modulating discrete outputs. The P&IDs shall use annotations attached to the PLC hard-wired I/O symbol to designate the type I/O terminated.

4.9 INSTRUMENT TAGGING

Symbology for instruments, control functions, shared display, and computer access shall include identification tagging that is based on the ISA-5.1-2009(1) standards. All tags are determined and provided by the Site Owner, not the City SCADA group. The identification tagging consists of an instrument identifier, control loop number, and additional descriptors for special instruments.. Characteristics of each are described in the following subparagraphs.

4.9.1 Instrument Identifiers

Instrument and control system identifiers are located in the upper half of the instrument bubble.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

4.9.2 <u>Control Loop Numbers</u>

Control loop numbers are located in the bottom half of the instrument symbol. A control loop is a collection of instruments or devices that control or monitor a single process parameter or item of equipment. The control loop number consists of six digits that identify the process, the facility where the process is located, and the specific device in the process. The instrument tag includes the instrument identifier and the control loop number as represented by the following format:

Instrument Tag: AAA-XXXYYY-ZZ

Where: AAA is the ISA instrument identifier

XXXYYY-ZZ is the control loop number

XXX is the process unit number

YYY is the device number

ZZ is the train number when there are multiple trains

The process unit number, as shown in Table 4.1 and Table 4.2, is sequential starting with processes in the Griswold WPF and continuing with processes in the Wemlinger WPF.

Example: Griswold WPF Filter 1 Effluent Flow Indicating Transmitter

Instrument Tag: FIT-00301

Where: FIT is the ISA instrument identifier for a flow indicating transmitter,

XXX, process unit number, is “003”, and

YYY, device number, is “01”.

Tags listed in Table 4.1 are provided as examples. The naming convention needs to be reviewed with the City prior to developing design drawings.

Table 4.1	Griswold WPF Process Units and Number Assignments[1]	
Facility	**Process Unit (XXX)**	**Process Area**
Griswold WPF	001	Raw water Flow control & Rapid Mix
	002	Contact Basin & Settled Water Channel
	003	Filtration
	004	Clearwells & Treated Water Storage
	005	Backwash Blowers, Backwash Supply Pumps, Zone 4 Pumps, & Service Water Pumps
	006	Washwater Recovery
	007	Chemical Feed
	008	Chemical Feed (continued)
	009	Chemical Feed (continued)
	010	Chlorine Scrubber
	011	Sampling & Analysis System
	012	Tertiary Containment
	013	Electrical System
	014	HVAC & Miscellaneous Systems

Table 4.2	Wemlinger WPF Process Units and Number Assignments[1]	
Facility	**Process Unit (XXX)**	**Process Area**
Wemlinger WPF	051	Raw Water Control Facility
	052	Flocculation
	053	Filtration
	054	10-MG Reservoir
	055	(Not Used)
	056	Backwash Blowers
	057	Backwash Water Supply Pump Station
	058	Zone 4 & 5 Pump Station
	059	(Not Used)
	060	(Not Used)
	061	Liquid Alum

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Table 4.2	Wemlinger WPF Process Units and Number Assignments[1]	
Facility	**Process Unit (XXX)**	**Process Area**
	062	Cationic Polymer
	063	Non-Ionic & Anionic Polymer
	064	Aqua Ammonia
	065	Chlorination
	066	Chlorine Scrubber
	067	Chlorine Dioxide
	068	Fluoride

For new facilities, suggested process unit numbers are listed in Table 4.3. In general, process units in water treatment, SOS, and T&D facilities will be assigned numbers in the range from 000 to 499. Process units in waste water and reuse facilities will be assigned numbers in the range from 500 to 999. The final approved control loop numbers must be coordinated with Water Department staff.

Table 4.3	Future Facility, Process Units, Number Assignments[1]	
Facility	**Process Unit (XXX)**	**Process Area**
Griswold WPF	001 thru 014 Varied	See Table 4.1
Wemlinger WPF	051 thru 069 Varied	See Table 4.2
Binney WPF	020 thru 039	To be assigned during design
PRV Vaults	040 thru 069	To be assigned during design
Tanks & Pump Stations	070 thru 079	To be assigned during design
Other new water facilities	080 thru 499	To be assigned during design
New wastewater & reuse facilities	500 thru 999	To be assigned during design

4.9.3 Special Instrument Description Fields

Instrument symbols for hand switches, signal conditions and converters, and analytical instruments typically utilize descriptor fields that provide additional information about the operation of the device and the control loop in general. This descriptor field is located in the one o'clock position next to the symbol.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Examples of special instrument descriptions include:

1. HOA for hand-off-auto switches.

2. I/P for current to pneumatic signal converter.

3. Cl_2 for chlorine residual analyzers.

4.10 EQUIPMENT TAGGING

All equipment shown on the P&IDs shall include an equipment tag number. Equipment tagging shall be as defined in the Water Department Drafting Standards and CAD Guidelines.

Equipment tags shall be unique and not duplicates of existing equipment tags. The designer shall coordinate with the Site Owner to determine equipment device tags and follow the process number assignments listed in Tables 4.1, Table 4.2 and Table 4.3. The City SCADA group does not decide specific equipment tags.

The equipment loop number shall be identical to the instrument loop number. The device number refers to a sequential number for multiple pieces of equipment in the same loop.

4.11 REPETITIVE OR TYPICAL LOOPS

Repetitive or typical loops are allowed to be represented on the drawings. Clearly identify or note the equipment that is repeated and address any deviations.

4.12 ELECTRICAL INTERLOCKS

Electrical interlock circuitry used at the field level is represented on a P&ID with a rhombus. Electrical control schematics should be provided for all electrical interlocks shown on the P&IDs. Detailed control descriptions should also define these electrical interlocks.

4.13 DIGITAL COMMUNICATION REPRESENTATION

Many process control systems utilize intelligent devices that communicate analog and discrete data to computer control systems using multi-signal digitally encoded methods which include a variety of fieldbus protocols. These intelligent devices include PLCs, valve actuators, instruments, and VFDs. Representation of digitally encoded data should be shown similar to data being collected from I/O modules. Electrical signal lines from the field devices are replaced with data link line symbols. The data link line symbol should also include a three-letter acronym indicating the type of protocol being used.

Often there is an excessive quantity of status points generated by a PLC that are non-critical to process operation and too numerous to show on a P&ID. These PLC generated points can be listed in a spreadsheet form on the drawing, I/O listing, or control narratives.

4.14 TEXT, FONT AND LINE STANDARDS

Text size, font type and line standards used on P&IDs shall be as defined in the Water Department Drafting Standards and CAD Guidelines.

5.0 INSTRUMENTATION CRITERIA

5.1 INTRODUCTION

This section provides design information to be used in the development of specifications for the design and installation of instruments on City of Aurora, Aurora Water projects. Instrumentation includes devices that monitor process variables like level, flow, and pressure. Instrumentation also includes devices that monitor process equipment such as vibration, operational status, and performance. Instrumentation typically measures a variable or a condition and transmits to the control system a real time value or a discrete true/false response.

Instruments can generally provide one of three of three types: digital, or 'smart,' analog, or discrete. Digital instruments provide a data signal to the control system that is usually terminated at the controller. The information transmitted on the digital connection may include measured values, alarms, status, and set-up parameters. Analog instruments provide electrical signals that vary in voltage or current according to the value of the measurement and discrete instruments provides a two-state electrical signal.

Digital instruments are not preferred and must be approved by the City on a per-instrument basis. Instrumentation for the City shall provide electrical interfaces to the SCADA system that meets the criteria below.

The Site Owner that the SCADA team supports may have preferred manufacturers, technologies, or specifications for instruments. These requirements must reviewed with the City Project Manager during design.

5.2 SIGNAL TYPES

The following signal characteristics are to be met for each output type:

1. Analog Signals, Current Type (preferred):
    a. 4 to 20 mA DC signals conforming to ISA S50.1(1).
    b. Unless otherwise indicated for specific SCADA system components, use the following ISA 50.1 options:

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

c. Transmitter Type Number 2, two-wire (preferred).

1) Transmitter Load Resistance Capacity: Class L.

2) Fully isolated transmitter and receivers.

d. Power source 24 volts VDC.

2. Analog Signals, Voltage Type: 1 to 5 Volts DC within panels where a common high precision dropping resistor is used.

3. Discrete signals, two-state logic signals using DC or 120 VAC sources (24 VDC preferred).

4. Pulse Frequency Signals:

a. Direct current pulse whose repetition rate is linearly proportional to process variable.

b. Pulses generated by contact closures or solid state switches (solid state preferred).

c. Power source less than 30 VDC.

5.3 PREFERRED INSTRUMENT TYPE AND MANUFACTURERS

Shown in the tables below are the details for instruments to be applied to various applications. These are instruments upon which the City has standardized. A detailed process for making revisions to the list is included in a later subsection. The Customers that the SCADA team serves may have preferred manufacturers, technologies, or specifications for instruments. The Site Owner must be consulted before any instruments are specified. Unless indicated or directed otherwise, no deviations should be made to this listing.

5.3.1 Level Applications

For measuring the surface level of a liquid, provide an instrument from one of the approved manufacturers as shown in Table 5.1:

Table 5.1 Approved Level Measurement Technologies[1]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous AI, All Applications	Ultrasonic level transmitter	Transmitter and indicator must be remote to the measuring element	Endress+Hauser, Siemens
Continuous AI, Tank Applications	Radar level transmitter	None	Endress+Hauser
Continuous AI, Well Applications	Submersible pressure	None	Endress+Hauser, GE Druck
Discrete, point level, all applications	Float type with integral switch	None	Flygt, Anchor Scientific

5.3.2 Pressure Applications

For pressure measurements, the approved manufacturers are shown in Table 5.2.

Table 5.2 Approved Pressure Measurement Technologies[1]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous, All Applications	Gauge, indication only	None	Ashcroft, WIKA, SOR
Continuous AI, All Applications	Pressure transmitter	Three-valve manifold	Rosemount, Endress+Hauser, GE Druck
Discrete, Single Point	Pressure switch with snap action switch	None	Ashcroft, SOR, Delta

5.3.3 Differential Pressure Applications

For differential pressure measurements, the approved manufacturers are shown in Table 5.3.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Table 5.3 Approved Differential Pressure Measurement Technologies[(1)]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous AI, In-Plant Applications	Differential pressure transmitter	Three-valve manifold	Rosemount, Endress+Hauser
Discrete, Single Point	Differential pressure switch with snap action switch	Three-valve manifold	SOR, Delta

5.3.4 Flow Applications

For flow measurements, the approved manufacturers are shown in Table 5.4.

Table 5.4 Approved Flow Measurement Technologies[(1)]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous AI, In-plant Applications	Electromagnetic flow transmitter and indicator	Remote indication	Endress+Hauser, Rosemount
Continuous AI, In-Plant Applications	Venturi	None	Primary Flow Signal, Badger
Continuous AI, Distribution System	Vortex	Remote Indication	Fluid Dyne
Continuous AI, Reuse Open Channel Applications	Ultrasonic level and velocity measurement with flow calculations	Remote indication	Marsh McBirney
Continuous AI, Raw Water Pipelines Transmitter/Calculator	Orifice plate with differential pressure	None	Wyatt Engineering, ABB, Meriam
Continuous AI, 4-inch Raw Water Pipelines	Propeller, insert with electronic pickup	None	Badger
Continuous AI, Sludge and Reuse Flumes	Ultrasonic level and velocity measurement with flow calculation	Remote indication	Siemens, Endress+Hauser
Continuous, air flow transmitter remote to Sensing unit	Thermal dispersion	Indication and	Sierra, Kurz

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

5.3.5 Analytical Applications

Table 5.5 Approved Analytical Measurement Technologies[1]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous AI, raw water and laboratory	Electrode style pH probe and transmitter	None	Foxboro
Continuous AI, all applications	Sodium Hydroxide/Hypochlorite analyzer and transmitter	None	ATI
Continuous AI, treatment plant raw water	Turbidity element and transmitter (>10 NTU)	None	Hach (Surface Scatter 7)
Continuous AI, filtered and reuse water	Turbidity element and transmitter (=<10 NTU)		Hach (TU5300)
Continuous AI, high range	Turbidity element and transmitter	None	Hach
Continuous AI, all applications	Residual chlorine analyzer and transmitter	None	Hach (CL 17)
Continuous AI, raw water	Streaming current element and transmitter	None	Chemtrac
Continuous AI, Scrubber Stack Applications	Chlorine Gas leak detector Analyzer	Remote Sensing from transmitter and Indicator	ATI (A14 type)
Continuous AI, Storage Area Applications	Chlorine Gas leak detector Analyzer	Remote Sensing from transmitter and Indicator	ATI (A14 type)
Continuous AI, Storage Area Applications	Chlorine Dioxide Gas leak detector Analyzer	Remote Sensing from transmitter and Indicator	ATI (A14 type)
Continuous AI, Storage Area Applications	Ammonia Gas leak detector Analyzer	Remote Sensing from transmitter and Indicator	ATI (A14 type)
Continuous AI, Storage Area Applications	Hydrogen Peroxide Gas leak detector Analyzer	Indication and from transmitter and Indicator	ATI (A14 type)

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Table 5.5 Approved Analytical Measurement Technologies[1]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous AI, Lift Station Wet/Dry Well	Carbon Dioxide gas IR element Analyzer	Indication and transmitter remote to and Indicator	MSA
Continuous AI, Lift Station Wet/Dry Well	Combustible gas (Methane) Analyzer	Remote Sensing Pumped to Sensor and Transmitter	MSA (Tri-Gas type)
Continuous AI, Lift Station Wet/Dry Well	Oxygen Gas Analyzer	Remote Sensing Pumped to Sensor and Transmitter	MSA (Tri-Gas type)
Continuous AI, Lift Station Wet/Dry Well	Hydrogen sulfide Analyzer	Remote Sensing Pumped to Sensor and Transmitter	MSA (Tri-Gas type)

5.3.6 Other Applications

For applications not covered in the subsections above, additional applications and approved manufacturers are shown in Table 5.6.

Table 5.6 Other Approved Measurement Technologies[1]			
Type of Measurements	**Technology**	**Required Accessories**	**Approved Manufacturers**
Continuous, all in-line and mobile applications	Suspended solids meter and transmitter	None	Hach
Continuous, panels and enclosures	Resistance type temperature element transmitter	DIN rail mountable	Dwyer

To the extent possible, instruments used for similar types of functions and services shall be of the same brand and model line. Similar components of different instruments shall be the products of the same manufacturer to facilitate maintenance and stocking of repair parts. Whenever possible, identical units shall be furnished.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

5.4 SUBSTITUTION OF ACCEPTABLE INSTRUMENTS

Instrument manufacturer preferences detailed in the previous section are based upon matching existing installed equipment and favorable experience with the installed units. If a consultant wishes to recommend an alternate unit, they should submit the form in §5.10 to the City's project manager 90 days prior to completing the design package. Suppliers and manufacturers wishing to submit requests for changes to the listings should submit the form to the appropriate City instrumentation staff. Contractors wishing to submit substitutions or alternates should submit a request for substitution as governed by the contract documents for the particular project. Acceptance of substitutions is contingent upon approval by the appropriate instrumentation staff within City operations.

When submitting the change request, specifications and product literature for the unit being submitted should accompany the form. The City employee receiving the form will present the request to the appropriate City personnel and an “Approved” or “Not Approved” determination will be made and returned within ten business days of submitting the form. If a “Not Approved” determination is made, the reason for that determination will be provided on the form. If an “Approved” determination is made, this section of the DEG will be updated to reflect the addition and redistributed to each consultant doing work for the City.

5.5 INSTRUMENT TAGGING AND TAG NAMING CONVENTION

All instrumentation should be specified to be provided with identifying stamped tags as follows:

Nametags: Component identification for field devices.

1. Inscription: Component tag number and calibrated range.
2. Materials: 16 gauge, Type 304 stainless steel.
3. Letters: 3/16-inch imposed.
4. Mounting: Affix to component with 16 or 18 gauge stainless steel wire or stainless steel screws.

Instrument tag naming conventions are detailed in Section 4-Process and Instrumentation Diagram Guidelines.

5.6 INSTRUMENT MOUNTING

Specifications and details shall include instrument mounting requirements that comply with the instrument manufacturer’s recommendations.

1. Instruments that require a static line connection to the process shall be provided with a stainless steel, isolation shut-off ball valve, a stainless steel tee, and plug.

2. All instruments should be provided with a mounted saddle pipe that should preferably be supported from a wall rather than the floor. Where a wall is not in close proximity, the mounting pipe may be anchored to the floor. Mounting pipes should be galvanized steel and shall be painted after installation.

3. Instruments mounted outdoors shall be provided with a sun shade.

4. Instrument transmitters shall be installed in a ventilated enclosure unless not required per the manufacturer.

5.7 SENSOR MATERIAL PREFERENCES

For instruments requiring a direct process connection to process, Table 5.7 shows the City's preferences for the materials that are in direct contact with the process.

Table 5.7 Approved Transmitter Materials(1)

Process Stream	Approved Materials
Alum	316 stainless steel
Aqua and Gaseous Ammonia	Hastelloy C
Carbon	Hastelloy C
Chlorine gas or Sodium Hypochlorite	Tantalum
Ferric Chloride	Tantalum or TFE & FEP
Fluoride (Hydrofluoric Acid)	Hastelloy C
Lime	316 stainless steel
Ozone	316 stainless steel
Polymer	316 stainless steel
Potassium Permanganate	316 stainless steel
Raw and finished water	316 stainless steel
Settled and filtered water	316 stainless steel
Sewage, Raw	316 stainless steel
Sodium Hydroxide	316 stainless steel
Storm water	316 stainless steel

5.8 INSTRUMENT FIELD WIRING

For connection to instruments with a 4 to 20 milliamp output:

1. Cable shall be shielded, twisted-pair.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

2. Each conductor for the instrument’s current output should be minimally sized 16 AWG.

3. Except where required by the instrument, wiring shields should be grounded at the point of termination inside the PLC cabinet or at the power source, rather than at the instrument itself. Shield grounds must only be grounded at one end.

For connection to instruments that use an RS-485 digital network:

1. Conductor size should minimally be 18 AWG.

2. For instruments requiring a DC power connection in addition to the communication network, the DC power connection should minimally use 14 AWG conductors. Actual size should be determined after performing a voltage drop calculation.

Instrument Ethernet communications shall use CAT-6A(1) cabling.

Instruments that are located outdoors or in an outdoor enclosure should be provided with surge protection on instrument wiring. The surge arresters should be installed at both the instrument and at the point of termination such as in the control panel. Surge arresters should be compatible with the digital communication protocol employed by the instrument. Outdoor cables must be include an outdoor rating, like OSP or CMR/CMX-Outdoor.

Instrument power should come from the SCADA or control panel rather than from a lighting panel and each instrument should be provided with an individual breaker in the panel. Instrument power shall be run in conduit separate from the signal wire conduit.

No splices are permitted for analog circuits. Cables must be directly connected from source to destination or landed on terminal blocks within a junction box.

5.9 ELECTRICAL TRANSIENT PROTECTION

1. General:

    a. Function: Protect elements of SCADA system against damage due to electrical transients in interconnecting lines induced by lightning or nearby electrical systems.

    b. Surge suppressers are not shown for external analog transmitters. Determine quantity and location and show in shop drawings. Refer to example wiring in installation details in drawings.

    c. Implementation: Provide, install, coordinate, and inspect grounding of surge suppressors at:

        1) Connection of AC power to SCADA system equipment including panels, consoles, assemblies and field mounted analog transmitters and receivers.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

2) At the field and panel, console, or assembly connection of signal circuits that have portions of the circuit extending outside of a protective building.

3) Sites with radio communications. The City uses Polyphaser lightning surge suppressors[1].

d. Construction: First-stage high energy metal oxide varistor and second-stage bipolar silicon avalanche device separated by series impedance. Includes grounding wire, stud or terminal.

e. Response: 5 nanoseconds maximum.

f. Recovery: Automatic.

g. Temperature Range: -20 ºC to 85 ºC.

2. Suppressors on 120 VAC Power supply connections:

a. Occurrences: Tested and rated for a minimum of 50 occurrences of IEEE 587 Category B test waveform.

b. First-Stage Clamping Voltage: 350 volts or less.

c. Second-Stage Clamping Voltage: 210 volts or less.

d. Continuous Operation: Power supplies for one four-wire transmitter or receiver: 5 amps minimum at 130 VAC. All other applications: 30 amps minimum at 130 VAC.

3. Suppressors on Analog Signal Lines:

a. Test Waveform: Linear 8 microsecond in current form 0 amps to a peak current value followed by an exponential decay of current reaching one-half the peak value in 20 microseconds.

b. Surge Rating: Tested and rated for 50 occurrences of 2,000 amp peak test waveform.

1) DC Clamping Voltage: 20 to 40 percent above operating voltage for circuit.

2) DC Clamping Voltage Tolerance: Less than plus or minus 10 percent.

3) Maximum Loop Resistance: 18 ohms per conductor.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

4. Physical Characteristics:
    a. Mounted in Enclosures: Encapsulated inflame retardant epoxy.
    b. For Analog Signal Lines: EDCO PC 642 or SRA 64 series[(1)].
    c. For 120 VAC Lines: EDCO HSP 121[(1)].
    d. Field Mounted at Two-Wire Instruments: Encapsulated in stainless steel pipe nipples. EDCO SS64 series[(1)].
    e. Field Mounted at Four-Wire Instruments: With 120 VAC outlet, AC circuit breaker and 10 ohm resistors on signal lines, all in enclosure.
        1) Enclosure:
           NEMA 4X fiberglass or Type 316 stainless steel with door.
           Maximum Size: 12 inches by 12 inches by 8 inches deep.
        2) Manufacturer and Product: EDCO SLAC series[(1)].
5. Analog Signal Isolators: Furnish signal isolation for analog signals that are sent from one enclosure to another and one structure to another.

