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Chapter 10 I&C - SCADA

This chapter of the Design Standards and Guidelines (DSG) contains standards and guidelines for Instrumentation and Control (also commonly referred to as SCADA or I&C) in the City of Lynnwood (City) water distribution and wastewater systems. This chapter consists of the following standards and guidelines:

- SCADA Electrical Standards – An expansion of the general electrical standards and guidelines identified in Chapter 10 that is specific to SCADA electrical designs.
- SCADA Control Panel Fabrication Standards – Identifies the hardware standards and guidelines required when designing SCADA control panels for fabrication by the City or an outside contractor.
- SCADA Installation Standards – Identifies the standards and guidelines for installing and testing SCADA system hardware and software.
- SCADA Instrumentation Standards – This section categorizes recommended SCADA instrumentation by facility type. This section also includes standards and guidelines for specific instrumentation categorized by use in water distribution and wastewater facilities.

Standards are shown as underlined text.

The primary audience for this chapter is planners and design engineers who develop water and wastewater infrastructure and require specific knowledge of SCADA design. These guidelines and design standards will also be useful to design engineers who work on future projects associated with the water distribution and wastewater systems. The City SCADA staff should be involved in all SCADA control system designs for new or upgraded facilities.

Note to User:

This chapter provides guidelines for developing contract requirements where interfacing or expanding the City SCADA system is part of a project. Comments and ideas presented in this standard are not designed to be directly included in a contract document but to inform the project design team of what should be required.

The SCADA Electrical Standards are a subset of the Electrical Design standards. I&C electrical design typically comprises low-voltage environments of 24 volts DC and below and requires additional design standards and guides. Design items not covered in this document shall follow the Lynnwood Municipal Code Chapter 16.10, National Electric Code (NEC), and Washington Cities Electrical Code (WCEC). Any conflicts between standards shall be discussed with City SCADA staff.

Unless specific reference is made to a particular piece of equipment, the term SCADA system will be used hereafter to mean all elements of the SCADA system.

10.1 KEY TERMS

The abbreviations and definitions given here follow common industry practice.

10.1.1 Abbreviations

Abbreviation	Term
A	Amp
AC	alternating current
AMR	automatic meter reading
Amp	Ampere
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
AWWD	Alderwood Water & Wastewater District
CMRR	common mode rejection ratio
City	City of Lynnwood
CSI	Construction Specifications Institute
CSO	Combined Sewer Overflow
Cv	value coefficient
DAQ	Data Acquisition
dB	Decibels
DC	direct current
DSG	Design Standards and Guidelines
EMT	electrical metallic tubing
EMI	electromagnetic interference
gpm	gallons per minute
GFI	Ground Fault Interrupter
HMI	Human Machine Interface
HOA	Hand-Off-Auto
I&C	instrumentation and control
ICEA	Insulated Cable Engineers Association
ICS	industrial control systems
IEEE	Institute of Electrical and Electronic Engineers
IMC	intermediate metal conduit
I/O	Input/Output
ISA	International Society of Automation
kV	Kilovolt
kVA	kilovolt ampere
kW	Kilowatt
kW-h	Kilowatt-hour
LED	light emitting diodes
L-O-R	Local-Off-Remote
mA	milliampere
MCC	motor control center
mm	millimeter
MOhm	Mega Ohms or million Ohms
ms	millisecond
mV	millivolt
MTW	Machine Tool Wire
NEC	National Electric Code
NECA	National Electrical Contractors Association
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NMRR	normal mode rejection ratios
OSHA	Occupational Safety and Health Administration
Ohm	Unit of Electrical Resistance
pF	Picofarad
PLC	Programmable Logic Controller

psid	Pounds per square inch differential
PRV	pressure regulating valve
PWM	pulse-width modulator
PVC	polyvinyl chloride
RCM	reliability centered maintenance
RFI	radio frequency interference
RMC	rigid metallic conduit
RMS	root mean square
RTD	resistance temperature devices
RTU	Remote Telemetry Unit
SCADA	Supervisory Control and Data Acquisition
SPG	Single point ground
SWC	Surge withstand capability
TFF	Thermoplastic Covered Fixture Wire Flexible Stranding
UL	Underwriters Laboratory
UPS	uninterruptible power supply
UV	Ultraviolet
V	Volt
VAC	volts alternating current
VA	Volt – Ampere
VAR	Volt Ampere reactive
VDC	Voltage Direct Current
VFD	variable frequency drive
WCEC	Washington Cities Electrical Code