5.10 INSTRUMENTATION SUBSTITUTION REQUEST FORM

CITY OF AURORA, AURORA WATER INSTRUMENTATION SUBSTITUTION REQUEST FORM			
Project Identification			
Project Title		Project ID Number	
Project Manager			
Submitting Firm			
Firm Name		Submittal Date	
Firm Address			
Project Manager			
Phone Number			
Application			
o Level	o Pressure	o Differential Pressure	o Flow
o Analytical	o Power Monitoring	o Other	
Proposed Alternate			
Manufacturer			
Model			
(Attach specification and product literature to this form)			
Justification			
o Technology Change	o Model Change	o Availability	
o Unique Application Requirement			
o Other			
Aurora Water Response			
o Approved			
o Not Approved (*reason*)			
Signature		Date	
Print Name		Title	

6.0 INPUT & OUTPUT CRITERIA

6.1 INTRODUCTION

Signals from process equipment, instruments, devices and other monitoring, measurement and controlling components are terminated to specialty equipment that enables the information to be viewed and manipulated through the SCADA system. When these signals provide status, measurement, or alarm information, they are termed Inputs. Signals from the SCADA system to actuators, starters, or other controllable devices are termed Outputs. Both inputs and outputs can interface to the SCADA system as traditional electrical signals or as a data stream. This section provides the requirements for signal characteristics and describes the standard equipment for interfacing with I/O.

The state a controlled device reverts to upon loss of the control signal must be specified by the designer. This failed or unpowered state is determined during the design phase and shall be independent of the SCADA system. Typical equipment affected includes modulating control valves and gates, pumps and chemical feed equipment. Regardless of how equipment is monitored and controlled through the SCADA system, the designer shall recommend the failsafe state, for instance open vs. closed for valves or running vs. shut down for pumps,to which the device shall revert.

6.2 SMART DEVICES AND DIGITAL INTERFACES

Many types of equipment, instrumentation and other controllable devices are optionally available with digital interfaces in place of the more traditional analog I/O interfaces. It is the City's current policy that all new equipment, instruments, and devices be interfaced to the SCADA system using only hardwired analog signals unless explicitly stated otherwise.

6.3 STANDARD SIGNAL LEVELS

The electrical characteristics of hardwired input signals varying from 120 VAC to 5 VDC. Output signals can likewise vary. The paragraphs below establish the standards for hardwired I/O to be used on all new field equipment to be interfaced to the SCADA system.

6.3.1 Discrete Inputs

As the name implies, discrete input signals vary between two states. The signal can therefore only convey information about a two state condition such as on/off, opened/closed, or alarm/no alarm. Discrete inputs are usually wired to the control system through a relay in the monitored device. In the monitored device, a dry contact is either closed to make or opened to break the circuit. The existence or lack of a circuit is monitored by the I/O equipment and interpreted as one state or another. The relay in the monitored device should be completely isolated from the control power for the equipment, thus the designation “dry contact.”

The power for the circuit is to originate from the cabinet that encloses the I/O equipment. The applied voltage or whetting voltage for all City of Aurora projects shall be 24 VDC. All digital input cards are to be individually isolated.

An exception to utilizing 120 VAC, such as where the signal must traverse a long distance, will be considered for specific applications. Interposing relays shall be used for 120 VAC applications.

6.3.2 PLC Discrete Outputs

Discrete output signals are similar to the discrete input signals in that they are either one state or another. The difference is that the output signal is used to control equipment as opposed to strictly monitoring the equipment.

Several types of discrete output signals and systems are available. All outputs should be designed as 24 VDC. The 24 VDC output signal should be connected to an interposing relay rated to accept the 24 VDC output. The output of the interposing relay will then be a dry contact"in the connected equipment control circuitry. The relay should be rated for the whetting voltage used by the controlled equipment. All digital output cards are to be individually isolated.

6.3.3 Analog Inputs and Outputs

Analog signals differ from discrete signals in that their current continuously varies over a predefined range of values. Through scaling in the PLC, they represent real time values. As inputs, analog signals are measured quantities and as outputs, they are typically used for indication or control. Analog input and output signals shall be 4 to 20 milliamps. Analog I/O modules shall have individually isolated channels.

6.3.4 Other Signal Types

To the maximum extent possible, all I/O signals should be of the type stated above. Use of pulse type signals should be approved by approved COA SCADA prior to developing design specifications.

6.4 HARD-WIRED I/O REQUIREMENTS FOR CONTROL OF EQUIPMENT

The paragraphs below detail the I/O that shall be provided for all equipment that requires a hard-wired connection for control.

6.4.1 Open/Close Valves and Gates

Open/close valves and gates can only be either fully opened or fully closed. The actuators for these appurtenances shall be specified to accept only momentary signals for control. It will be required that the actuator be provided with the necessary seal-in relay logic to drive the valve or gate to the fully open or fully closed position. Table 6.1 shows the minimum I/O that shall be provided for these types of valves and gates.

Note that the actuator should also provide local controls that allow for calibration and local control of the valve or gate. Typically for Open/Close appurtenances this includes a Hand-Off-Auto selector switch and an Open/Stop/Close pushbutton station with indicating lights that show when the valve/gate is fully opened, fully closed, and in travel (both lights off).

Table 6.1 Open/Close Valve and Gate Required I/O

Signal Type	**Description**
Discrete Input	HOA selector switch in "Auto"
Discrete Input	Valve Fully Opened position (limit switch contact closed at end of full open travel)
Discrete Input	Valve Fully Closed position (limit switch contact closed at end of full close travel)
Discrete Output-Momentary	Valve Open command
Discrete Output-Momentary	Valve Close command

6.4.2 Modulating Valves and Gates

Modulating valves and gates are those that permit positioning at an intermediate position in addition to fully open and fully closed. Modulating valves and gates can be controlled using discrete outputs or an analog output. If using discrete outputs, the actuator must accept momentary open, close, and stop commands for operations. The actuator must be provided with the necessary seal-in relay logic to hold the open and close signals. The stop command will break the seal-in relay, which resets the latching circuit. Actuators that are controlled using analog outputs can accept a 4 to 20 mA signal to position the valve. Actuators for this type of service contain a “comparator” board that can accept the analog signal and position the valve accordingly.

Table 6.2	Modulating Valve and Gate Required I/O - Discrete Controlled
Type of Signal	**Signal Description**
Discrete Input	HOA selector switch in "Auto"
Discrete Input	Valve Fully Opened position (limit switch contact closed at end of full open travel)
Discrete Input	Valve Fully Closed position (limit switch contact closed at end of full close travel)
Analog Input	Valve position indication
Discrete Output-Momentary	Valve Open command
Discrete Output-Momentary	Valve Stop command
Discrete Output-Momentary	Valve Close command

For modulating valves and gates that are controlled remotely, such as in field SCADA sites, the City requires control using analog outputs only. Modulating valves and gates that are directly connected to the process control system, such as in the reuse facilities and the water treatment plants, can be either type. Table 6.2 and Table 6.3 shows the minimum I/O that shall be provided for modulating valves and gates.

Note that the actuator should also provide local controls that allow for calibration, and local control of the valve or gate. Typically for modulating appurtenances, this will include a Hand-Off-Auto selector switch and an Open/Stop/Close pushbutton station or an adjustable potentiometer for positioning. Local indication can be supplemented with indicating lights that show when the valve/gate is fully opened, fully closed and in travel where both lights are off).

Table 6.3	Modulating Valve and Gate Required I/O - Analog Controlled
Type of Signal	**Signal Description**
Discrete Input	HOA selector switch in "Auto"
Discrete Input	Valve Fully Opened position (limit switch contact closed at end of full open travel)
Discrete Input	Valve Fully Closed position (limit switch contact closed at end of full close travel)
Analog Input	Valve position indication
Analog Output	Valve position control

6.4.3 On/Off Motors and Equipment

Pump motors and other equipment typically operate at one speed and provide On/Off operational status and control. Table 6.4 shows minimum I/O that shall be provided for On/Off pump motors and equipment. Similar to the outputs for valves and gates, the pump motors and equipment must be provided with the necessary seal-in relay logic to accept momentary discrete outputs for control.

Table 6.4 On/Off Pump Motors and Equipment Required I/O

Type of Signal	Signal Description
Discrete Input	HOA selector switch in "Auto"
Discrete Input	Running status
Discrete Input-Momentary	Start command (with latching done at the starter
Discrete Output-Momentary	Stop command

Depending on the application and type of motor, additional discrete alarm inputs may be available, for example high vibration or high temperature alarms. The design consultant shall meet with City staff to review all optional and standard I/O provided with the motor.

6.4.4 Adjustable Motors and Drives

Pump motors and other equipment provided with adjustable speed controllers or variable speed drives shall require additional I/O to monitor and control the equipment. In addition to the minimum required I/O listed in Table 6.4, Table 6.5 shows the minimum I/O that shall be provided for variable frequency drives.

Table 6.5 Adjustable Motors and Drives Required I/O

Type of Signal	Signal Description
Discrete Input	LOR Selector switch in “Remote”
Analog Output	Equipment speed control
Analog Input	Equipment speed feedback

Depending on the application and type of adjustable motor and drive, additional discrete alarm inputs may be available. The design consultant shall meet with staff to review all standard and optional I/O provided with the equipment.

6.5 I/O FOR EQUIPMENT WITH PLC-BASED CONTROLLER

Packaged process equipment may be provided with embedded automation that controls the operation of the various components of the package. The controller make and model must be specified to comply with the City standards and is to be connected to the SCADA system as discussed in Section 7 - Programmable Logic Controller Guidelines.

6.6 STANDARD I/O LIST FORMAT

Every project that includes equipment that is monitored and/or controlled through the SCADA system is to provide a list of hard-wired I/O. The I/O list must include the fields shown in Table 6.6:

Table 6.6 I/O List Required Fields

Column Heading	Description
Panel/PLC ID	Identification for the I/O cabinet or controller where the I/O signal terminates.
I/O Tagname	Database identification for the I/O point.
Type	Type of I/O signal, including AI (analog input), AO (analog output), DI (discrete input), DO (discrete output), PI (pulse input for totalization only).
Description	Description of the function of the I/O signal.
Field Device Tagname	Tag number of the instrument or equipment device associated with the I/O point.
Analog Data	4-20 mA for all analog signals (individually isolated).
Analog Data	Scaled value in engineering units.
Analog Data	2-wire (loop powered, 24VDC)) or 4-wire (120 VAC powered from the I/O cabinet).
Discrete Data Signal	24 VDC for all discrete signals.
Discrete Data Closed	Indicates the state of the signal when the I/O point is energized
Discrete Data Power Source	Location of the power source for the whetting voltage. This should be the I/O cabinet for most signals. Where an externally powered signal is the only available source of indication, an interposing relay should be provided to isolate the power sources.
Discrete Data Interposing	“Yes” for all discrete outputs.
Comments/Notes	This column may contain cross-reference to specification sections, designation of changes to existing I/O or other notes as required to clarify the origin or purpose of the I/O point.

7.0 PROGRAMMABLE LOGIC CONTROLLER GUIDELINES

7.1 INTRODUCTION

This chapter of the Design Engineering Guidelines summarizes programmable logic controller design and programming guidelines. The designer shall provide a 50 percent review document to the Aurora Water Department SCADA staff that outlines their understanding of the standards and their adherence to these guidelines.

7.2 ACCEPTABLE MANUFACTURERS

Aurora Water has standardized on one PLC manufacturer. PLCs connected within the Aurora Water SCADA system shall be Allen-Bradley ControlLogix programmable controllers(1). No other manufacturer or equals shall be considered. Other controllers embedded or included in a pre-packaged system must also be Allen-Bradley and strictly follow the City of Aurora programming standards.

7.3 PLC NETWORK CONNECTIONS

Wherever PLCs are used for equipment or process control, they shall be connected to the plant control system or, at remote sites, the SCADA system. The preferred method of providing this connection is through a TCP/IP Ethernet connection. Where connections are made within the same building and in an environmentally-controlled structure, the connection can be made using CAT-6A cabling, unshielded twisted pair, or approved alternative. Where strong electromagnetic interference exists, for example in a networked MCC or VFD, provide shielded twisted pair (STP) cables. Connections over 300 feet and all other connections on the premises shall use fiber optic cabling and transceivers unless otherwise approved by the Aurora Water SCADA group.

7.4 NETWORK REDUNDANCY

The media for communicating to the PLCs and/or to remote I/O shall be redundant. Spare fibers shall be included in fiber optic cabling. Minimally, the number of spare fibers shall equal the number of used fibers up to a twelve-fiber cable. Beyond that, the number of spare fibers shall minimally be half the number of used fibers. One-line diagrams and cable schedules shall detail the number of spare fibers at the time of installation. Where STP or UTP cabling is used, spare media shall be provided.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

7.5 CONTROLLER RACK ARRANGEMENT

Analog I/O modules must be segregated from discrete I/O to the maximum extent possible. On singular rack, the discrete input and output modules shall be placed on the left-most slots immediately to the right of the processor and network communications modules. The analog input and output modules shall occupy the rightmost slots. Where multiple racks are required, discrete input and output modules shall occupy the top or left rack and the analog input and output modules shall occupy the right or bottom rack.

A minimum of two spare slots or 20 percent of total I/O slots, whichever is greater, shall be provided between the digital modules and the analog modules to allow expansion of the digital I/O. Each I/O rack shall minimally contain four spare slots or 20 percent spare slots, whichever is greater.

Spare processors may be required and should be discussed on a project by project basis with City staff.

Modules required to communicate to device-level networks (HART, Fieldbus, etc.) shall be contained in the same area as the analog cards.

7.6 INPUT & OUTPUT REQUIREMENTS

I/O preferences are covered in more detail in Section 6.0 - INPUT & OUTPUT CRITERIA. Digital outputs shall be provided with an interposing relay. Analog inputs and outputs shall be 4-20 milliamps. All modules shall have individually isolated channels. All hardwired I/O shall use cable-fast systems. The cable-fast system shall consist of prefabricated PLC terminal adapter, a multi-conductor cable of appropriate current rating, and terminals. The multi-conductor cabling shall have prefabricated plugs on each end as the sole means of termination.

7.7 INPUT AND OUTPUT MODULE DENSITIES

Density requirements stated here are minimums. Higher density cards are acceptable to obtain the number of spare channels required. SCADA staff must approve the use of cards not normally used by the City to avoid excessive spare maintenance quantities.

- Discrete input modules must have a minimum density of 16 channels.
- Discrete output modules must have a minimum density of channels points.
- Analog input modules must have a minimum density of 6 channels.
- Analog output modules must have a minimum density of 4 channels.

7.8 PROGRAMMING

The following sections provide minimum requirements for programming and documenting programs to be executed in PLCs. The City of Aurora requires both the architecture and programming languages be strictly followed for both developed and Vendor-provided programs included with pre-packaged process equipment.

Prior to initiating PLC programming, the PLC programmer shall schedule and hold a programming workshop with the City of Aurora to go over the specifics of these requirements. These workshops should take at least one half day, depending on the size or complexity of the project. All programming parties, regardless of past projects or experience with the City, are required to participate in this workshop. Following this required workshop, each programmer shall present a programming guideline to provide detail on how the program and logic for the specific project will be developed and organized. Standards contained herein shall apply to both new PLC installations and modifications to existing PLCs.

Programming shall be done in Function Block format unless otherwise approved by the Aurora Water SCADA staff. No indirect, indexed addressing nor non-City sanctioned programming shall be used.

The Contractor shall furnish the hardware and software necessary to program any PLCs. The City does not provide programming computers, software, or licenses. Contractor computer connections to the City network are prohibited. See Section 3.6 - REMOTE SITE CONTROLLERS for access procedures.

7.8.1 Programming Organization/Architecture

The main project task shall include several programs to easily identify different sections of the code. Furthermore, each program will include routes specific to equipment, process, communication, or system information exchange.

The following subsections provide a general example of organization but are not all inclusive. During the programming workshop, details regarding the organization of specific projects will be discussed. For a general project, the PLC may have the following programs under the main task:

7.8.1.1 "IO_Mapping" Program

Each routine in this program references the Rack & Slot number in its name for all PLC modules. Each physical input or output is moved to or from its respective database tag.

7.8.1.2 "Comm" Program

Each routine in this program references the target device in its name for all external communications. The database tags are moved data arrays for radio communications or Message block routines will be communicating from PLC to PLC.

7.8.1.3 “PLC_Monitoring” Program

Each routine in this program monitors the PLC status and faults. The system status and faults are moved to communication arrays for SCADA monitoring.

7.8.1.4 “ATS” Program (for remote sites with a generator)

Each routine in this program monitors the ATS status and faults.

7.8.1.5 “Generator” Program (for remote sites with a generator)

Each routine in this program monitors the Generator status and faults.

7.8.1.6 “Power_Monitoring” Program

Each routine in this program monitors the Power Monitors and VFDs. Power status, totalizers, and faults are handled.

7.8.1.7 “UPS” Program

Each routine in this program monitors the Intellipower Uninterruptible Power Supplies for status, and faults.

7.8.1.8 “Gas_Detector” Program (for remote sites with a detectors)

Each routine in this program references the gas detector location in its name for all hazardous gas detectors. The routine will scale the raw analog signal and any alarm handling.

7.8.1.9 “Security” Program

Each routine in this program monitors the intrusion and motion detection of the security system.

7.8.1.10 “Clock_Logic” Program

This program will be dedicated for monitoring the PLC clock and adjusting it from the OIT/HMI.

7.8.1.11 “Fire_Panel” Program

This program will be dedicated for monitoring the fire alarm panel common alarm.

7.8.1.12 “Exhaust_Fans” Program

Each routine in the program is named after the P&ID tag name and dedicated for monitoring makeup air units, supply fans and exhaust fans.

7.8.1.13 “Pump_Control” Program

Each routine in this program monitors and controls VFD pumps.

7.8.1.14 “Analog_Loops” Task

Each program is named after the Instrument type that uses an analog input, such as flow, pressure, level, vibration, and temperature. Each routine in the program is named after the P&ID tag name.

7.8.1.15 “Switch_Logic” Program

This program will be dedicated for monitoring and alarming digital switches.

7.8.2 Acceptable Programming Languages

Programming shall be done in Function Block format[1] unless otherwise approved by the Water Department SCADA staff. No indirect, indexed addressing or non-City of Aurora Standard programming shall be used. The City may, for specific instructions, use different programming styles. The programmer shall attend a programming meeting with City SCADA staff to review program language requirements specific to the project.

7.8.3 Tag Naming Convention

Aurora Water SCADA group has developed a standard for tag name structure that is used to label data objects, both source data and calculated data, in the PLC and in the HMI program databases. The intent of the naming structure is to use consistent references and identifiers to minimize confusion in referencing common data between the two groups of programs.

The tag name structure sets the model for all SCADA tag names for the City of Aurora Water Support Services Division. The required standard structure utilizes numbers and letters to provide recognizable descriptor fields. The tag name will consist of 4 fields and no more than 30 characters as shown below:

Node Process Equipment Tag Name_Modifier: The fields above are described below.

- Node: The field is an abbreviation for an entire facility or site; at Everist Reservoir Site Improvements SCADA the node will be Everist with an abbreviation “EV”
- Process: The field is an abbreviation for the actual process or building; at Everist Reservoir Site Improvements SCADA the process will be a pump station with an abbreviation “PS”

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

- Equipment Tag Name: This field utilizes ISA standards for tag number identification of instruments. Similarly process equipment will use an abbreviation for the type of equipment preceding the equipment number. The tag name is made up of 5 fields as follows:

AAAA-831BB-CCD

Where:

AAAA: Instrument or equipment abbreviation per ISA standards and defined equipment abbreviations as shown on P&ID's

831: Facility unit process number, three digits per P&ID

BB: Loop Number, two digits per P&ID

CC: Unit number, two digit consecutive no. for multiple components with the same unit process and loop number per P&ID. Where there is only one component this field is left blank.

D: Set letter, used where there are multiple components within a unit process and loop with the same unit number per the P&ID

- Modifier: The modifier field identifies the PLC, HMI or OIT action for the point. These tags are generated by the PLC program development routines and further modified by the HMI or OIT as necessary for unique identification.

Table 7.1 below includes common field abbreviations for instruments per ISA standards.

Table 7.1 Instruments ISA Abbreviations

Abbreviation	**Description**	**Note**
AIT	Analysis Indicating Transmitter	
FIT	Flow Indicating Transmitter	
FC	Flow Controller	
FCV	Flow Control Valve	(Modulating)
FSL	Flow Switch Low	
FV	Flow Valve	(OPEN/CLOSE)
HS	Hand Switch	
LIT	Level Indicating Transmitter	
LSH	Level Switch High	
LSHH	Level Switch High-High	
LSL	Level Switch Low	

Table 7.1	Instruments ISA Abbreviations	
Abbreviation	**Description**	**Note**
LSLL	Level Switch Low-Low	
PSH	Pressure Switch High	
TIT	Temperature Indicating Transmitter	
UC	Undefined Controller	Use P&ID modifier to uniquely define
XS	Undefined Switch	Use P&ID modifier to uniquely define
YC	Event Controller	
YL	Event Light	
YS	Event Switch	
ZC	Position Controller	Use P&ID modifier to uniquely define

Table 7.2 below includes common field abbreviations for:

Table 7.2	Equipment
Abbreviation	**Description**
M	Mechanical Process Equipment
P	Pump
T	Tank
PLC	Programmable Logic Controller
RIO	Remote I/O
MOV	Gates and Valves
EF	Exhaust Fan
MUA	Air Supply Fan

Table 7.3 includes common modifier abbreviations to identify PLC, HMI, or OIT action for tag point.

Table 7.3 Modifier	
Abbreviation	**Description**
ALMCKT	Analog Channel Alarm For Circuit Failure
ALMCLSFAIL	Alarm For A Valve Failed To Close
ALMFAIL	Alarm For A Fail Condition
ALMHIGH	Alarm For A High Condition
ALMHIHI	Alarm For A High-High Condition
ALMINTR	Alarm For Intrusion
ALMLOLO	Alarm For A Low-Low Condition
ALMLOW	Alarm For A Low Condition
ALMOPNFAIL	Alarm For A Valve Failed To Open
ALMPWRFAIL	Alarm For A Power Fail Condition
ALMRUNFAIL	Alarm For Equipment Failed
ALMSPN	Analog Channel Alarm For Out Off Span condition
HMICMDAUTO	Operator Input From The HMI For Auto Command
HMICMDCLS	Operator Input From The HMI For Close Command
HMICMDMAN	Operator Input From The HMI For Manual Command
HMICMDOPN	Operator Input From The HMI For Open Command
HMICMDSTOP	Operator Input From The HMI For Stop Command
HMICMDSTRT	Operator Input From The HMI For Start Command
HMISP	Operator Input From The HMI For a Set point
HMISPHIGH	Operator Input From The HMI For a High Set point
HMISPHIHI	Operator Input From The HMI For a High-High Set point
HMISPLOLO	Operator Input From The HMI For a Low-Low Set point
HMISPLOW	Operator Input From The HMI For a Low Set point
HMISPPOS	Operator Input From The HMI For A Valve Position Set Point
HMISPSPD	Operator Input From The HMI For A Equipment Speed Set Point
INDPOS	Indication of the Valve Position
INDPV	Indication of the Process Variable
INDSP	Indication of the Set Point
INDSPD	Indication of the Equipment Speed
SPCLSD	Valve Closed Set Point
SPOPND	Valve Opened Set Point
SPSTOP	Stop Set Point

Table 7.3 Modifier	
Abbreviation	**Description**
SPSTRT	Start Set Point
STSAUTO	Status for Auto Condition
STSCLSD	Status for Valve Closed Condition
STSHSAUTO	Status for Remote Hand Switch Auto Condition
STSMAN	Status for Manual Condition
STSON	Status for Equipment On Condition
STSOPND	Status for Valve Opened Condition
STSHSRMT	Status for Remote Hand Switch Remote Condition
TZRTDAY	Totalized Value for “Today”
TZRYDAY	Totalized Value for “Yesterday”

7.8.4 Function Blocks

Specific Function Block templates will be provided as required on a project by project basis during SCADA programming workshops. Any function blocks developed by Contractors are to be provided to the City as part of a programming library at the completion of all projects.

7.8.5 User-Defined Data Types (UDT)

User-defined data types create customized memory records that consolidate multiple fields of data into a contiguous group with a hierarchal layout. Aurora Water SCADA team has built a library of UDT for use inside their existing PLC programs that selected Vendors and Contractors shall utilize where appropriate. A sample list of the UDTs available for use is summarized in Table 7.4.

Table 7.4 User-Defined Data Types (UDT)	
UDT	**Description**
AIT01UDT	Data structure for analyzers
AlarmDiscrete	Used for discrete alarms
ASD02UDT	Data structure for variable speed drives
COM01UDT	Used for message communication information
CycleCountUDT	Used for Cycle Counter Subroutines
UDT	**Data Structure Description**
ElapsedTimeUDT	Elapsed Timer and Cycle Counter
FaultRecord	Minor PLC Fault
FIT02UDT	Flow meters

Table 7.4 User-Defined Data Types (UDT)	
UDT	**Description**
FV01UDT	Open/Close valves
GEN00UDT	Generators
LIT03UDT	Level transmitters
MTR01UDT	Constant speed motors
P2P01UDT	Peer-To-Peer communication data
PIT01UDT	Data structure for pressure transmitters
PLC03UDT	PLC Diagnostics data
PowerCommUDT	Power monitors communication
PowerMonUDT	Data structure for power monitors information
RTC04UDT	Data structure for real time clock
STS00UDT	Data structure for status of equipment
TIT00UDT	Data structure for temperature transmitters
TotalizeUDT	Used for flow totalization
XSX00UDT	Process switches
XVY00UDT	Vibration transmitters

7.8.6 Add-On Instructions (AOI)

Add-On Instructions for Allen-Bradley RSLogix 5000 software(1) allows PLC users to easily implement control logic that supports complicated functionality. Aurora Water SCADA programming team has built a library of AOIs supporting many of its popular control functions. Vendors and integrators will select the appropriate AOI from a menu displayed in the RSLogix 5000 application and insert it directly into the code.

A sample list of the AOI instructions available for use is summarized in Table 7.5.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

Table 7.5 Add-On Instructions (AOI)	
AOI	**Description**
ALMAIAOI	Generate High/Low alarms from an analog reading with a dead-band
ALMTMRAOI	Generate an alarm with on/off time delay
AUTOMANAOI	Determine Auto/Manual Status of equipment
CLRHMICMDAOI	Clear HMI Commands
AOIDeviceMonitoring	Monitors the runtime and number of starts of equipment
CYCLESAOI	Monitors cycles and reset cycle count
DEGFDEGCAOI	Converts Degrees Fahrenheit to Degrees Celsius
MOVEBOOLAOI	Move Digital Bit
MTRCTRLAOI	Constant Speed Pump Control
PUMPINTERLOCKAOI	Generate Pump Interlock
READYAOI	Generate Pump Ready Status
RUNFAILAOI	Generate Fail to Run Alarm
RUNTIMEAOI	Calculate Equipment Runtime
SPLIMITAOI	Limits set points between high and low values with a cutoff value
STOPFAILAOI	Generate Fail to Stop Alarm
TOTPRMSAOI	Provide Flow Totalization

7.8.7 Project File Names, Program & Routine Names

Main project file names shall be coordinated with the Aurora Water SCADA staff. As a general rule, the file name shall include the location, program type and revision number.

- Example: EBPS_PLC_v3 means Eagle Bend Pump Station, PLC program revision 3.
- Example: WWTF_PLC-10_v2 means Wemlinger Water Treatment Facility, PLC-10 program version 2.

Names of subroutine files within the main program should also include the specific equipment with which it is associated utilizing a maximum of ten characters. File names for PLC programs should be sufficiently descriptive and minimize abbreviations.

7.8.8 Control Outputs

All control outputs shall be momentary or maintained as appropriate. When momentary outputs are required, the end devices' controller shall provide any seal-in relay and circuitry required by the starter or other type of circuitry. Controllable end devices include valve actuator starters, variable frequency drives, motor starters, etc.

7.8.9 Controller Inter-Communications

Peer-to-peer communication between PLC processors shall use both read and writes commands to initiate and transfer information as appropriate. This applies to for both reading status information and for conveying control commands. Using the appropriate will optimize the use of communication tokens on a highly populated network.

7.8.10 Network Communications

Specific AOI, UDT, and Function Block templates related to network communications will be provided as required on a project by project basis during SCADA programming workshops. Any templates developed by Contractors are to be provided to the City as part of a programming library at the completion of all projects.

PLC to PLC communications traffic may be used on the SCADA network. However, if PLC to RIO is used the RIO connection must be through separate network via a 1756-EN2T card(1). Consult with the City when designing RIO applications.

7.8.11 Analog Scaling

Each analog input shall be scaled into appropriate engineering units within the PLC. The engineering units shall then be used for any logic within the PLC program and for immediate display to a directly connected OIT such as a panel viewer.

7.8.12 Flow Totalization

Flow totals, including flow totalization factors, i.e. 100 gallons per pulse, shall always be calculated in the PLC logic and shall be transferred to the HMI for indication.

7.8.13 Equipment Run-Time Calculations

As with flow totalization, run-time calculations shall be computed in the PLC program. Run-times shall be calculated in units of hours and tenths of an hour only. Run-times shall be reset only by command from the HMI.

7.8.14 Clock Synchronization

PLCs containing a real time clock shall be synchronized twice a year to account for daylight savings time. The synchronization shall be accomplished automatically by the control system server.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

The City of Aurora uses RSLogix5000 Clock Update Tool v.2.4.2(1) to synchronize controllers' wall clock time with the selected site master PLC's time. This software appears on the custom tools menu of RSLogix 5000 version 19 and higher and supports Logix5000 and other devices:

- ControlLogix
- CompactLogix
- Flexlogix
- DriveLogix
- GuardLogix
- MicroLogix 1500
- SLC500
- PLC5
- PowerMonitor II
- PowerMonitor 3000
- PowerMonitor 5000

It is the Vendor's responsibility to verify the current version of software used by the City of Aurora.

7.8.15 Program Documentation

Documentation for all PLC programs shall include comments, tag/register descriptions, or any other programming tags. All PLC programs shall be documented with comments provided for each subroutine, function, and/or section. For PLCs provided outside of a Vendor-provided control system, the PLC program and associated documentation shall be stored in the PLC memory. Use of abbreviations in comments and subroutine/section titles should be avoided. At the completion of the project, copies of programming, I/O list, memory map, and communications map shall be provided in both printed and PDF format, as well as the raw code files.

7.8.16 Analog Input Checks

The raw counts of all hardwired analog inputs shall be checked for compliance with value bounds. Raw counts within set bounds will set the normal flag bit; raw counts outside set bounds will set a fault flag bit. These flags shall be used to detect instrumentation failures, automatically adjust the process as needed, and create an HMI alarm. All analog inputs shall have a live zero to differentiate between a zero value and a failed analog input. As an example, a 4 to 20 milliamp input card shall return raw values of 3277 to 16383, rather than 0 to 4000.

7.8.17 Entry Input Check

HMI or OIT software shall check set points, entered as engineering units, sent to the PLC for valid boundaries and, if exceeded, reset with the previous value.

8.0 CONTROL PANEL GUIDELINES

8.1 INTRODUCTION

The objective of this section is to establish minimum standards of materials and achieve consistency in panel construction, layout, wiring, and installation across projects. Adhering to these guidelines will directly impact the performance of the maintenance staff in maintaining and correcting problems that may arise with the enclosed equipment.

8.2 PANEL CONSTRUCTION

In panel design, material of construction, method of fabrication, and equipment arrangement must be addressed. These are addressed in the section below. Hoffman manufactured panels and enclosures shall be the reference minimum acceptable level of quality(1).

8.2.1 Materials of Construction

Panels designed for indoor applications shall be of NEMA 12 rating with a gasket, painted, carbon steel shell. Steel plates shall be United States Standard (USS) 12 gauge or heavier for floor mount or freestanding panels. Wall mounted panels shall be constructed of USS 14 gage or heavier steel plates.

Panels designed for installation outdoors shall be NEMA 4, constructed of stainless steel (316L or better) or painted carbon, fitted with sun-shields, and powder coated white. Stainless steel, NEMA 4X panels shall be used for corrosive areas. Panels designed for installation within an outdoor enclosure shall be NEMA 4, painted carbon steel.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

8.2.2 Panel Doors

Panel doors, whether front or back mounted, shall be no wider than 30 inches. Doors shall be specified with stiffeners as required to meet UL508 requirements. Each door shall be provided with a continuous, piano-style hinge. Every panel door shall be provided with a door handle and three-point latching mechanism. For panels located outside of the fenced secured areas that are monitored 24 hours per day and 7 days per week, the door handle shall be provided with padlocks.

Panel door requirements for piano-style hinge and three point latching may be difficult to meet for smaller panel sizes. The designer shall consult with panel manufacturers during design to determine if these requirements can be met.

8.2.3 Panel Placement

Panels shall be arranged so conduits enter the panels from the bottom or sides only. Conduit entries from the top are not permitted. A four-inch tall, concrete maintenance pad shall be provided under each freestanding panel.

Network cabinets with front and back entries shall be positioned such that entry is permitted without the need to move or otherwise maneuver the cabinet.

Panels located outdoors should be positioned such that direct sun exposure is minimized or avoided. Panels should not be located under objects that pose a falling hazard or continuous water stream, like trees or gutters.

8.2.4 Panel Layout

Panels containing a field interface device such as a PLC or RTU shall have that unit mounted in the upper portion of the panel. Incoming power connections, power distribution, power supplies, and other devices related to panel and instrument power shall be located below the field interface device. If no field interface devices are contained in the panel, panel and instrumentation power equipment shall be located at the top of the panel. Field terminals shall be installed in the lower portion of the panel. In freestanding panels, the field terminations must be no lower than 2 feet above the floor. Analog and digital signals shall be segregated to the maximum extent possible to minimize interference. Control panels with PLCs, analog signals, or sensitive instruments, shall not house variable frequency drives, soft starters, or other electrically noisy equipment, or equipment operating at higher than 120 VAC equipment. This equipment must be located in a separate panel.

On the panel exterior, operator interface terminals such as touch screen panels or operator workstation devices, shall be installed at a viewing height of 5’-5”. Switches, push buttons, or other panel-front devices shall be located at a mean height of 4'-6" above the base of the panel.

For outside, unsecured, and owner-specified enclosures, a dead front door shall be utilized to prevent unauthorized access to pilot devices and displays.

8.2.5 Special Coating/Conditions

Where stainless steel is incompatible with process conditions, for instance in specific halogen applications, a NEMA 4X fiberglass panel shall be provided. Provide panels with captivated stainless steel door screws, sealed seams, and hinges lacking exposed metal parts. Include confirmation from the manufacturer deeming the enclosure suitable for the application.

Figure 8.1 LCP Cabinet Elevation

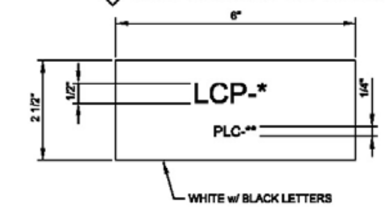
User: LPitchley Plot Date: 27-MAR-2017 9:17:07 AM $$$$FILE$$$$

GENERAL NOTES:

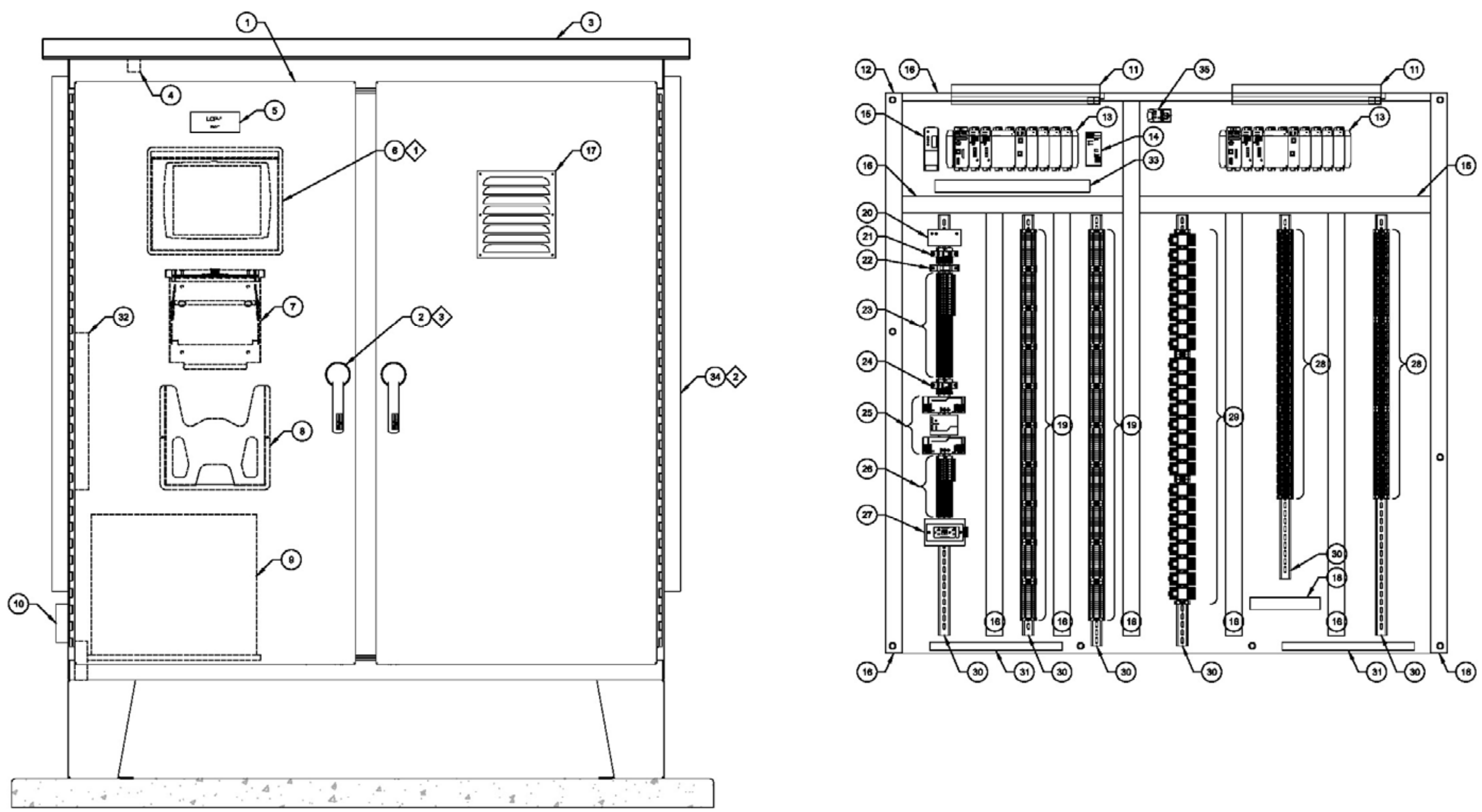
1. ENCLOSURE DRAWINGS INDICATES DESIGN INTENT. SIZE LCP CABINET IN ACCORDANCE WITH SPECIFICATIONS AND I/O INDICATED ON THE DRAWINGS. CONTRACTOR WILL SUPPLY AS-BUILT DRAWINGS SHOWING ACTUAL LCP ENCLOSURE LAYOUT WITH EQUIPMENT MANUFACTURER, PART NUMBERS AND PARTS COUNT.

KEY NOTES:

1. FOR PANELS LOCATED IN UNSECURED LOCATIONS, THE ENCLOSURE SHALL HAVE A DEAD FRONT DOOR WITH A LOCKABLE LATCH AND THE OIT SHALL BE ACCESIBLE ONLY AFTER UNLOCKING THE DEAD FRONT DOOR.
2. PROVIDE HEAT SHIELD MOUNTED AT THE BACK OF THE ENCLOSURE IN ADDITION TO SIDE MOUNTED SHIELDS.
3. ALL PANEL LATCHES TO BE KEYED THE SAME.



NAMEPLATE
SCALE: NOT TO SCALE
FILE: 10466A0002N601



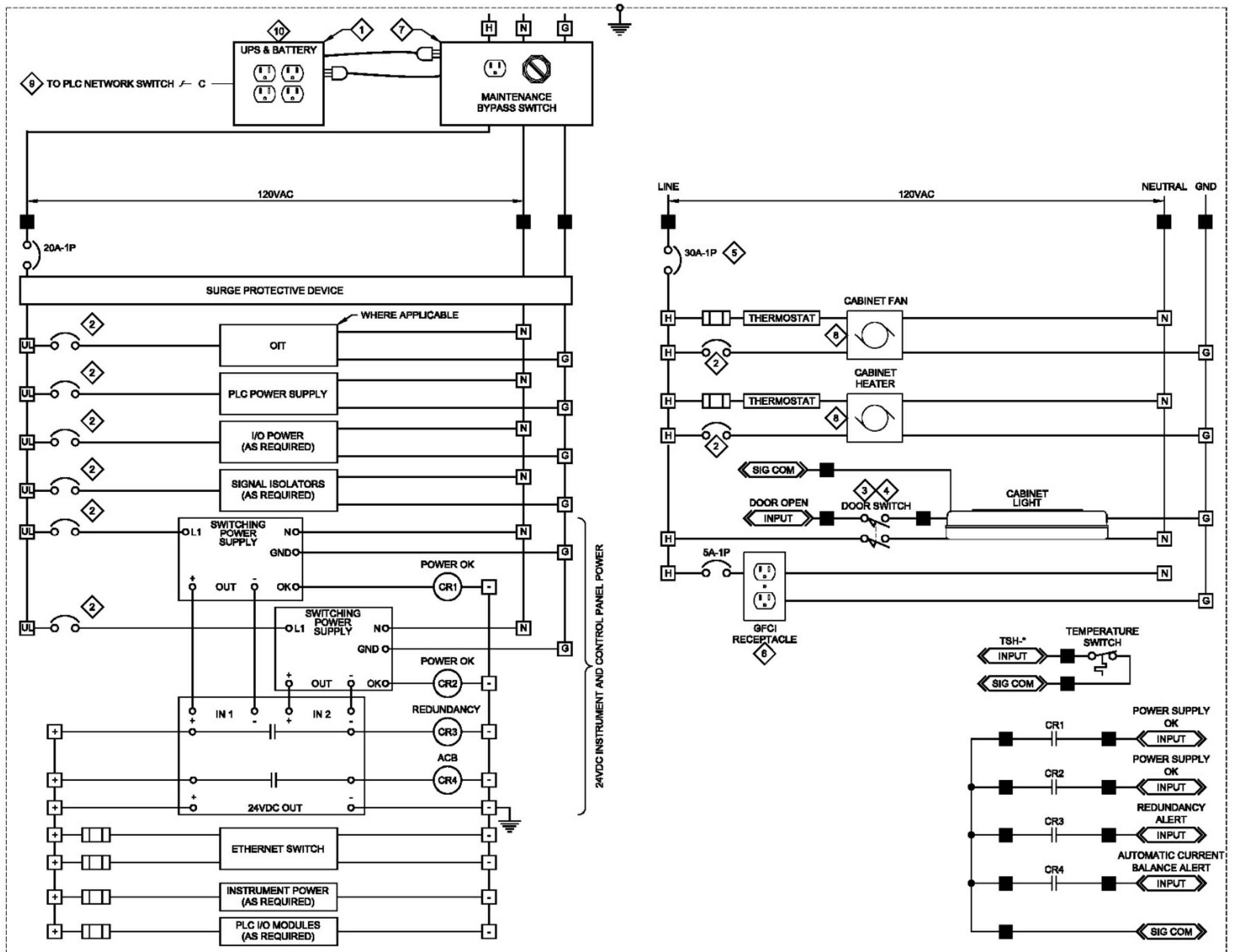
EXTERNAL ELEVATION
SCALE: NOT TO SCALE
FILE: 10466A0002N601

INTERNAL ELEVATION
SCALE: NOT TO SCALE
FILE: 10466A0002N601

BILL OF MATERIALS	
ITEM	DESCRIPTION
1	NEMA 4 DEADFRONT ENCLOSURE 74"Hx72"WX24"D
2	LOCKABLE LATCH
3	SUNSHIELD
4	DOOR SWITCH OPEN
5	NAMEPLATE
6	OIT
7	FOLDING SHELF
8	DOCUMENT HOLDER
9	UPS ON PIVOT MOUNT
10	NEMA 4 INTAKE LOUVER
11	LIGHTING PACKAGE
12	BACKPANEL WITH PANEL SUPPORTS
13	PLC WITH POWER SUPPLY, AS REQUIRED
14	WIRELESS ETHERNET RADIO
15	ETHERNET SWITCH, 8 PORTS
16	PANDUIT, AS REQUIRED
17	COOLING FAN
18	STRIP HEATER
19	DISCRETE TERMINAL BLOCKS, AS REQUIRED
20	PHASE MONITOR
21	120VAC POWER (UPS) CIRCUIT BREAKER
22	120VAC SPD
23	120VAC POWER DISTRIBUTION BLOCK
24	120VAC POWER
25	24VDC POWER SUPPLY AND DIODE
26	24VDC POWER DISTRIBUTION BLOCK
27	120VAC GFCI DUPLEX RECEPTACLE
28	ANALOG TERMINAL BLOCKS, AS REQUIRED
29	CONTROL RELAYS
30	DIN-RAIL, AS REQUIRED
31	GROUND BAR
32	MAINTENANCE BYPASS SWITCH
33	FIBER OPTIC PATCH PANEL
34	SIDE MOUNTED HEAT SHIELD WITH 2 INCH SPACERS
35	TEMPERATURE SWITCH

LCP CABINET ELEVATION
CITY OF AURORA

Figure 8.2 Typical LCP Schematic



GENERAL NOTES:

1. SCHEMATIC ILLUSTRATES DESIGN INTENT ONLY. PROVIDE ALL NECESSARY COMPONENTS TO MEET PROJECT REQUIREMENTS.
2. INSTRUMENTS POWER TO BE SOURCED FROM UPS CLEAN POWER AT 120VAC OR 24VDC AS REQUIRED. UPS MUST BE SIZED ACCORDINGLY.

KEY NOTES:

1. SIZE UPS AND BATTERY BASED ON UPS SPECIFICATION REQUIREMENTS.
2. SIZE BASED ON PROTECTION NEEDS.
3. INTEGRAL SWITCH WITH LIGHT.
4. PROVIDE QUANTITY REQUIRED. FOR A TWO-DOOR ENCLOSURE, A SINGLE LIMIT SWITCH IS ACCEPTABLE, PROVIDED IT IS INSTALLED TO SWITCH ON THE LAST DOOR TO CLOSE.
5. SIZE BASED ON LOAD REQUIREMENT.
6. RECEPTACLE FOR LAPTOP.
7. PROVIDE HARDWIRED CONNECTIONS OR RECEPTACLE/PLUG AS REQUIRED BY MAINTENANCE BYPASS SWITCH.
8. VERIFY LOADS BASED ON TEMPERATURE CALCULATIONS. PROVIDE ADDITIONAL CIRCUIT IF REQUIRED.
9. CONNECT UPS TO A DEDICATED NETWORK MODULE ON PLC CHASSIS. DO NOT CONNECT TO NETWORK SWITCH.
10. PROVIDE DEDICATED, NON-GFCI RECEPTACLE FOR UPS POWER.

TERMINAL BLOCK LEGEND

■	LCP
H	120VAC
N	NEUTRAL
G	GROUND
UL	UPS 120VAC
+	24VDC (+)
-	24VDC (-)

TYPICAL LCP SCHEMATIC

CITY OF AURORA

8.3 INTERIOR WIRING/CABLING

Panel wiring shall conform to the requirements detailed in the subsections below.

8.3.1 <u>Wiring Sizes</u>

Wire sizes indicated herein are minimum size preferences. The designer shall also perform all calculations as required by the current version of the NEC to verify that conductors are sized accordingly. Panel power distribution wiring on the line side of panel fuses or circuit breakers shall be minimally 12 AWG. Secondary power distribution wiring shall minimally be 14 AWG. Analog circuits in a panel shall use, at minimum, 18 AWG shielded twisted pair with a drain wire. For all wire types, insulation shall be rated for 600 volts.

Unless directed otherwise by the instrument manufacturer, shields for analog circuits shall be clipped at the field end and drain wires terminated on individual green/yellow terminal block in the control panel. All instrument grounds in the panel shall be tied together.

Install all wiring without splices, except where terminal blocks are used. Tap wires only at terminal blocks. Arrange wire with sufficient clearance for all leads.

8.3.2 <u>Wireways</u>

Wireway shall be provided to route all wiring within the panel. Wireway shall be sized for 50 percent spare capacity over the current project requirements. A minimum one inch of clearance shall be provided between the wire way and the nearest point of termination.

For wiring routed to the panel door, wiring shall be neatly bundled and wrapped with plastic spiral wrap and secured at each end so that bending or twisting will be around the longitudinal axis of the wire.

Provide separate conduit for 120 VAC and 24 VDC circuits. Where intersections between circuits of varying voltages occur, run wires at 90º.

8.3.3 Wiring Colors

Power wiring colors shall be provided as shown in Table 8.1 below.

Table 8.1 Power Wiring Colors

Phase or Type of Conductor	240/120 Volts	208/120 Volts	240 Volts	480/277 Volts
Phase A	Black	Black	Black	Brown
Phase B	Red	Red	Red	Orange
Phase C	N/A	Blue	Blue	Yellow
Neutral	White	White	White	Gray
Ground	Green	Green	Green	Green

Wiring colors for other types of panel wiring shall be provided as shown in Table 8.2 below.

Table 8.2 Panel Wiring Colors

Type of Wiring	Color
L1	Black
L2	White
AC control circuits	Red
DC Positive	Blue
DC Common	Blue/White
Interlocked control circuits powered externally from panel	Yellow
Equipment ground	Green

8.3.4 Fiber Optic Cabling

Where fiber optic cabling passes through a control panel, all fibers shall be terminated on a fiber patch terminal. Fiber patch panels shall be located in the upper portion of the control panel. Where necessary, fiber patch panels are permitted to be mounted to a side-mounted backpanel.

8.3.5 Wire Tags

Shrink-on sleeve type wire tags shall be affixed to every end of each conductor terminated in the panel. Wire tags shall match the tags shown on the control panel supplier’s drawings. The device and signal tags shown on the P&ID drawings shall be used to derive wire tag identifiers. Multiple signal wires within the same signal identifier shall be appended by -1, -2, etc. for digital circuits. Analog circuits shall be appended by (+) and (-) as appropriate.

8.4 PANEL ACCESSORIES

8.4.1 Terminals

Terminals shall be of the screw-down type and not spring loaded. Terminals shall be provided with a stand-off rail to allow easy access to the terminals and to the wiring. Terminals shall be equivalent in quality and durability to those manufactured by Phoenix Contact. Terminals shall be single-high construction with labels on each wired terminal. A minimum of 20 percent spare terminals shall be provided in each panel. All spare I/O terminals shall be wired. Backpanel space for future terminals shall also be identified and included in the panel. Space for future terminals shall be 20 percent of the supplied terminals. Fused terminal blocks shall have a blown fuse indicating light.

For panels housing field interface devices, a cable-fast solution shall be used for terminating all I/O points (see Section 6 - INPUT & OUTPUT CRITERIA for additional details). In PLC panels that are provided with spare slots in the rack, space shall be provided for additional terminals to be mounted on both the analog and digital sides of the panel.

8.4.2 Power Distribution and Circuit Breakers

All process-critical control panels shall be powered by an uninterruptible power supply. This includes all communication components, processor components, and critical process instrumentation. City staff will provide guidance in identifying 'process-critical.' A separate, non-UPS powered circuit shall be provided to all control panels for powering accessories such as lighting, ventilation, and heating circuits in the panel. The non-UPS powered circuit shall also be used to power non-critical instruments. Panels with two supply circuits shall be labeled as required by the latest version of the NEC to warn of the presence of two power feeds. For panels with two power supply connections, a separate, isolated ground shall be provided for UPS circuits.

Each incoming power circuit to outdoor enclosures shall be provided with a power surge suppressor that protects against transient voltage spikes and surges. Power surge suppressors shall be provided for both UPS and non-UPS circuits.

Each 120VAC device powered out of the control panel, whether sourced from a UPS or not, shall be provided with a DIN-rail mounted circuit breaker for protection and isolation from other devices.

8.4.3 Uninterruptible Power Supply

The City has standardized on the IntelliPower UPS. IntelliPower has created a UPS specific to Aurora's needs with the model number IHT1500V-I-1.05Kw-120V-FC60-120V-6BFB-2U20(1) that shall be used. For monitoring and diagnostics, the UPS shall be connected directly to a dedicated Ethernet port on the PLC chassis. The Contractor shall use the City's standard programming block to incorporate the UPS into SCADA via EtherNet/IP™.

The UPS shall be sized 1500VA. If additional capacity is required, provide additional 1500VA UPS. Provide a minimum of 15 minutes runtime.

The City, in conjunction with Easter-Owens, has a standard detail for UPS mounting in a control panel. This detail, shown in Figure 8.3 enables the UPS to be pivoted outside the panel, providing access to terminals and equipment otherwise concealed by the UPS.

The UPS shall powered on a dedicated power circuit, separate from the panel's convenience circuit. The UPS must be plugged into a non-GFCI outlet. It may not be powered from a GFCI-protected circuit.

8.4.4 Heaters and Ventilation

Every panel provided for indoor service shall be provided with a thermostatically controlled ventilation fan. The thermostat shall be specifically designed for cooling with no interposing relay necessary. Each vent in the panel shall be provided with a filter to minimize dust intrusion. Blank panel inserts shall be provided with the panels to slide in place of the filter to completely enclose the panel, if desired. A disconnect switch shall be provided to prevent the fan from running.

Panels for outdoor service shall be provided with a thermostatically controlled strip heater mounted at the bottom of the enclosure. The thermostat shall be specifically designed for heating service with no interposing relay necessary. A disconnect switch shall be provided to prevent the heater from turning on. Panels for outdoor service shall not have ventilation provisions and will rely on proper sizing and material, adequate component spacing, and an internal fan for cooling as required.

8.4.5 Lighting

Each freestanding control panel for indoor or outdoor enclosure service shall be provided with a panel light. Light emitting diode (LED) panel fixtures are the preferred type of panel light for panels mounted inside. Incandescent fixtures are preferred for outdoor service. A light switch inside the panel as opposed to a door switch shall control the light. Provide one light fixture for every 36" of panel width.

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(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

8.4.6 Convenience Receptacle

Each panel, regardless of size or mounting, shall be provided with a duplex, ground fault circuit interrupting (GFCI) receptacle. This receptacle shall be in addition to those needed for plug-in transformer type power supplies for communication or other permanently installed equipment.

A dedicated, orange-colored, isolated ground receptacle shall be provided and connected to the UPS power feed for panels that are powered from the UPS circuits. This receptacle shall not have GFCI protection.

No standalone receptacles are to be installed in vaults. Provide the receptacle mounted in an enclosure for all vault applications.

8.4.7 Nameplates

The outside of each panel shall be provided with a nameplate. Additionally, each permanently mounted component in the panel interior shall be provided with an identifying nameplate. Nameplates shall be phenolic black with white lettering. Nameplates shall be attached using self-tapping stainless steel screws. Mounting method must preserve the panel's NEMA rating.

8.4.8 Power Supplies

Power supplies for DC circuits in panels shall be DIN rail mounted and provide regulated voltage. UPS shall be installed for easy removal, be provided with maintenance bypass switch and utilize plugs and receptacles for connection to powered components.

8.4.9 Indicating Lights

Indicating lights shall be transformer type with LED bulbs. Lights shall be push-to-test, oil tight, and complete with the appropriate color lens. All pilot devices shall preserve the rating of the enclosure. Lens color shall be as indicated in Table 8.3 below.

Table 8.3 Indicating Light Color Scheme

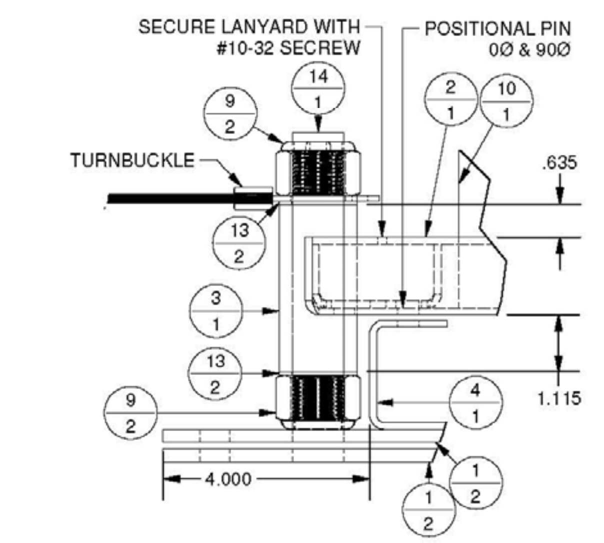
Indication	Color
Running	Green
Stopped	Red
Valve Opened	Green
Valve Closed	Red
Control Power On	White
Fault/Alarm	Amber

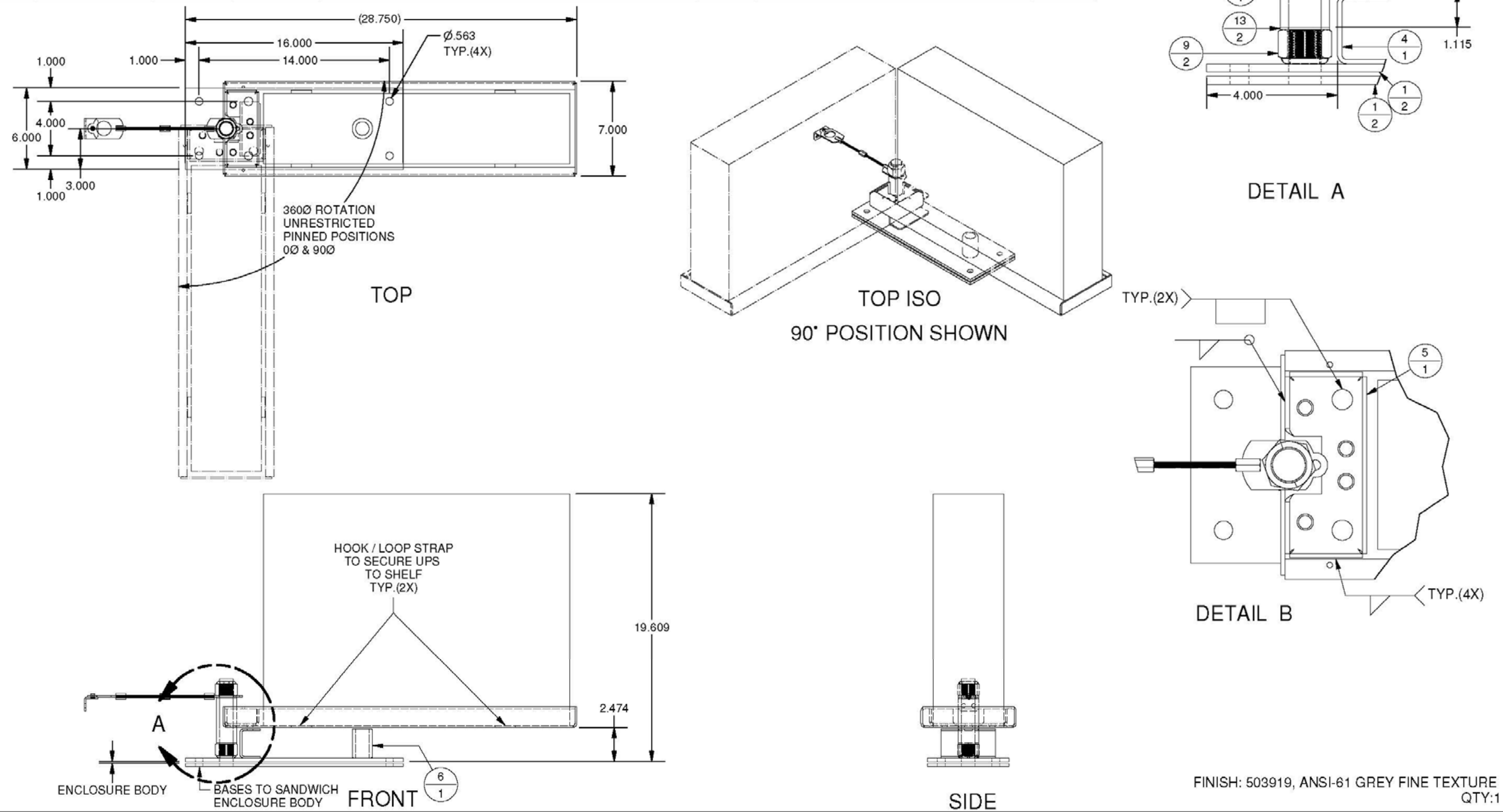
Figure 8.3 UPS Pivot Mount Detail

MODEL:F:\Projects_2016\16-30538 CAROLLO ENGINEERS\E-O DOCS\DRAWINGS\MECHANICAL\30538-100B.iam
DRAWING:C:\Users\cthompson\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\5B19FI7B\EM-E45691C-001A.idw

Parts List

ITEM	ITEM QTY	COMPANY	PART NUMBER	STOCK NUMBER	DESCRIPTION	Thickness	MATERIAL	LENGTH
1	2	E-O	30538-101A		BASE	0.250 in	Steel, ASTM A36	0.000 in
2	1	E-O	30538-103A		BASE	0.135 in	Steel, Mild	0.000 in
3	1	E-O	30538-104A		SLEEVE		RND. TUBE, 1.500 OD, 1.000 ID, STEEL	3.250 in
4	1	E-O	30538-108A		BASE	0.135 in	Steel, Mild	0.000 in
5	1	E-O	30538-109C		BASE GUSSET	0.135 in	Steel, Mild	0.000 in
6	1	E-O	30538-110B		SLEEVE		RND. TUBE, 1.500 OD, 1.000 ID, STEEL	2.125 in
7	1	E-O	30538-300B		TURNBUCKLE ASSY			
8	1	E-O	30538-400B		TURNBUCKLE BRACKET			
9	2	FASTENAL	0169775		1-12 Grade 2 Zinc Finish NE Steel Nylon Insert Lock Nut		Steel, Zinc Plated	
10	1	INTELLIPOWER	UPS		CUSTOMER SUPPLIED UPS		Steel	0.000 in
11	1	LEFTOVER	PIN		PIN WITH LANYARD	0.135 in	Steel, Mild	0.000 in
12	1	MCMASTER	3955T291		Hook and Loop Cable Tie with Buckle 48" Overall Length	0.135 in	Generic	0.000 in
13	2	MCMASTER	5906K412		Oil-Embedded Thrust Bearing for 1 ID, 1-1/2 OD, 1/16 Thickness		Bronze, Cast	
14	1	MCMASTER	98750A521		Grade B7 Steel Threaded Stud 1"-12 Thread, 6" Long, Fully Threaded		Steel, ASTM A36	6.000 in





FINISH: 503919, ANSI-61 GREY FINE TEXTURE
QTY:1

CUSTOMER:
PROJECT:
EASTER-OWENS
"IF YOU CAN THINK IT, WE CAN BUILD IT."
6692 Fig Street
Arvada, Colorado 80004
Tel: (303) 431-0111
Fax: (303) 424-2040
3RD ANGLE PROJECTION
EASTER-OWENS PROJECT NO.
REVISIONS
SCALE: 1:1
DRAWN BY: CET 11/7/2016
ENGINEER:
CHECK BY:
CAD FILE EM-E45691C-001A.idw
PART DESCRIPTION:
UPS PIVOT SHELF
PART NUMBER:
30538-100B.iam
SHEET NUMBER 1 /1
REV. A

8.5 PANEL LOCATIONS

Panel locations shall meet NEC requirements for clearance and working space, even when they do not have power distribution provisions.

9.0 OPERATOR INTERFACE TERMINAL (OIT) CRITERIA

9.1 INTRODUCTION

This section details operator interface terminal design and programming for terminals connected directly to PLCs.

9.2 OIT ACCEPTABLE MANUFACTURERS

Aurora Water SCADA has standardized on the Allen-Bradley PanelView Plus 7(1) with a minimum display size of 10". The 7-Series is a color touchscreen for local process visualization and supervisory control.

Prior to the start of any project, it is the Contractor/Vendor’s responsibility to verify the City of Aurora’s current programming software version though the workshop.

9.3 OIT OPERATING SYSTEM SOFTWARE

Current software used by the City of Aurora is Rockwell Software FactoryTalk View ME Version 7.1(1). OIT touch screens shall be configured with the City approved version of FactoryTalk operating system software. Because Rockwell's software suites may undergo renaming, requests for touch screens to be configured with an alternative operating system will be considered by the Aurora Water SCADA. Otherwise, no other OIT application will be accepted.

Prior to the start of any project, it is the Contractor/Vendor’s responsibility to verify the City of Aurora’s current version though the workshop.

9.4 OVERALL OIT DESIGN

All process control will be prepared in the PLC. Rockwell Software FactoryTalk will not be used to perform any control or other function that would, on its own, change the way that the controller controls the process. All commands must be initiated by an operator, not by any programming. All timers, totalizers, counters, or any control function device will be implemented in the PLC. The basis for this constraint is that in the event of an OIT failure:

- The process won’t be disrupted.

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

- The controller's ability to control the process won’t be disrupted.
- The process will operate correctly.

Operator interface terminals will be used by operations to interface with any controlling devices to display process data, equipment status and alarm information. It will also be used to transfer operator-initiated control commands to the controlling PLCs.

The premise driving these standards is the desire to promote consistency in graphical and tabular presentation of processes being monitored and controlled by the SCADA system. A common “look and feel” among displays will facilitate movement add to staff flexibility, and reduce training needs for operators and system maintenance staff.

To best provide OIT screens that are consistent with those in place, multiple meetings between the screen developer and City staff are necessary. Those requirements can be found in §2.3

9.5 OIT HIERARCHY

Displays shall be organized in a logical fashion to ease navigation through the processes, remote sites, equipment, and alarms. Defined herein are the general OIT hierarchy levels and types of displays. For display types, see Table 9.1 below.

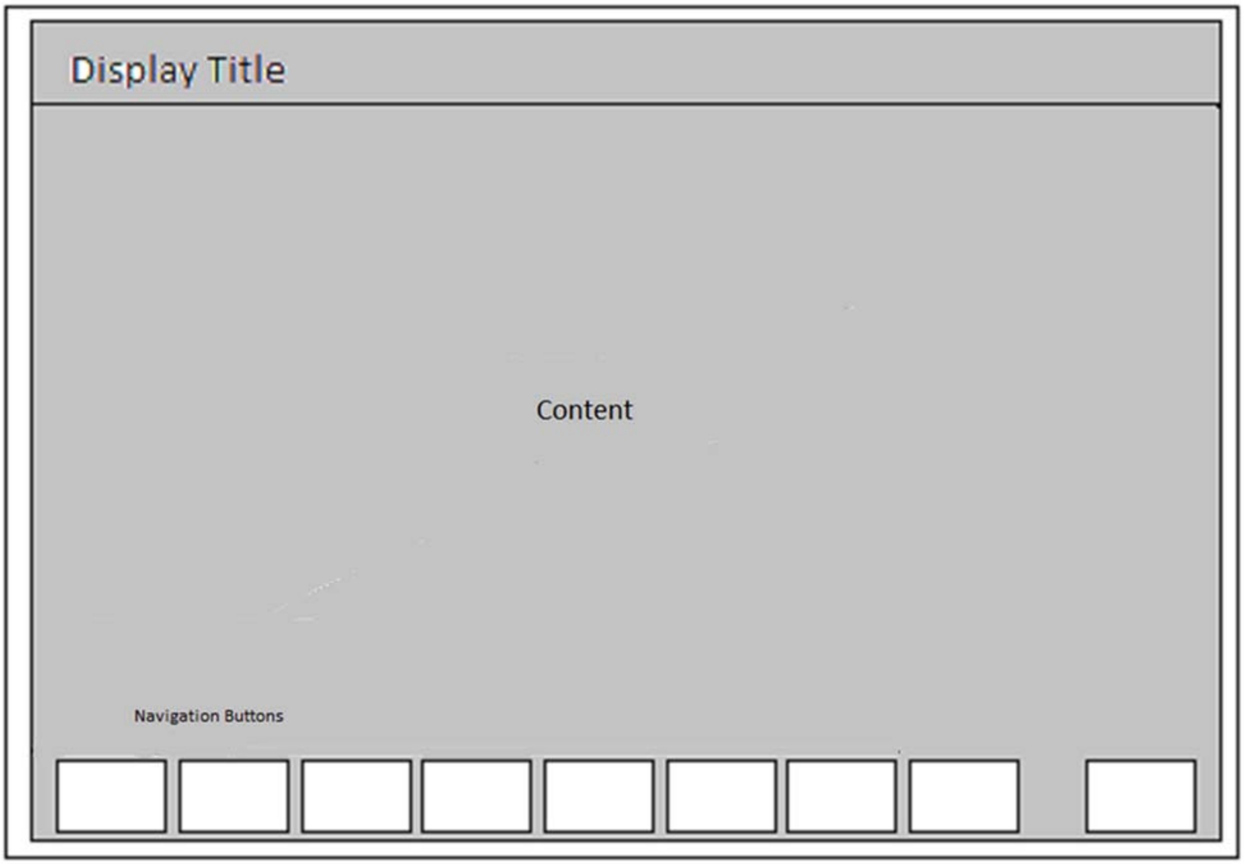
Table 9.1 Display Types

Display Type	**Description**
Process Area Overview	Displays equipment related to one specific process in P&ID-like format with little detail.
Alarm Summary	Display that provides a history of all alarm occurrences.
Detailed Process	Displays equipment, including related status and alarm text and related instrumentation in P&ID format.
Equipment Detail	Displays all status and alarm conditions, as well as control buttons for individual pieces of equipment.
Security Overview (Remote Sites)	Display that provides an animated overview of all doors, hatches, roof access, motion sensors in the facility superimposed on the facility facsimile.
Utility Overview (Remote Sites)	Display that provides an animated overview of all utility, generator and Automatic Transfer Switches for the facility.
Set points	Display that provides an animated overview of all doors, hatches, roof access, motion sensors in the facility superimposed on the facility facsimile.

9.6 OIT DISPLAY LAYOUT

The general layout of the Facility Overview, Process Area and Detailed Process Area graphics should have portions of the display which are consistently assigned to specific functions and information. For example, Aurora Water desires to always the page title in the upper left corner. Each of these graphic screens should additionally be provided with global navigation buttons, pull-down menus, pop-up windows, etc. Figure 9.1 demonstrates the layout that shall be followed for all graphic screens.

Figure 9.1 Typical OIT Display Layout



Displays shall be designed using a resolution of 1024 by 768 pixels and a 24-bit color palette. Graphic displays should flow from left to right, top to bottom. Processes enter on the left and exit to the right. In each system, one screen shall be developed with all the important and frequently used information and controls. Equipment placement need not be spatially or geographically correct.

9.7 OIT DISPLAY CONTENT

OIT graphics should represent major pieces of equipment, piping, valves, and gates schematically. OIT graphics are not meant to depict all pipe fittings and similar ancillary devices. In general, overview type displays should have less detail than process or equipment displays. Any piece of equipment associated controls should be represented on an OIT equipment detail graphic. Manual isolation valves should only be shown as deemed helpful by operations staff. Help screens shall be configured to direct operators to the appropriate SOP for the process depicted. The help screen shall additionally direct the operator to other screens or offline documentation for details concerning the piping and associated isolation valves.

Any equipment shown on the OIT graphic should be designated with its tag number shown directly above a common description of the equipment. Additionally, the position of any local control, like an LOR, should be shown in proximity to the equipment.

9.8 PROCESS AND EQUIPMENT SYMBOLS

The OIT software package includes an extensive library of process and equipment representations. Aurora Water utilizes FactoryTalk dynamo objects for pumps, valves, indicators, tanks, blowers, pipes, etc. Use these pre-made objects and their complete functionality where applicable.

Additionally, there may be custom symbols created by the Water Department. Before undertaking any OIT graphic development task, the programmer shall review the acceptable symbols with the Water Department staff to match existing or planned graphic standards.

9.9 NAMING CONVENTIONS

When provided by a Consultant or Contractor, the naming of OIT related hardware, software files and database entries must follow specific conventions. This applies to server and work station node names, display file names, tag groups and database point names. In general, the names include an abbreviation of the site or facility with which it is associated. The table below includes a list of facility/site abbreviations currently being used in the construction of database point names. It is important to note that all OIT related naming assignments must be reviewed and approved by the Water Department staff prior to any configuration or programming activities.

See Table 9.2 for example facility/site naming abbreviations.

Table 9.2 Facility/Site Naming Abbreviations[(1)]	
Abbreviation	**Facility/Site**
APS	Aurora Pump Station
BP	Binney WPF
CCW	Cherry Creek Wells
EBEND	Eagle Bend
FRA	Front Range Airport
GUN	Gun Club
INTER	Intertie
POWPS	Powhaton Pump Station
PRV02	PRV02: Potomac PRV
QUIN	Quincy
RAMP	Rampart
SMH	Smoky Hill
SSP	Strontia Springs
WP	Wemlinger WPF
GP	Griswold WPF
SP	Sand Creek RWF
WF	Wemlinger Field SCADA site
SF	Sand Creek Field SCADA site

9.9.1 Graphic Display File Naming

The workstation operating system does not significantly restrict the length of file names; hence abbreviations are not needed in describing the facilities, equipment, processes, or screen function. Display file names associated with monitoring/controlling plant processes are a concatenation of the facility name and a descriptor of what is represented on the OIT graphic. Some examples include “WPWemlingerOverview,” “SPScreening,” and “GPBackwash.” Display file names associated with remote sites are a concatenation of the Field SCADA server name and a descriptor of the process or equipment that is represented on the OIT graphic. An example of a Field SCADA display file name is “WFSmokyHillOverview.”

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

9.9.2 Database Tag Naming

The database point tag names are mnemonic in construct and may include ISA function names and the point's numeric loop as it relates to the associated instrument or equipment as defined in Section 2 - CONTROL NARRATIVES and Section 4 - PROCESS AND INSTRUMENTATION DIAGRAM GUIDELINES These tag names are a concatenation of the site abbreviation, process, the process equipment, and its purpose. FactoryTalk database tag names are identical to their corresponding PLC I/O names. The Site Owner determines equipment tag names. The SCADA group provides database tag names to the OIT developer.

Database descriptions are displayed as part of the alarm message in the alarm summary. Database descriptions and tags need to be meaningful to plant operators.

Alarms from many different areas are alarmed on one FactoryTalk node. The description needs to contain enough information so operators can determine exactly what piece of equipment the alarm or trend graph refers to and what the problem is with that equipment.

9.9.3 Tag Group Naming

Tag Groups shall be a concatenation of the facility abbreviation as shown in Table 9.2, the type tag group and the ISA function abbreviation. Examples include "WPTRENDFIT02," "NCTRENDMTPSCTRLSHPUMP1," and "WPTRENDSMOKYHILLTANKLEVEL."

9.9.4 Node Names

Proficy FactoryTalk node names are assigned by Water Department staff.

9.10 OIT COLOR CONVENTIONS

Standard colors shall be used for display of static and dynamic elements, analog values, graphics background, tables, text and flow streams. The following sections provide examples of color assignment for possible applications. All preliminary and final assignments of color must be approved by the SCADA team prior to any configuration work.

9.10.1 Non-Dynamic Element Color Conventions

Static element color conventions shall be as shown in Table 9.3. Non-dynamic elements in graphic displays include static text, static symbols, graphic display background and process flow streams. This section includes the requirements for general static elements and process flow stream color conventions.

Table 9.3 Static Element Colors	
Static Elements	**Color**
Static Text:	Black
Display Titles	
Equipment Identifiers	
Display Background	Light Gray
Static Equipment Symbols:	Dark Gray
Isolation Valves	
Flow Meters	
Similar Devices	
Static Process Symbols:	Dark Gray
Basins	
Filters	
Vessels	

9.10.2 Dynamic Element Color Conventions

Color conventions for two-state devices shall be as shown in Table 9.4. Color conventions for valves shall be as shown in Table 9.5. Dynamic elements consist of symbols and texts for both analog and discrete signals. Color is used to indicate equipment status, operational mode, alarm, valve position, and quality of process signals. Equipment status indicates whether the device is running or stopped. Equipment mode indicates whether the device is being controlled locally or through the computer control system. Alarm indication may represent low, high, or critical priority alarms. The quality of the process signal may indicate out-of-service, inhibited alarms or off scan. Symbols and text should flash to indicate unacknowledged alarms and signals not being scanned.

Table 9.4 Color Conventions for Two-State Devices		
Element	**Color**	**Usage**
	Green	Running, On, In-Service
	Red	Stopped or Off

Table 9.5	Color Conventions for Valves	
Element	**Color**	**Usage**
	Green	Fully Open
	Red	Fully Closed
	Yellow	In Transition

9.10.3 Dynamo Color Conventions

Dynamo color conventions shall be as shown in Table 9.6. Typical uses for dynamos on graphic displays include tank levels, pump status, valve status and blower status. Dynamo objects should be used as needed on process detail graphic displays, equipment detail graphic displays or control function pop-up windows. Dynamo objects shall always be a steady state color and should not change color or flash.

Table 9.6	Color Conventions for Dynamos	
Element	**Color**	**Usage**
	Green	On/In Service
	Red	Off/Out of Service
	Yellow	In Transition
	Red-Flashing	Fault

9.10.4 Dynamic Text

Dynamic text is used to represent discrete or analog signals being monitored by the SCADA system including analog process variables, alarms and equipment mode and status. Dynamic text should employ color to indicate status, alarms and process signal quality. In addition, dynamic text representing an alarm condition should flash until the alarm has been acknowledged. Dynamic text color conventions are summarized in the following paragraphs.

9.10.5 Equipment Mode and Status

Equipment mode and status text colors shall be as shown in Table 9.7. Equipment mode text is used to indicate if the equipment is set to be controlled manually or automatically and either locally, at the process control panel, or through the computer control system. Text used to indicate equipment status should be used on equipment detail graphics and control function pop-up windows to indicate control mode and equipment conditions. Equipment status text should not be used on process area graphic displays and on process detail graphic displays.

Table 9.7 Color Conventions for Equipment Mode			
Element	**Text Color**	**Background Color**	**Usage**
Equipment Status Text (Equipment Detail Graphic)	Black	Transparent	All occurrences

9.11 OIT TEXT SIZE AND FONT

Arial text shall be used for all process graphics and tabular displays. Font size shall be 16 point bold for screen titles and 10 point bold for all other text. Exceptions may be approved by Aurora Water.

9.12 OIT TABULAR DISPLAY CONVENTIONS

Tabular displays are useful for displaying on one graphic display information for multiple trains or to compile all relevant data from a facility. Tabular display formats shall be reviewed with Water Department staff prior to implementing the screen configuration.

9.13 OIT CONTROL FUNCTIONS

Pop-up windows shall be used to provide access to control functions for all equipment controlled by the SCADA system. If the pop-up window is larger than one-half of the full-size display, then a separate graphic display should be provided for the control functions.

Auto-manual control stations should be configured as pop-up windows which provide the user a means of switching equipment modes, controlling equipment in-manual, entering set points, and providing relevant equipment status information.

9.13.1 Auto-Manual Discrete Stations

Discrete control stations should be configured for equipment such as constant speed pumps and open-close valves. Functions such as start, stop, auto and manual should be accessed by selecting the appropriately labeled button. The button should not remain depressed; however, the text color changes to provide visual feedback to the operator.

Status, alarm conditions, and process variables that aid the user in performing control functions and are not readily available on the current display should be included in the popup window. Examples include selector switch status, control parameters and calculated values.

9.13.2 Auto-Manual Analog Control Stations

Analog control stations should be configured for variable speed pumps, chemical feed control, modulating and throttling valve control and similar processes. Functions such as start, stop, auto, and manual should be accessed by selecting the appropriately labeled button. The button does not remain depressed; however, the text color changes to provide visual feedback to the operator.

Status, alarm conditions and process variables that aid the user in performing control functions and are not readily available on the current display should be included in the pop-up window. Examples include selector switch status, control parameters and calculated values. Dynamic text should follow the color conventions defined in this section.

Process variables (PV), set points (SP) and output points (OP) should be displayed as dynamic analog text and as bar graphs in the pop-up window. Dynamic analog text and bar graphs shall follow the color conventions defined in this section. Bar graphs should be scaled in the appropriate engineering units. Windows-style check boxes and options buttons may be used to select control modes and other parameters.

9.14 REAL-TIME TRENDS

Real time trend colors shall be as shown in Table 9.8. Real time trends should be accessible from the OIT display system. The trending and reporting display should include Windows-style pushbuttons which navigate the user to pre-configured or ad-hoc trends. General display criteria for trends include the following:

Table 9.8	**Color Conventions for Trends**
Background Color	Gray
Pen Colors	Automatic or manual assignment at creation
Pen Quality	Six maximum
Axis Labels	Individual engineering units on Y-Axis
Stacked Trends	Three maximum

10.0 COMMUNICATION CRITERIA

10.1 INTRODUCTION

The City of Aurora’s SCADA communication system must meet some desired provisions. There are five important design criteria: Performance, Consistency, Reliability, Recovery, and Security.

Network performance is primarily measured from an end-user perspective, i.e. quality of network services delivered to the user. Broadly, network performance is measured by reviewing the statistics and metrics from the following network components:

- Network bandwidth or capacity - available data transfer.
- Network throughput - the amount of data successfully transferred over the network in a given time.
- Network delay, latency, and jittering - any network issue causing packet transfer to be slower than usual.

- Data loss and network errors - packets dropped or lost in transmission and delivery.

Consistency is the predictability of response time and accuracy of data.

- Users prefer to have consistent response times. These response times develop a feel for what is considered to be normal operating conditions.
- Accuracy of data determines if the network is reliable. If a system loses data, then its users will not have confidence in the information.

Reliability is measured by how often a network is useable. Mean Time Between Failures (MTBF) is a measure of the average time a component is expected to operate between failures.

Recovery is the network's ability to return to a prescribed level of operation after a network failure. This level is where the amount of lost data is nonexistent or kept to a minimum.

Security is the protection of hardware, software, and data from unauthorized access. Restricted physical access to computers, password protection, limiting user privileges, and data encryption are common security methods. In addition, anti-virus monitoring software applications are utilized to defend against computer viruses.

10.2 FIBER OPTIC COMMUNICATION

Some City of Aurora sites use fiber communication. See §3.3 for specific fiber optic communication details. It is the Vendor's responsibility to determine the communication type at each site.

10.3 RADIO COMMUNICATION

Some City of Aurora sites use 900MHz radio communication. Depending on its location, these remote sites utilize a directional Yagi antenna that points to one of seven head-end SCADA towers: Aurora Reservoir, Griswold WPF, Mexico and Buckley, Northeast Plains, Sand Creek WRF, Smoky Hill, or Wemlinger WPF. Writing PLC logic for these sites is typically different than writing logic for a wired site. SLC address mapping must be programmed into the driver. It is the Vendor's responsibility to utilize Aurora Water standards.

Licensed Ultra High Frequency (440MHz) is also used when necessitated by radio path studies or interference. The preferred radio model is the 4RF Aprisa SR+(1).

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

10.4 LEASED LINE/MODEM COMMUNICATION

Although the City of Aurora is weaning itself from leased lines and modem communication, several sites still utilize this technology. Modems are also used when fiber communication is cost prohibitive or radio communication is not feasible.

The Vendor must program PLC logic differently for each type of communication utilized. It is the Vendor's responsibility to determine what communication method is utilized for each site.

11.0 HUMAN MACHINE INTERFACE (HMI) CRITERIA

11.1 INTRODUCTION

This section of the DEG details HMI design and programming guidelines.

11.2 HMI ACCEPTABLE MANUFACTURERS

The Water Department has standardized on the GE Fanuc Proficy iFIX HMI/SCADA(1) automation product for process visualization, data acquisition, supervisory control and historical archiving/retrieval. No other HMI application will be accepted. The City of Aurora currently uses Version 5.8. Prior to the start of any project, it is the Contractor's/Vendor's responsibility to verify the City of Aurora's current version. Other software modules associated with this product by the same manufacturer, GE Fanuc, will be considered for approval.

11.3 HMI OPERATING SYSTEM SOFTWARE

All HMI computers shall be configured with operating system software Microsoft Windows 10 Professional x64 latest release(1). Requests for computers to be configured with an alternative operating system will be considered by the Water Department as required.

11.4 OVERALL HMI DESIGN

All process control will be prepared in the PLC. iFix will not be used to perform any control or any function that would, on its own, change the way that the controlling device controls the process. Any command must be initiated by an Operator, not by any programming within iFix. All timers, totalizers, counters or any control function device will be implemented in the controller, not iFix. The basis for this constraint is that in the event of an iFix failure:

- The process won't be disrupted.
- The means to control the process won't be disrupted.
- The process will operate correctly.

---

(1) Specific manufacturer, standard, or version to be coordinated with City Project Manager during design.

iFix will be used by operations to interface with controlling devices to display process data, equipment status and alarm information. It will also be used to transfer operator-initiated control commands to the controlling PLCs.

The premise driving these standards is the desire to promote consistency in graphical and tabular presentations of processes being monitored and controlled by the SCADA system. A common “look and feel” among displays will facilitate portability of staff, add to staff flexibility, and reduce training needs for operators and system maintenance staff.

To best provide HMI screens that are consistent with those in place in the City's SCADA system, multiple meetings between the screen developer and City are necessary. Those requirements can be found in §2.3.

11.5 HMI HIERARCHY

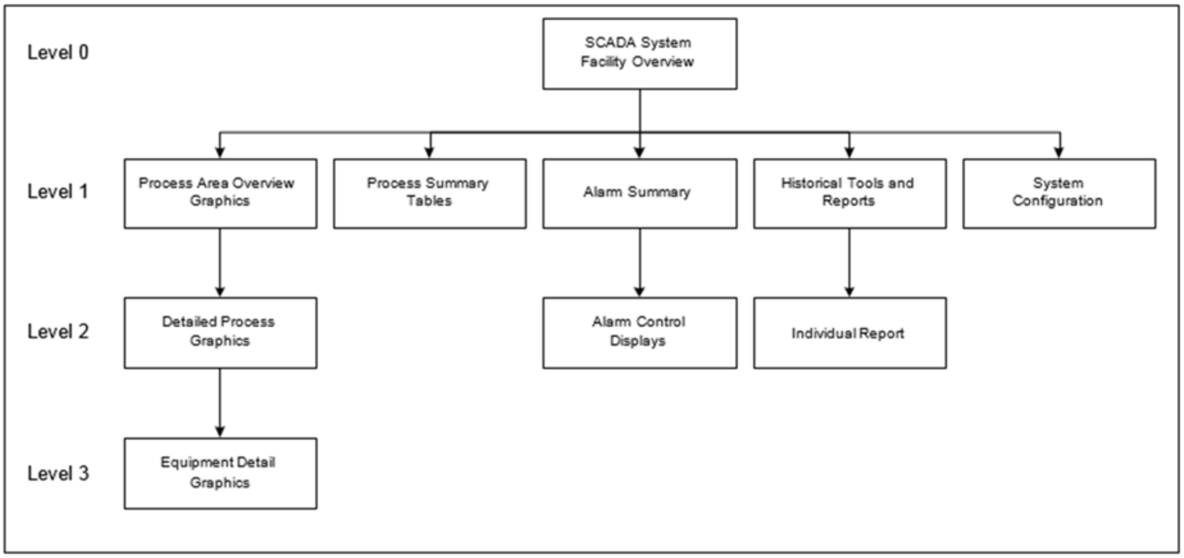
Displays shall be organized in a logical fashion to ease navigation through the processes, remote sites, equipment, and alarms. Defined herein are the general HMI hierarchy levels and types of displays. For display types, see Table 11.1.

Table 11.1 Display Types

Display Type	Description
Facility Overview (Level 0)	Represents the entire facility as a site plan or in a process flow diagram (PFD) format.
Process Area Overview (Level 1)	Represents equipment related to one specific process in P&ID-like format with little detail.
Alarm Summary	Display that provides a history of all alarm occurrences.
Detailed Process (Level 2)	Represents equipment, including related status and alarm text and related instrumentation in P&ID format.
Equipment Detail (Level 3)	Represents all status and alarm conditions, as well as control buttons for individual pieces of equipment.

General relations of the displays are shown in Figure 11.1 below.

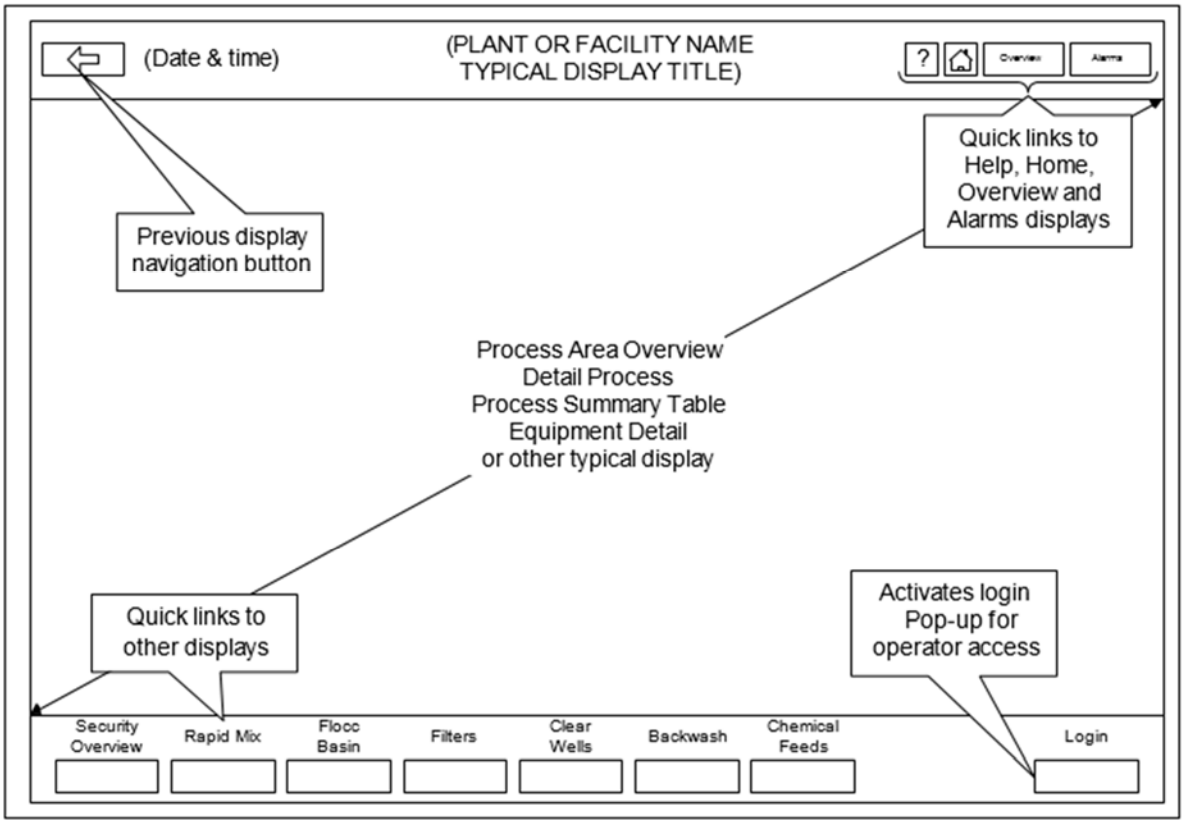
Figure 11.1 Display Hierarchy



11.6 HMI DISPLAY LAYOUT

The general layout of the Facility Overview, Process Area, and Detailed Process Area graphics should have sections of the display which are consistently assigned to specific functions and information. For example, the Water Department desires to always have date and time in the upper left corner and the display title centered at the top. Each of these graphic screens should additionally be provided with global navigation buttons, pull-down menus, pop-up windows, etc. Figure 11.2 demonstrates the layout that shall be followed for all graphic screens.

Figure 11.2 Typical Graphic Screen Layout



Displays shall be designed using a resolution of 1024 by 768 pixels and a 24-bit color palette. Graphic displays should flow from left to right, top to bottom. Processes enter on the left and exit to the right. In each system, one screen shall be developed with all the important and frequently used information and controls. Equipment placement need not be spatially or geographically correct.

11.7 HMI DISPLAY CONTENT

HMI graphics should represent major pieces of equipment, piping, valves, and gates schematically. HMI graphics are not meant to depict all pipe fittings and similar ancillary devices. In general, overview type displays should have less detail than process or equipment detail type displays. Any piece of equipment with associated controls should be represented on an HMI equipment detail graphic. Manual isolation valves should only be shown as deemed helpful by operations staff. Help screens shall be configured to direct operators to the appropriate SOP for the process depicted. The help screen shall additionally direct the operator to other screens or offline documentation for details concerning the piping and associated isolation valves.

Any equipment shown on the HMI graphic should be designated with its tag number shown directly above a common description of the equipment. Additionally, the position of any local control switch, like an LOR, should be shown in proximity to the equipment.

11.8 PROCESS AND EQUIPMENT SYMBOLS

The HMI software package includes an extensive library of process and equipment representations. The City of Aurora utilizes iFix dynamo objects for pumps, valves, indicators, tanks, blowers, pipes, etc. Use these pre-made objects and their complete functionality where applicable.

Additionally, there may be custom symbols created by the Water Department. Before undertaking any HMI graphic development task, the programmer shall review the acceptable symbols with the Water Department staff to match existing or planned graphic standards.

11.9 NAMING CONVENTIONS

When provided by a Consultant or Contractor, the naming of HMI related hardware, software files, and database entries must follow specific conventions. This applies to server and work station node names, display file names (screen names), tag groups and database point names. In general, the names include an abbreviation of the site or facility with which it is associated. The table below includes a list of facility/site abbreviations currently being used in the construction of database point names. More detail on the naming convention for each application is provided in the sub-paragraphs below. It is important to note that all HMI related naming assignments must be reviewed and approved by the Water Department staff prior to any configuration or programming activities. See Table 11.2 for example facility/site naming abbreviations.

Table 11.2 Facility/Site Naming Abbreviations	
Abbreviation	**Facility/Site**
APS	Aurora Pump Station
BP	Binney WPF
CCW	Cherry Creek Wells
EBEND	Eagle Bend
FRA	Front Range Airport
GUN	Gun Club
INTER	Intertie
POWPS	Powhaton Pump Station
PRV02	PRV02: Potomac PRV
QUIN	Quincy
RAMP	Rampart
SMH	Smoky Hill
SSP	Strontia Springs
WP	Wemlinger WPF
GP	Griswold WPF
SP	Sand Creek RWF
WF	Wemlinger Field SCADA site
SF	Sand Creek Field SCADA site

11.9.1 Graphic Display File Naming

The workstation operating system does not significantly restrict the length of file names; hence abbreviations are not needed in describing the facilities, equipment, processes, or screen function. Display file names associated with monitoring/controlling plant processes are a concatenation of the facility name and a descriptor of what is represented on the HMI graphic. Some examples include “WPWemlingerOverview”, “SPScreening”, and “GPBackwash”. Display file names associated with remote sites like Field SCADA sites are a concatenation of the Field SCADA server name (an abbreviation) and a descriptor of the process or equipment that is represented on the HMI graphic. An example of a Field SCADA display file name is “WFSmokyHillOverview”.

11.9.2 Database Tag Naming

The database point tag names are mnemonic in construct and may include ISA function names and the point's numeric loop as it relates to the associated instrument or equipment as defined in Section 2 - Instrumentation Guidelines and Section 4 - PROCESS AND INSTRUMENTATION DIAGRAM GUIDELINES. These tag names are a concatenation of the site abbreviation, process, the process equipment and its purpose. iFix database tag names are identical to their corresponding PLC I/O names. The Instrumentation and Controls team provides tag names to the HMI team.

11.9.2.1 Database Description Naming

Database descriptions are displayed as part of the alarm message in the alarm summary. Database descriptions and labels need to be meaningful to plant operators.

Alarms from many different areas are alarmed on one iFix node. The description needs to contain enough information so operators can determine exactly what piece of equipment the alarm or trend graph refers to and what the problem is with that equipment.

11.9.3 Tag Group Naming

Tag Groups shall be a concatenation of the facility abbreviation (see Table 8.2), the type tag group and the ISA function abbreviation. Examples include "WPTRENDFIT02," "NCTRENDMTPSCTRLSHPUMP1," and "WPTRENDSMOKYHILLTANKLEVEL."

11.9.4 Node Names

Proficy iFIX node names are assigned by Water Department staff.

11.10 HMI COLOR CONVENTIONS

Standard colors shall be used for display of static and dynamic elements, analog values, graphics background, tables, text and flow streams. The following sections provide examples of color assignment for possible applications. All preliminary and final assignments of color must be approved by the SCADA/HMI office prior to any configuration work.

11.10.1 Standard Color Palette

The standard color palette shall be as shown in Table 11.3. The graphic display system should use a limited number of colors. The Water Department has selected colors that shall be used as detailed herein. Wherever possible, standard RGB levels have been used to further define the individual colors such as "red", "blue", etc. Within these standards, the intensity for Hue, Saturation (Sat), Luminance (Lum), Red, Green, and Blue have been defined for commonality between programmers and HMI packages. Following below are the colors referenced in the standards and the associated attributes for each defined color.

Table 11.3 Standard Color Palette						
Color	**Hue**	**Sat**	**Lum**	**Red**	**Green**	**Blue**
Black	160	0	0	0	0	0
Blue	160	240	120	0	0	255
Dark Blue	160	240	60	0	0	128
Cyan	120	240	180	128	255	255
Dark Cyan	133	240	90	0	128	192
Gray	160	0	181	192	192	192
Dark Gray	160	0	120	128	128	128
Light Gray	160	0	206	219	219	219
Green	80	240	120	0	255	0
Dark Green	80	240	60	0	128	0
Light Green	80	240	180	128	255	128
Magenta	220	240	60	128	0	64
Dark Magenta	220	240	39	83	0	41
Red	0	240	120	255	0	0
Dark Red	0	240	60	128	0	0
White	160	0	240	255	255	255
Yellow	40	240	120	255	255	0
Brown	20	240	60	128	64	0
Light Brown	24	126	135	202	155	85
Orange	20	240	120	255	128	0

11.10.2 Non-Dynamic Element Color Conventions

Static element color conventions shall be as shown in Table 11.4. Process flow stream color conventions shall be as shown in Table 11.5. Non-dynamic elements in graphic displays include static text, static symbols, graphic display background and process flow streams. This section includes the requirements for general static elements and process flow stream color conventions.

Table 11.4 Static Element Colors	
Static Elements	**Color**
Static Text:	Black
Display Titles	
Equipment Identifiers	
Button Labels	
Display Background	Light Gray
Static Equipment Symbols:	Dark Gray
Isolation Valves	
Flow Meters	
Similar Devices	
Static Process Symbols:	Dark Gray
Basins	
Filters	
Vessels	

Table 11.5 Process Flow Stream Colors	
Process Flow Stream	**Color**
Main Process Flow Streams:	
Raw Water	Standard 3D Piping
Settled Water	Standard 3D Piping
Filtered Water/Effluent	Standard 3D Piping
Final Water	Standard 3D Piping
Raw Sewage	Standard 3D Piping
Primary/Secondary Effluent	Standard 3D Piping
Secondary Process Flow Streams:	
Recovered Water	Standard 3D Piping
Mixed Liquor/Return	Standard 3D Piping
Return/Waste Activated Sludge	Standard 3D Piping
Primary/Secondary Scum	Standard 3D Piping

Table 11.5 Process Flow Stream Colors	
Process Flow Stream	**Color**
Minor Process Streams and Chemical Feed Lines:	
Alum	Yellow/Green Bands
Ammonia (Aqueous and Gaseous)	Yellow/Brown Bands
Calcium Thiosulfate	Dark Gray/Green Bands
Carbon	Black
Chlorine and Sodium Hypochlorite	Yellow
Ferric Chloride	Orange
Hydrofluosilicic Acid	Yellow/Blue Bands
Lime	Light Brown/Green Bands
Oxygen	Light Green
Ozone	Orange/Green Bands
Polymer	Light Brown/Red Bands
Potassium Permanganate	Orange/White Bands
Residuals	Light Brown/White Bands
Sodium Hydroxide (Caustic)	Orange/Brown Bands
Service Water	Black
Sample Lines	Black
Plant Air, Instrument Air	Light Green/Dark Green Bands

11.10.3 Dynamic Element Color Conventions

Color conventions for two-state devices shall be as shown in Table 11.6. Color conventions for valves shall be as shown in Table 11.7. Dynamic elements consist of symbols and texts for both analog and discrete signals. Color is used to indicate equipment status, operational mode, alarm, valve position and quality of process signals. Equipment status indicates whether the device is running or stopped. Equipment mode indicates whether the device is being controlled locally or through the computer control system. Alarm indication may represent low, high, or critical priority alarms. The quality of the process signal may indicate out-of-service, inhibited alarms or off scan. Symbols and text should flash to indicate unacknowledged alarms and signals not being scanned.

Table 11.6	**Color Conventions for Two-State Devices**	
Element	**Color**	**Usage**
	Green	Running, On, In-Service
	Red	Stopped or Off
Backwash	Light Blue	Stand-By
Filter to Waste	Yellow	

Table 11.7	**Color Conventions for Valves**	
Element	**Color**	**Usage**
	Green	Fully Open
	Red	Fully Closed
	Yellow	In Transition
	Red-Flashing	Unacknowledged Alarm

11.10.4 <u>Bar Graph Color Conventions</u>

Typical uses for bar graphs on graphic displays include tank level, pump speed, and process set points. Bar graphs should be used as needed on process detail graphic displays, equipment detail graphic displays, or control function pop-up windows. Bar graphs shall always be a steady state color and should not change color or flash.

The City of Aurora will provide sample pictures to the developer.

11.10.4.1Dynamo Color Conventions

Dynamo color conventions shall be as shown in Table 11.8. Typical uses for dynamos on graphic displays include tank levels, pump status, valve status, and blower status. Dynamo objects should be used as needed on process detail graphic displays, equipment detail graphic displays or control function pop-up windows. Dynamo objects shall always be a steady state color and should not change color or flash.

Table 11.8	**Color Conventions for Valves**	
Element	**Color**	**Usage**
	Green	On/In Service
	Red	Off/Out of Service
	Yellow	In Transition
	Red-Flashing	Fault

11.10.5 Dynamic Text

Dynamic text is used to represent discrete or analog signals being monitored by the SCADA system including analog process variables, alarms and equipment mode and status. Dynamic text should employ color to indicate status, alarms, and process signal quality. In addition, dynamic text representing an alarm condition should flash until the alarm has been acknowledged. Dynamic text color conventions are summarized in the following paragraphs.

11.10.5.1 Analog Text

Analog text and background colors shall be as shown in Table 11.19.

Table 11.9 Color Conventions for Analog Text

Element	Text Color	Background Color	Usage
	Black	Gray	Normal

11.10.5.2 Alarm Summary Text

Alarm summary text and background colors shall be as shown in Table 11.10. City of Aurora standard colors for alarm priorities must be maintained.

Table 11.10 Color Conventions for Alarm Text

Element	Text Color	Background Color	Usage
Critical	White	Red	
HiHi	White	Gray75	
High	White	Bright Red	
Medium	White	Magenta	
Low	White	Bright Blue	
LoLo	White	Green	Comm
Info	White	Comm	

11.10.5.3 Equipment Mode and Status

Equipment mode and status text colors shall be as shown in Table 11.11. Equipment mode text is used to indicate if the equipment is set to be controlled manually or automatically and either locally, at the process control panel, or through the computer control system. Text used to indicate equipment status should be used on equipment detail graphics and control function pop-up windows to indicate control mode and equipment conditions. Equipment status text should not be used on process area graphic displays and on process detail graphic displays.

Table 11.11 Color Conventions for Equipment Mode			
Element	**Text Color**	**Background Color**	**Usage**
Equipment Status Text (Equipment Detail Graphic:	Black	Transparent	All occurrences

11.11 HMI TEXT SIZE AND FONT

Arial text shall be used for all process graphics and tabular displays. Font size shall be 16 point bold for screen titles and 10 point bold for all other text. Exceptions may be approved by Aurora Water.

11.12 HMI TABULAR DISPLAY CONVENTIONS

Tabular displays are useful for displaying on one graphic display information for multiple trains or to compile all relevant data from a facility. Tabular display formats shall be reviewed with Water Department staff prior to implementing the screen configuration.

11.12.1 iFIX DATABASE

The iFix Process Database holds various Function Blocks that can be defined using the iFix Database Manager. The main purpose of these Function Blocks is:

- To map device specific I/O addresses into meaningful tag names.
- To take raw data from a device or PLC as provided by an iFix I/O driver or OPC server and scale it to meaningful real-world value.
- To monitor and report alarm conditions on these values.
- To perform other higher-level processing functions using this data such as PID control and statistical monitoring.

11.12.2 Database Blocks

Use Analog Input (AI), Analog Register (AR), Digital Alarm (DA), Digital Input (DI), Digital Register (DR), Event Action (EV), and Multi-State Digital Input Block (MDI) blocks. Any other database block requires the approval of Aurora Water.

11.12.3 Scan Time

The default scan time value is five seconds. The scan time interval may be adjusted appropriately based on how often values are changed or needed to be collected.

11.12.4 Alarms

Enable alarming on DI database blocks only. Do not enable alarming on AI database blocks.

Set the appropriate alarm areas to database blocks and alarm destinations. Set alarm limits. Set alarm priority.

11.12.5 Security Area

This is the plant area designation the node serves.

11.12.6 Labels

Use the most descriptive and appropriate narrative to indicate the action. For database blocks that have alarming enabled, use “ALARM” in the close state and leave the open state blank. Aurora Water must approve any database point that alarms on anything other than close.

11.12.7 Tag Group Editor

Use the Tag Group Editor whenever a single picture can be used to display more than one nearly identical process or groups of equipment. An example of this is the North Campus Recovery Well Pumps one through twenty-seven; Tag Group NCRCVRYWELLPUMP*.TGD, where the * represents a pump number. These pictures display identical data for each pump.

11.13 HMI CONTROL FUNCTIONS

Pop-up windows shall be used to provide access to control functions for all equipment controlled by the SCADA system. If the pop-up window is larger than one-half of the full-size display, then a separate graphic display should be provided for the control functions.

Auto-manual control stations should be configured as pop-up windows which provide the user a means of switching equipment modes, controlling equipment in-manual, entering set points and providing relevant equipment status information. Targets to higher-level control functions should appear “unavailable” and should not function if the user does not have the appropriate authority level.

11.13.1 Auto-Manual Discrete Stations

Discrete control stations should be configured for equipment such as constant speed pumps and open-close valves. Functions such as start, stop, auto and manual should be accessed by selecting the appropriately labeled button. The button does not remain depressed; however, the text color changes to provide visual feedback to the operator.

Status, alarm conditions, and process variables that aid the user in performing control functions and are not readily available on the current display should be included in the popup window. Examples include selector switch status, control parameters and calculated values.

11.13.2 Auto-Manual Analog Control Stations

Analog control stations should be configured for variable speed pumps, chemical feed control, modulating and throttling valve control and similar processes. Functions such as start, stop, auto, and manual should be accessed by selecting the appropriately labeled button. The button does not remain depressed; however, the text color changes to provide visual feedback to the operator.

Status, alarm conditions and process variables that aid the user in performing control functions and are not readily available on the current display should be included in the pop-up window. Examples include selector switch status, control parameters and calculated values. Dynamic text should follow the color conventions defined in this section.

Process variables (PV), set points (SP) and output points (OP) should be displayed as dynamic analog text and as bar graphs in the pop-up window. Dynamic analog text and bar graphs shall follow the color conventions defined in this section. Bar graphs should be scaled in the appropriate engineering units. Windows-style check boxes and options buttons may be used to select control modes and other parameters.

11.13.3 PID Tuning Stations

PID Tuning Stations should be configured as pop-up windows which provide the operator a means of switching equipment modes, controlling equipment in-manual, entering set points, and entering PID tuning parameters. The PID Tuning Station should include a trend which, at a minimum, displays the process variable, set point, and output point.

PID Tuning Stations should be accessed by selecting the button target labeled “PID Tune” on the associated Auto-Manual Analog Control Station. PID Tuning Stations should include discrete control functions, process variables, controlled variables, and set point functions similar to the auto-manual analog control stations. The PID Tuning station may display other process variables as needed to aid the user in tuning the PID loop but should not include detailed status, alarm or control mode normally shown on the analog control station or on the current display.

11.14 HISTORICAL AND REAL-TIME TRENDS

Historical and real time trend colors shall be as shown in Table 11.12. Historical and real time trends should be accessible from the HMI display system. The trending and reporting display should include Windows-style pushbuttons which navigate the user to pre-configured or ad-hoc trends. General display criteria for trends include the following:

Table 11.12 Color Conventions for Trends	
Background Color	Gray
Pen Colors	Automatic or manual Assignment at creation
Pen Quantity	Six Maximum
Axis Labels	Individual engineering units on Y-Axis
Stacked Trends	Three maximum

12.0 PROGRAMMING WORKSHOP

12.1 Introduction

For projects involving the addition of new PLCs or modifications to existing PLC code, the designer, integrator, and programmer shall schedule a programming workshop with the City of Aurora SCADA Team. The ICSC personnel physically performing the programming (PLC or HMI), regardless of prior experience programming COA PLCs / HMI, must attend this workshop. If different personnel will be programming the PLC versus the HMI, then each of the personnel must attend this workshop, other personnel are optional. This programming workshop needs to be scheduled and held prior to initiation of any programming performed. No copies of existing PLC programs or screens will be provided prior to the programming workshop.

Workshop Requirements

General workshop requirements include:

- Workshop will be scheduled for at least four hours. Depending on project size and complexity, additional time may be necessary. The duration shall be determined by the COA SCADA Engineer prior to scheduling this workshop.
- The individual(s) responsible for performing the programming for the ICSC is (are) required to be present at this workshop. If different individuals will be performing PLC and HMI programming those individuals must also be present.
- The location of the workshop needs to be able to display a laptop screen via projector or flat screen TV large enough for attendees to satisfactorily view the screen details.
- The location of the workshop must accommodate the ICSC programmer, and COA SCADA Engineer. Additional personnel may be asked to attend at the discretion of the Project Manager or Site Owner.
- The ICSC will propose workshop dates at least one week in advance for proposed dates of the workshop in order for COA SCADA to determine and approve the availability of the required COA personnel. Only after approval from the COA SCADA Engineer shall the

workshop be scheduled. Once approved, the ICSC shall provide a meeting invite (preferably via Microsoft Outlook) with date, time, and directions to the workshop facility.

This workshop will be led by the COA SCADA Engineer. The purpose of the programming workshop is to ensure the ICSC is well versed in the required COA Standard TAG naming convention and standard programming and screen architecture; utilizes the most recent AOI(s) and UDT(s) that exist within the COA SCADA programming library; is made aware of any potential programming updates or any other nuances associated with PLC or HMI code that has been modified to benefit maintenance or security. The workshop also ensures that updates to this "living" DEGs document are implemented.

COA SCADA personnel will discuss examples of template PLC programs and OIT/HMI screens and highlight the specific programming standard requirements. COA SCADA will provide the ICSC a copy of the programs that were reviewed at the conclusion of the workshop.

Following the workshop, the ICSC shall provide the COA SCADA Engineer an Excel spreadsheet of the intended I/O list with associated TAG names from the PLC to OIT to Headend (if applicable) to/from HMI. Once the I/O list with associated TAG names is approved, the ICSC shall initiate programming. The ICSC shall provide a preliminary draft of the PLC code and HMI screens / database for COA SCADA to review, in order to ensure the ICSC is following the standards requirements outlined in the workshop.

The ICSC is required to provide the COA SCADA Engineer the PLC program(s) and HMI screens for review. The final programs / screens must be approved by the COA SCADA Engineer prior to scheduling of the Factory Acceptance Test (FAT) and any on-site activities.

13.0 FACTORY ACCEPTANCE TEST (FAT)

The FAT is to be performed prior to site delivery of any panels or control system equipment and scheduled only after the PLC, OIT, and Head End, HMI programming has been reviewed and approved by COA SCADA. The ICSC shall schedule the FAT for one-week duration for each control panel provided within the scope of the project, in a facility capable of housing the networked system and the team (personnel) performing the FAT (inclusive of COA invitees - see below).

13.1 Introduction

The Factory Acceptance Test demonstrates all SCADA and controller software, hardware, and panel components are working properly and all software configurations match the requirements identified within the design, including detailed process narratives, operating manuals, and logic flow chart diagrams. The goal is to identify and resolve any problems in the control system (Field Device → PLC → OIT → HMI) before it arrives at the installation site.

All equipment shown on the network architecture drawings shall be connected and tested for interoperability, including equipment address, I/O mapping, and any failover measures. If the project involves multiple components that communicate with one another as a system, those components shall be set up together (i.e. ten new recovery well panels, or three filter panels) at the factory or other location if the integrator's facility does not suffice. The Contractor shall also demonstrate network operation of all network switches, media converters, and servers. Additionally, the panels to be tested shall be fully built and wired prior to scheduling the FAT. Incomplete assembly, like a panel with a back plane hanging from a crane, missing PLC cards, or missing UPS is not acceptable. COA SCADA reserves the right to cancel FAT activities if the panels are found to be incomplete upon arrival on the first day of the FAT. The ICSC will be responsible for properly completing the panels(s) in question to the satisfaction of COA SCADA and then reschedule the FAT.

For the physical testing, the ICSC will provide analog and discrete sourcing devices for use on each I/O point, including spares, to ensure field terminals are correctly mapped to the PLC and that any displays show correct signal and confirm control panels are wired per shop drawings. The ICSC shall provide an I/O check list (see below for more detail) for all I/O that will be tested from the field terminal blocks, to the individual PLC card channels, to the PLC, to the OIT, to the Head End PLC (if applicable), and finally to the HMI screens and database. The return path shall also be tested. This checklist will be signed off by the Lead COA SCADA Technicians (I&C and HMI) witnessing the FAT.

Once the communication and I/O testing has been completed and approved, the ICSC will provide as many sourcing devices as required to functionally test the PLC program under normal control narrative process conditions to ensure the software contains no defects. This testing shall include a wide range of operating scenarios for all process set points, interlocks, and alarm limits. The Site Owner shall be invited to this portion of the FAT. The ICSC shall provide a functionality check list that allows the SCADA technicians and Site Owner to sign off that the system operates as described in the control narrative.

Once the functional testing has been approved, the FAT will proceed into "break" testing. The "break" testing will be identical to the functional testing except it tests typical failure scenarios experienced by the Site Owner. Examples include simulating a running wetwell pump, then fail the level transmitter; simulate a pump fail in the middle of a pump rotation; source an analog signal outside of a 4-20mA range. This confirms the system responds in a manner acceptable to the Site Owner.

The I/O, functional, and "break" testing must be reviewed and approved by COA SCADA and the Site Owner prior to scheduling of the required Site Acceptance Testing.

13.2 Testing Requirements

The general testing procedure should outline the details to be addressed in the FAT. These should include the following:

- The location and dates of the FAT.
- A check list inclusive of all I/O, from field terminal blocks to the PLC, to the OIT, to the Head End PLC (if applicable), and to HMI - with an area for the lead SCADA technicians to individually sign and date. The return path shall also be tested.
- A check list inclusive of each aspect of the control narrative with an area for the lead SCADA technicians and site owner to individually sign and date.
- A blank check list form to document the individual “break” test conducted during the FAT with an area for the Lead SCADA technicians and site owner to sign and date.
- Specification of the revision levels of the hardware and software to be tested.
- Specification of the exact configuration of equipment being tested.
- Personnel safety issues that may apply during the test.

The ICSC and Aurora Water SCADA personnel shall conduct the tests. The City reserves the right to test any specified hardware/software function whether or not explicitly stated in the design.

Two members of the City of Aurora SCADA team (one HMI and one I&C specialist) shall be designated by the COA Project Manager as the team project lead for the FAT. The City of Aurora SCADA team project lead is to invite the following representatives or the following groups to attend the FAT:

- Facility Operations.
- Process End Users.
- Aurora Water Instrumentation and Controls technicians.
- Aurora Water HMI technicians.
- Vendor personnel responsible for the software programming/configuration.
- Vendor personnel responsible for the hardware integration.
- Additional support personnel as deemed necessary.

The number of participants depends on the technologies involved and the size and complexity of the system to be tested.

The ICSC shall schedule for one week of Factory Acceptance Testing per panel. The City is the sole decider in modifying these durations. Limit testing to seven hours per day. Hold a meeting each morning to review the day’s test schedule as well as a meeting after that day's testing to review the test results and review or revise the subsequent day’s test schedule. At the completion of all testing, meet to review the list of deficiencies. The City of Aurora will indicate those items which must be corrected prior to sign-off.

For projects with multiple panels that communicate with one another, each of these panels must be at the FAT. They shall be connected or networked as shown on the block diagram using the appropriate media connection, e.g. copper, fiber, or wireless. All efforts should be taken to include networked equipment at the FAT, including VFDs, instruments, Vendor packaged controls, and 3rd party panels.

The FAT shall test every I/O point, including ON/OFF status for discrete signals and full range for analog signals, from the field terminal to the PLC and OIT/HMI. This loop test will include all intermediate equipment including network switches and media converters, as well as Head End communications if radio is utilized on the project.

13.2.1 Detailed Test Procedure

The FAT shall test all I/O from the field terminal blocks, to the individual PLC card channels, to the PLC, to the OIT, to the Head End PLC (if applicable), and finally to the HMI. The return path shall also be tested.

- A description of an analog signal loop test for all I/O in the system using the proper test equipment.
  - Inputs should be simulated at 0%, 25%, 50%, 75% and 100% signal input.
  - Outputs should be monitored at 0%, 25%, 50%, 75% and 100% of output level.
- A description of a typical method for testing each classification of software programs in the system, including but not limited to interlocks, special calculation blocks, and batch control programs.
- A description of what checks are to be made on graphic displays. These should include graphic layout, color specifications, text, touch areas, paging functions, point addressing, and any system-specific items.
- A description of the method to ensure proper DCS tag point configuration. Included in this check should be a point range, signal conditioning, alarm settings, and point type.

- Provision for a method for checking all other aspects of the system, for instance visual checks, trends, logs, and system failures.

13.3 Testing Forms

For every panel being tested, submit an example of a test form for approval. For all points:

- List the device tag name.
- RPU Tag Name.
- Description of the Point.
- RPU I/O Address if applicable.
- Date Verified.
- Comments.
- Issue Log Number.

For field inputs and outputs also list:

- HMI/RPU Address.
- I/O Type.
- Rack.
- Slot.
- Remote I/O Block if applicable.
- Module Point.
- RPU Device Range (Minimum, Maximum, and Units).
- RPU Range Raw Signal Test (Minimum, Mid-range, and Maximum).
- HMI Device Range (Minimum, Maximum, and Units).
- HMI Engineering Units (Minimum, Mid-range, and Maximum).

For analog input alarms:

- Trip point for the alarm in percent.
- Engineering Units.

- Time Delay.
- Alarm ACK.
- Operator Control (Adjust Trip point and Disable).
- Alarm Area.
- Alarm Priority.
- Paging Group and Data Transfer Frequency.

For discrete input alarms:

- Time Delay.
- Alarm ACK.
- Operator Control (Disable).
- Alarm Area.
- Alarm Priority.
- Paging Group and Data Transfer Frequency.

For all alarms: Show and Test each alarm is conditioned as documented in the process control narratives.

For trended points:

- List trending attributes.
  - Frequency.
  - Deviation.
  - Data Transfer Frequency.

Provide a row for each transition to be tested as shown in Table 13.1:

Table 13.1 Process Logic Test			
Current State	**Action/Transition**	**Final State/Effect**	**Comments**
List the tags and their current state relevant to testing the transition or action and observing the final state or effect.	Describe the action or transition that is being tested, e.g. Field Mounted Start P.B. is Depressed.	List the tags and their expected final state.	During the test, note any deviation from the expected final state or effect.
List the HMI symbol, color and shape.		List the HMI symbol expected color and shape.	

Normal Device Operations:

- Local Mode Operations.
- Remote Manual Mode Operations
- Transfer from Local to Remote.
- Transfer from Remote to Local
- Remote Automatic Mode Operations.
- SCADA/Automation.

Abnormal Device Operations:

- Uncommanded Operations.
- Unresponsive Commands.
- Device Operation Permissives.
- Device Alarms.
- Emergency Stop.

Additionally, the test forms at the end of this section are provided as a starting point for the development of project specific test forms. They are not intended to be complete nor are they applicable to all projects:

13.4 Sign-Off Requirements

All test results of the FAT shall be documented; include whether or not the objectives and criteria of the testing have been met. Discovered weaknesses or failures during testing shall be documented; include reasons for the weaknesses or failures along with necessary actions to correct the weaknesses or failures.

If the FAT reveals weaknesses or failures in the design and engineering phase or in the safety requirements specification phase, these phases must be modified according to the result of the FAT. In order to verify the modifications meet engineering and safety requirements, the system must be re-tested and approved by COA SCADA. The associated panels may not be shipped from the factory until the FAT has been approved by COA SCADA.

13.4.1 Equipment Acceptance

The equipment shall only be released for shipping upon approval of the FAT. Once COA SCADA has approved the FAT to be concluded, an official document shall be signed by both the City of Aurora project team lead and by the Vendor. The acceptance document will identify whether open items on the punch-list are to be resolved in the field or prior to shipping. The City of Aurora has the right to return to the factory to asses any items that were agreed to be resolved at the factory.

Figure 13.1 SCADA I&C Checklist

PLC Tag	Description	Array Tag	Head End	VERIFIED? (DATE AND INITIAL)				TEST W/O FLOW?
				PLC	OIT	HEADEND	HMI	
PLNT_NRTH_FIT101.INDPV	North Plant Flow Meter 1	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[0]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[0]					
PLNT_NRTH_FIT102.INDPV	North Plant Flow Meter 2	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[1]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[1]					
PLNT_NRTH_FIT103.INDPV	North Plant Flow Meter 3	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[2]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[2]					
PLNT_NRTH_PMP101.ALMFAIL	North Plant Pump 1 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].0	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].0					
PLNT_NRTH_PMP101.ALMRNG	North Plant Pump 1 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].1	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].1					
PLNT_NRTH_PMP101.ALMTEMP	North Plant Pump 1 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].2	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].2					
PLNT_NRTH_PMP101.ALMLEAK	North Plant Pump 1 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].3	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].3					
PLNT_NRTH_PMP102.ALMFAIL	North Plant Pump 2 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].4	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].4					
PLNT_NRTH_PMP102.ALMRNG	North Plant Pump 2 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].5	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].5					
PLNT_NRTH_PMP102.ALMTEMP	North Plant Pump 2 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].6	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].6					
PLNT_NRTH_PMP102.ALMLEAK	North Plant Pump 2 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].7	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].7					
PLNT_NRTH_PMP103.ALMFAIL	North Plant Pump 3 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].8	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].8					
PLNT_NRTH_PMP103.ALMRNG	North Plant Pump 3 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].9	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].9					
PLNT_NRTH_PMP103.ALMTEMP	North Plant Pump 3 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].10	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].10					
PLNT_NRTH_PMP103.ALMLEAK	North Plant Pump 3 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].11	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].11					
PLNT_NRTH_PMP104.ALMFAIL	North Plant Pump 4 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].12	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].12					
PLNT_NRTH_PMP104.ALMRNG	North Plant Pump 4 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].13	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].13					
PLNT_NRTH_PMP104.ALMTEMP	North Plant Pump 4 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].14	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].14					
PLNT_NRTH_PMP104.ALMLEAK	North Plant Pump 4 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].15	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].15					

Figure 13.2 Factory Acceptance Test Forms

	FACTORY ACCEPTANCE TEST - CONTROL PANELS	

1. GENERAL INSPECTION

A. Structural Inspection

- ☐ Verify Lifting Lugs Installed
- ☐ Verity enclosure has lock and lock is functional
- ☐ Confirm that seismic bracing components are provided per manufacturer's installation instructions

B. Exterior Inspection

- ☐ Cabinet exterior is clean, scratch, and dent free
- ☐ Inspect externally for corrosion and damage
- ☐ Verify enclosure door opens and closes easily
- ☐ Verify enclosure has a 3-point latch
- ☐ Verify enclosure has a flange mounted disconnect (where voltages greater than 120 VAC enter the cabinet)
- ☐ Verify enclosure has the appropriate NEMA rating (1, 1G, 12, 3R, 4, 4X, etc)
- ☐ Verify enclosure is the appropriate size (not grossly larger than design, and will still fit in the plant)

Nameplates

- ☐ Cabinet has identification nameplate
- ☐ All door labels are straight, spelled correctly, and match the tagging defined in the Contract
- ☐ Cabinet has a nameplate that includes the following:
  - ☐ Power source(s)
  - ☐ Integrator's Logo
  - ☐ Circuit ID(s)
  - ☐ Short Circuit KAIC ratings
- ☐ If labels are screwed to door, silicone was utilized to cover screw holes (Labels screwed to the door of a NEMA 4/4X panel technically violates the NEMA rating.)

Door Devices

- ☐ All devices penetrating the outside of panel have gaskets, silicone or both
- ☐ All door devices are installed (OITs, Pilot Devices, etc)
- ☐ Door mounted equipment is mounted straight and square
- ☐ All exterior or door mounted equipment present and accounted for, installed and securely fastened
- ☐ NEMA classification has not been violated due to penetrations
- ☐ Door mounted equipment has the same NEMA rating as the panel
- ☐ All door mounted equipment installed at the correct height
- ☐ All door mounted equipment installed in the correct positions and order (layout of door mounted equipment is grouped properly and in a logical manner)
- ☐ Doors with multiple penetrations have adequate bracing (if needed)
- ☐ Visually check condition of indicators , controllers and annunciators
- ☐ Check that pilot lights illuminate correctly
- ☐ Check the Push-To-Test function
- ☐ Ensure correct pilot light color

Peripheral Devices

- ☐ Horn / Beacon is installed (where required)
- ☐ Silence and Reset pushbutton

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	FACTORY ACCEPTANCE TEST - CONTROL PANELS	

1. GENERAL INSPECTION (continued)

C. Interior Inspection

- ☐ Cabinet is cleaned of marks and dirt.
- ☐ Inspect internally for corrosion and damage.
- ☐ Back panel is clean of marks and dirt.
- ☐ Interior of panel vacuumed and shall be free of all debris.
- ☐ Check that the panel roof is clean and clear of foreign materials.
- ☐ Bottom of panel has been cut out (where bottom entry is required), with angle iron welded around the bottom perimeter. Re-painting has been performed.
- ☐ If internal light door limit switch is provided, ensure the light automatically turns "on" when the doors are open.
- ☐ Intrusion alarms (where required).

Interior Labeling

- ☐ All panel mounted equipment has identification labeling, by using either a Brothers or Phenolic type tags.
- ☐ Verify that door mounted components are mounted square and symmetrical.
- ☐ Verify that nameplates are straight, legible, and spelled correctly.
- ☐ All terminal blocks are identified/labeled with permanent labels including tight end blocks and caps.
- ☐ All wiring shrink labeled and or phased correctly to the specifications.
- ☐ All wire labels shrunk completely rotated and aligned alike for easy identification.
- ☐ All fuses and circuit breakers are labeled with ID and current rating.
- ☐ System Integrator’s label or labels installed on door.
- ☐ Panel manufacturer model/serial number tag is present.
- ☐ All required safety/warning tags installed and straight.
- ☐ Correct UL (typically UL 508) or cUL tag installed and registered and all other associated tags installed and straight (the UL tag might not be installed in the panel at the factory test. If the panel is modified due to changes during the factory test or a punch list generated from the factory test, the UL labeling would need to be re-applied. Some UL shops do not apply the UL label until the panel is released to be shipped.).

Wireways

- ☐ Plastic wire way covers installed properly.
- ☐ Plastic wireways have no sharp edges.
- ☐ No wire Ties inside the wireways.
- ☐ No sharp edges on wire ties.
- ☐ Separation: White duct is used for DC voltages, Gray duct is used for AC voltages.
- ☐ Ensure wiring duct is not over-full, includes provision for 20% more wiring and the cover may easily be installed. Panduit recommends 50% duct fill, but 40% is a better practice.

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	FACTORY ACCEPTANCE TEST - CONTROL PANELS	

1. GENERAL INSPECTION (continued)

C. Interior Inspection (continued)

Wiring

- ☐ Visually check terminals and condition of internal wirings
- ☐ Verify that the control panel has been assembled and wired as designed
- ☐ Verify that all components are operational and perform the functions intended
- ☐ Verify that all components are sized appropriately for the application
- ☐ Verify that equipment control circuits function as intended
- ☐ Back of door wiring is labeled and neatly formed
- ☐ Back panel to door wiring has sufficient bending radius with spiral wrap
- ☐ Wire connection has been verified wired to correct points within the panel
- ☐ Individual wires have been given a pull test to verify a good terminal connection
- ☐ Wire and cable minimum bending radius have not been violated
- ☐ All equipment installed straight and square to back panel
- ☐ Wire colors are correct:
  - ☐ Black and White > AC hot and neutral, respectively
  - ☐ Red > AC control signals
  - ☐ Blue > DC power and control (Blue w/White stripe for DC ground)
  - ☐ Yellow > Foreign voltages (those still present when panel power is disconnected)
  - ☐ Green > AC equipment ground
  - ☐ Black > TSP (+)
  - ☐ White> TSP(-)
- ☐ Analog wiring shields are continuous (connected by a dedicated terminal block for such shields)
- ☐ Analog shield wires are grounded within the panel, where not otherwise grounded at the transmitter itself
- ☐ Discrete inputs are separately fused or protected by a circuit breaker on a “per loop” basis
- ☐ Intrinsic Safety Wiring
  - ☐ Ensure wiring associated with intrinsic safety circuits or intrinsic safety barriers is kept away from all other wiring by UL minimum distances or by a physical (grounded metal) barrier preventing non-intrinsically safe wiring from coming in contact with intrinsically safe circuits or wiring
- ☐ Verify all spare terminals are installed according to the percentage listed in the specifications

Grounding

- ☐ Equipped with “Blackburn” or other grounding type lug
- ☐ Lug is securely fastened to the panel structure
- ☐ Verify Grounding bar is installed
- ☐ Verify Isolated ground bar is installed

PROJECT NAME: ______________________ TEST DATE: ____________

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2. POWER TEST

A. AC Power

- ☐ AC Power is routed correctly within the panel, and is isolated from DC and network wiring.
- ☐ All fuses are installed and sized properly.
- ☐ All breakers are installed and sized properly.
- ☐ 24 VDC Power Supplies are functional.
- ☐ 24 VDC Power fail contacts are functional.
- ☐ 24 VDC power supplies are redundant, and have diode modules enabling the hot swap-over between supplies.
  - ☐ 24 VDC supplies are equipped with dry contact failure alarms, wired as PLC inputs to signal failure of any DC power supply. Such alarm inputs to the PLC have been tested as being functional.
- ☐ Dedicated receptacle is wired to receive a dedicated AC supply.
- ☐ Verify continuity for all DC commons, ground and AC neutrals.
- ☐ Verify that the CP temporary input power is connected correctly and is the correct voltage.
- ☐ Close the CP main circuit breaker(s).
- ☐ Verify that voltages at subsequent circuit breakers are correct.
- ☐ Close circuit breakers.
- ☐ Verify that power feeding interruptible and uninterruptible power supplies is correct.
- ☐ Turn on power supplies if they are not already on.
- ☐ Verify that voltages at distribution terminals are correct.
- ☐ Energize any remaining hardware such as the PLC.

B. Uninterruptible Power Supply (UPS)

- ☐ Mounted appropriately within the cabinet, on a dedicated shelf, or rear of a swing-out sub panel.
- ☐ Is equipped with maintenance bypass switch (or at least plug/receptacle means for bypassing the unit).
- ☐ Test all UPS alarms (on inverter, failure, battery failure etc)
- ☐ Turn off the AC power supply and verify that the UPS will be switched on to supply the designated vital loads in the control panel.

3. CONTROLS & AUXILIARY DEVICES TEST

- ☐ Verify all interposing and auxiliary relays are functioning.
- ☐ Verify panel lights are functioning.
- ☐ Test or confirm OIT for screen illumination, touchscreen response, and accurate color representation.

Ventilation and Heating

- ☐ If ventilation fans are fitted, check the fans operate correctly any associated air filters are clean and not blocked.
- ☐ Verify components are installed in the correct orientation for proper air flow.

4. HARDWIRED INTERLOCK AND SAFETY TEST

- ☐ Verify that hardwired interlocks through the control panel as shown on schematic drawings are functioning. For example, outlet high pressure switch interlock to a pump.
- ☐ Verify that all hardwired safety devices through the control panel is functioning. For example, the pull cord emergency stops of conveyors.

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5. PLC TEST

A. Components

- ☐ PLC interior High Temperature alarm is installed, wired to the PLC, and is shown to be functional.
- ☐ Relays have transient suppression across their coils. This is particularly important for DC coil relays, where diodes in reverse polarity are often used.
- ☐ TVSS is installed across the main incoming 120 VAC.

PLC and PLC Rack

  - ☐ Verify all cards are securely seated.
  - ☐ Ensure clearance around PLC rack has been met, such that convective heat transfer is not impeded by devices erroneously mounted in the “no encroachment” area. Confirm with manufacturer clearance recommendations.

B. PLC I/O Test

- ☐ Furnish **I/O test forms** and test all the listed input and output points as follows:
  - ☐ Discrete Inputs: Simulate a field contact closure by “shorting” across the appropriate terminal blocks. Observe the transition between a logical “0” and “1” in the PLC software.
  - ☐ Discrete Outputs: Force the output bit to toggle between logical “0” and logical “1” using the PLC software. Measure contact resistance at the wired terminal blocks using a digital meter selected for the “ohms” setting.
  - ☐ Analog Inputs: Connect a signal generator to the appropriate terminal blocks. Tailor the connection depending on whether a 2-wire or 4-wire simulation is required. Modulate the 4-20mA signal. Observe the associated PLC internal memory register to transition between 0-65535 or if scaled in engineering units, between 0 and the maximum scaled engineering unit. The latter method is preferred.
  - ☐ Analog Outputs: Force the output register to a value between 0-65535 or 0-100%, if the scaling block can be manipulated. Observe the measured 4-20mA value increment and decrement using a digital ammeter.

C. Redundant Controllers (where required) Test

- ☐ Remove Communication cable from PLC-1 to verify switching to PLC-1A
- ☐ Remove Communication cable from PLC-1A to verify switching back to PLC-1
- ☐ Remove Power from PLC-1 to verify switching to PLC-1A
- ☐ Remove Power from PLC-1A to verify switching to PLC-1
- ☐ Remove Communication cable from PLC-1 to I/O rack and verify switching to PLC-1A
- ☐ Remove Communication cable from PLC -1A to I/O rack and verify switching to PLC-1

D. PLC Control Logic Verification

- ☐ The PLC control strategy is verified by following the Control Logic Verification Form based on the specifications. Each control strategy will be verified by simulating the process and checking the state or value of PLC outputs. The results of equipment status and alarms and process instrument values and trends shall also be verified on the Plant SCADA graphic screens stored in a temporary SCADA computer. Since all PLC input and output wiring has been verified and some field devices are not available during Factory Acceptance Testing, certain inputs will be simulated either by means of additional hardware and/or software as described below.
  - ☐ DI states are either simulated by hardwired switches or forced inputs using a programming terminal.
  - ☐ For example, when starters and drives are not provided as part of the contract, jumpers may be installed from the output call relays to the running confirmation inputs to simulate the running state of the motors.
  - ☐ AI values are either simulated by an external source or within software using a programming terminal.
  - ☐ For example, when a level transducer is not provided as part of the contract the level transducer loop current may be simulated with a loop powered potentiometer and adjusted manually for the level input.

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5. PLC TEST (continued)

D. PLC Control Logic Verification (continued)

Typical Fault Logic

- ☐ If the fault input is high and the disable (if applicable) for the fault is not high and the common disable (if applicable) is not high begin timing. If any of these conditions changes, stop timing and reset the timer. If the timer reaches its preset, activate the alarm output. If the fault alarm is a shutdown alarm stop the associated motor and latch the alarm so that it remains present even if the condition clears.
- ☐ The fault condition must return to normal and the alarm must be reset for a latched alarm to clear.

Typical Fail to Start Logic

- ☐ If the motor is called to run (call output high) and no running feedback is received (running input is low) and the fail to start and common alarm disables (if applicable) are not high start timing. If any of these conditions changes, stop timing and reset the timer. If the timer reaches its preset, activate the alarm output, stop calling the motor and latch the alarm.

6. HMI OR OIT TEST

HMI / OIT Functionality

- ☐ Communication with PLC
- ☐ Screen Layouts
- ☐ Screen Navigation
- ☐ Set Point Entry
- ☐ Animation
- ☐ Color Correctness (Green=Run, Red=Off, Amber=Alarm, or the agreed upon convention)
- ☐ Alarms
- ☐ Acknowledge and Reset
- ☐ Security / Access Levels / Passwords

7. NETWORK COMMUNICATION TEST

A. Network Components

- ☐ Fiber optic cabling terminates in a patch panel
- ☐ Media converters are installed and functional
- ☐ Terminating resistors have been installed for trunk/tap topologies or where required
- ☐ Wire and cable bending limitations have not been violated

B. Networking Functions

- ☐ Verify data transfer via the network to different PLCs as shown on the Network Block Diagrams
- ☐ Verify network traffic rate and error margin is acceptable

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8. FAT DOCUMENTATION AND RECORD

Panel Documentation

- ☐ As-built panel drawings showing actual panel construction and devices arrangement and c/w Bill of Material.
- ☐ Panel schematic and interconnection drawings.
- ☐ P&ID drawings and schematic drawings for the process area controlled by the panel that is to be tested.
- ☐ I/O list test forms of the process area to be tested.
- ☐ FAT procedure of the process area to be tested.
- ☐ Test record forms of the process area to be tested. Forms shall include area for signature of responsible test personnel.
- ☐ Hard copy of the PLC application program of the process area to be tested.
- ☐ Hard copy of the HMI/OIT graphic screens of the process area to be tested.

9. FAT TOOLS AND SOFTWARE

- ☐ Simulation software if required
- ☐ Digital volt meter Fluke 87
- ☐ Process meter Fluke 787
- ☐ Laptop computer with PLC application program
- ☐ Temporary SCADA computer with HMI software and applicable graphic screens
- ☐ Jumper wires

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14.0 SITE ACCEPTANCE TEST (SAT)

The SAT is to be scheduled on-site only after:

- The PLC, OIT, Head End (if applicable), and HMI programs have been approved by COA SCADA
- COA SCADA has completed and approved necessary Factory Acceptance Testing
- The equipment has been shipped to site (only after approved FAT)
- The panel equipement has been fully wired
- The ICSC has performed their pre-check. Note that this check is at the discretion of the ICSC or General Contractor.

14.1 Introduction

After the control system has been completely installed, the ICSC shall schedule the Site Acceptance Test. Site Acceptance Testing shall be identical to the Factory Acceptance Testing, except that instead of artificially sourcing analog and discrete signals, testing is conducted using the actual field devices and foreign device interfaces.

Site Acceptance Testing is meant to prove the delivered system, including the PLC control logic and operator stations, is interfaced to the site I/O correctly, undamaged, identical with the system tested at the factory, and performs in accordance with the project specifications. Site Acceptance Testing consists of repeating the Factory Acceptance Testing using the actual site instruments, I/O, and service connections once all site equipment has been installed and successfully tested.

14.2 Testing Requirements

The general testing procedure should outline the details to be addressed in the SAT. These should include:

- The location and date(s) of the SAT.
- A check list inclusive of all I/O, from field terminal blocks to the PLC, to the OIT, to the Head End PLC (if applicable), and to HMI - with an area for the lead SCADA technicians to individually sign and date. The return path shall also be tested.
- A check list inclusive of each aspect of the control narrative with an area for the lead SCADA technicians and site owner to individually sign and date.

- A blank check list form to document the individual “break” test conducted during the SAT with an area for the Lead SCADA technicians and site owner to sign and date.
- Specification of the revision levels of the hardware and software to be tested.
- Specification of the exact configuration of equipment being tested.
- Personnel safety issues that may apply during the test.

The Vendor and Aurora Water SCADA personnel shall conduct the tests. The City reserves the right to test any specified hardware/software function whether or not explicitly stated in the design.

Two members of the City of Aurora SCADA team (one HMI and one I&C specialist) shall be designated by the COA Project Manager as the team project lead for the FAT. The City of Aurora SCADA team project lead is to invite the following representatives or the following groups to attend the FAT:

- Facility Operations.
- Process End Users.
- Aurora Water Instrumentation and Controls technicians.
- Aurora Water HMI technicians.
- Vendor personnel responsible for the software programming/configuration.
- Vendor personnel responsible for the hardware integration.
- Additional support personnel as deemed necessary.

The number of participants depends on the technologies involved and the size and complexity of the system to be tested.

The ICSC shall schedule for one week of Site Acceptance Testing per panel. The City is the sole decider in modifying these durations. Limit testing to seven hours per day. Hold a meeting each morning to review the day’s test schedule as well as a meeting after that day's testing to review the test results and review or revise the subsequent day’s test schedule. At the completion of all testing, meet to review the list of deficiencies. The City of Aurora will indicate those items which must be corrected prior to sign-off.

The SAT shall test every I/O point, including ON/OFF status for discrete signals and full range for analog signals, from the field terminal to the PLC and OIT/HMI. This loop test will include all intermediate equipment including network switches and media converters, as well as Head End communications if radio is utilized on the project.

The SAT shall include a Site Owner or operator from the City of Aurora to provide guidance on 'break' testing to simulate commonly encountered system failures. “Break” testing shall be at the sole discretion of the City as some systems may not allow for “break” testing on a live City system. For this reason it is addressed during the FAT. This functional test shows how the logic responds to issues like transmitter failures or loss of communication.

14.2.1 Detailed Test Procedure

All aspects of the system are to be checked against system documentation.

- A description of a typical loop test for each type of I/O in the system using the proper test equipment.
  - Inputs should be simulated at 0%, 25%, 50%, 75% and 100% signal input.
  - Outputs should be monitored at 0%, 25%, 50%, 75% and 100% of output level.
- A description of a typical method for testing each classification of software programs in the system, including but not limited to interlocks, special calculation blocks, and batch control programs.
- A description of what checks are to be made on graphic displays. These should include graphic layout, color specifications, text, touch areas, paging functions, point addressing, and any system-specific items.
- A description of the method to ensure proper DCS tag point configuration. Included in this check should be a point range, signal conditioning, alarm settings, point types, and system specific items.
- Provision for a method for checking all other aspects of the system, for instance visual checks, trends, logs, and system failures.

14.3 Testing Forms

For every panel being tested, submit an example of a test form for approval. For all points:

For all points:

- List the device tag name.
- RPU Tag Name.
- Description of the Point.
- RPU I/O Address, if applicable.
- Date Verified.

- Comments.
- Issue Log Number.

For field inputs and outputs also list:

- HMI/RPU Address.
- I/O Type.
- Rack.
- Slot.
- Remote I/O Block if applicable.
- Module Point.
- RPU Device Range (Minimum, Maximum, and Units).
- RPU Range Raw Signal Test (Minimum, Mid-range, and Maximum).
- HMI Device Range (Minimum, Maximum, and Units).
- HMI Engineering Units (Minimum, Mid-range, and Maximum).

For analog input alarms:

- Trip point for the alarm in percent.
- Engineering Units.
- Time Delay.
- Alarm ACK.
- Operator Control (Adjust Trip point and Disable).
- Alarm Area.
- Alarm Priority.
- Paging Group and Data Transfer Frequency.

For discrete input alarms:

- Time Delay.
- Alarm ACK.
- Operator Control (Disable).
- Alarm Area.
- Alarm Priority.
- Paging Group and Data Transfer Frequency.

For all alarms: Show and Test each alarm is conditioned as documented in the process control narratives.

For trend points:

- List trending attributes:
  - Frequency.
  - Deviation.
  - Data Transfer Frequency.

Provide a row for each transition to be tested as shown in Table 14.1:

Table 14.1 Process Logic Test

Current State	Action/Transition	Final State/Effect	Comments
List the tags and their current state relevant to testing the transition or action and observing the final state or effect.	Describe the action or transition that is being tested, e.g. Field Mounted Start P.B. is Depressed.	List the tags and their expected final state.	During the test, note any deviation from the expected final state or effect.
List the HMI symbol, color, and shape.		List the HMI symbol expected color and shape.	

Normal Device Operations:

- Local Mode Operations.
- Remote Manual Mode Operations.
- Transfer from Local to Remote.
- Transfer from Remote to Local.
- Remote Automatic Mode Operations.
- SCADA/Automation.

Abnormal Device Operations:

- Uncommanded Operations.
- Unresponsive Commands.
- Device Operation Permissives.
- Device Alarms.
- Emergency Stop.

Provide a test form showing all networked equipment and the SCADA communication network. Confirm continuity between all nodes and show signals are correctly mapped from the field device, through any network equipment, and displayed on the HMI or OIT.

Additionally, the test forms at the end of this section are provided as a starting point for the development of project specific test forms. They are not intended to be complete nor are they applicable to all projects:

Figure 14.1 SCADA I&C Checklist

PLC Tag	Description	Array Tag	Head End	VERIFIED? (DATE AND INITIAL)				TEST W/O FLOW?
				PLC	OIT	HEADEND	HMI	
PLNT_NRTH_FIT101.INDPV	North Plant Flow Meter 1	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[0]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[0]					
PLNT_NRTH_FIT102.INDPV	North Plant Flow Meter 2	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[1]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[1]					
PLNT_NRTH_FIT103.INDPV	North Plant Flow Meter 3	PLNT_NRTH_COMMS_TO_HEAD_FLOAT[2]	NPT.HEADEND.RTU_PLC_PLNT_READ_FLOAT[2]					
PLNT_NRTH_PMP101.ALMFAIL	North Plant Pump 1 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].0	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].0					
PLNT_NRTH_PMP101.ALMRNG	North Plant Pump 1 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].1	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].1					
PLNT_NRTH_PMP101.ALMTEMP	North Plant Pump 1 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].2	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].2					
PLNT_NRTH_PMP101.ALMLEAK	North Plant Pump 1 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].3	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].3					
PLNT_NRTH_PMP102.ALMFAIL	North Plant Pump 2 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].4	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].4					
PLNT_NRTH_PMP102.ALMRNG	North Plant Pump 2 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].5	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].5					
PLNT_NRTH_PMP102.ALMTEMP	North Plant Pump 2 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].6	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].6					
PLNT_NRTH_PMP102.ALMLEAK	North Plant Pump 2 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].7	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].7					
PLNT_NRTH_PMP103.ALMFAIL	North Plant Pump 3 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].8	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].8					
PLNT_NRTH_PMP103.ALMRNG	North Plant Pump 3 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].9	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].9					
PLNT_NRTH_PMP103.ALMTEMP	North Plant Pump 3 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].10	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].10					
PLNT_NRTH_PMP103.ALMLEAK	North Plant Pump 3 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].11	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].11					
PLNT_NRTH_PMP104.ALMFAIL	North Plant Pump 4 Fail	PLNT_NRTH_COMMS_TO_HEAD_INT[0].12	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].12					
PLNT_NRTH_PMP104.ALMRNG	North Plant Pump 4 Running	PLNT_NRTH_COMMS_TO_HEAD_INT[0].13	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].13					
PLNT_NRTH_PMP104.ALMTEMP	North Plant Pump 4 High Temp	PLNT_NRTH_COMMS_TO_HEAD_INT[0].14	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].14					
PLNT_NRTH_PMP104.ALMLEAK	North Plant Pump 4 Leak	PLNT_NRTH_COMMS_TO_HEAD_INT[0].15	NPT.HEADEND.RTU_PLC_PLNT_READ_INT[0].15					

Figure 14.2 Loop Test Verification Sheets

LOOP TEST VERIFICATION SHEET - DISCRETE INPUT

Project:		**Control Panel**	
Customer:			
Plant:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

LOOP TEST VERIFICATION SHEET - DISCRETE OUTPUT

Project:		**Control Panel**	
Customer:			
Plant:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
Specification No.		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**	**Spare Discrete Output**					
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
		Engineer:				Date:		
Installation Detail								
Comments:		**Terminated**	**Signal Tested**		**To PLC**		**To Scada**	

LOOP TEST VERIFICATION SHEET - ANALOG INPUT

Project:		**Control Panel**	
Customer:			
Plant:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**

Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**
Calibration Range (Engineering Units)						
Measured Range (Engineering Units)						
Contractor:			Date:			
Engineer:			Date:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**

Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**
Calibration Range (Engineering Units)						
Measured Range (Engineering Units)						
Contractor:			Date:			
Engineer:			Date:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**

Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**
Calibration Range (Engineering Units)						
Measured Range (Engineering Units)						
Contractor:			Date:			
Engineer:			Date:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**

Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**
Calibration Range (Engineering Units)						
Measured Range (Engineering Units)						
Contractor:			Date:			
Engineer:			Date:			

LOOP TEST VERIFICATION SHEET - ANALOG OUTPUT

Project:		**Control Panel**	
Customer:			
Plant:			

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor Inst.**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**
Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**		
Calibration Range (Engineering Units)								
Measured Range (Engineering Units)								
Contractor:			Date:					
Engineer:			Date:					

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor Inst.**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**
Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**		
Calibration Range (Engineering Units)								
Measured Range (Engineering Units)								
Contractor:			Date:					
Engineer:			Date:					

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor Inst.**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**
Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**		
Calibration Range (Engineering Units)								
Measured Range (Engineering Units)								
Contractor:			Date:					
Engineer:			Date:					

Loop No.		**Point Description:**						
Manufacturer:								
Model No.		**Surge Arrestor Inst.**		**Yes**		**No**		**N/A**
Sensor Model No.		**Proper Grounding**		**Yes**		**No**		**N/A**
Installation Detail		**Terminated**		**Signal Tested**		**To PLC**		**To Scada**
Calibration Signal Applied [4-20mA]	4	8	12	16	20	**Comments:**		
Calibration Range (Engineering Units)								
Measured Range (Engineering Units)								
Contractor:			Date:					
Engineer:			Date:					

14.4 Sign-Off Requirements

All test results of the SAT shall be documented; include whether or not the objectives and criteria of the testing have been met. Discovered weaknesses or failures during testing shall be documented; include reasons for the weaknesses or failures along with necessary actions to correct the weaknesses or failures.

If the SAT reveals weaknesses or failures in the design and engineering phase or in the safety requirements specification phase, these phases must be modified according to the result of the SAT. In order to verify the modifications meet engineering and safety requirements, the system must be re-tested.

The SAT is only considered complete and approved by COA SCADA once all aspects of the FAT, and agreed upon corrections have been made to the satisfaction of COA SCADA. However, once COA SCADA signs off on the SAT, the SAT may not be complete as site owners may have additional requirements that may need to be met prior to full completion of the SAT. The ICSC is required to complete the SAT to the satisfaction of COA SCADA and the site owner prior to requesting substantial completion.