10.1.2 Definitions

Term	Definition
4-20mA	An analog current loop used by instrumentation for transmitting engineering values to control equipment. 4ma value would typically represent the lowest engineering unit and 20ma would represent the highest engineering unit.
codes	Refers to the legal documents whose use is determined by the jurisdictions governing a project or electrical manufacturing industry codes. Codes are typically geographically dependent.
DIN Rail	35MM metal rail used for mounting control equipment.
guidelines	Advice for preparing an engineering design. Guidelines document suggested minimum requirements and analysis of design elements to produce a coordinated set of design drawings, specifications, or lifecycle cost estimates. Design guidelines answer *what*, *why*, *when* and *how* to apply design standards and the level of quality assurance required. See also *standard*s.
Human Machine Interface	Computer systems used as an interface between utility operations staff and SCADA system.
I/O	The collection of input and output signals connected to a site's PLC or RTU. The signals are provided by instruments and control components at the site.
PLC	Programmable logic controller is a digital computer used for automation of electromechanical processes. These devices are used for monitoring and control of equipment in the City's utility facilities. These devices are also referred to as Remote Telemetry Units (RTU), Master Telemetry Units (MTU) and Programmable Automation Controllers (PAC).
references	In this DSG chapter on Electrical Design, *references* are sources of content and include sufficient detail (e.g. document, section and table number and/or title) that the user can easily refer to the source. The National Electrical Code (NEC) and National Electrical Manufacturers Association (NEMA) documents are frequent references in this chapter.
regulations	Legal design standards that must be incorporated into design. Examples include Occupational Safety and Health Administration (OSHA) requirements, the Americans with Disabilities Act (ADA), etc.

reliability centered maintenance	Abbreviated as RCM. A process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context.
SCADA	Supervisory control and data acquisition is a term that refers to an entire industrial control system that consists of instrumentation, communications, PLC automation equipment and Human Machine Interface (HMI) computer systems. The term I&C (Instrumentation and control) and SCADA are interchangeable in the context of this design guide.
SCADA communications	SCADA communications refers to the methods of transmission of data between facilities that are part of the SCADA system. SCADA communications can travel over telecommunication landlines and wireless radio networks.
SCADA database	A collection of tags that are entered into the SCADA System's real-time database.
standards	The word "*standard*", refers to the following: drawings, technical or material specifications, and minimum requirements needed to design a particular improvement. A design standard is adopted by the department and generally meets the functional and operational requirements at the lowest life-cycle cost. It serves as a reference for evaluating proposals from developers and contractors. For a standard, the word "must" refers to a mandatory requirement. The word "should" is used to denote a flexible requirement that is mandatory only under certain conditions.
tag	A name within the SCADA Database that uniquely defines data used by the SCADA system. A tag has a number of attributes that, together, completely define the tag.

10.1.3 Panel Interior and Appurtenances

All interior panels must be specified to be primed and finished with a factory finished ANSI #61 light gray lacquer finish on all exterior surfaces. The panel interior must be white. All exterior pedestals and panels will be type 316 stainless steel.

Suitable strip heaters (heat reflector assemblies) must be specified with thermostat control for condensation and freezing protection in all outdoor panels. The City recommended assemblies are:

- Hoffman D-AH1001A, 100-watt heater for panels under 36 inches high, or approved equal
- Appropriately sized Hoffman type D-AH heaters for larger panels or approved equal.

An interior light fixture and a duplex GFI convenience outlet with on/off GFI circuit breaker for maintenance purposes must be specified for all medium and large panels, including communications and termination panels. Small handhold and junction boxes may be excluded from the requirement.

10.2 SCADA ELECTRICAL STANDARDS

This section identifies electrical standards that are specific to SCADA system design and implementation. The electrical standards identified in this section are an expansion of the City electrical standards (Lynnwood Municipal Electrical Code, WCEC, NEC).

Lynnwood Electrical Code:
https://www.codepublishing.com/WA/Lynnwood/#!/Lynnwood16/Lynnwood1610.html#16.10.

10.2.1 Power Requirements

Providing power that is free from voltage fluctuations and power outages for the SCADA system is critical. Voltage fluctuations and outages can cause output errors, data loss, equipment damage, and other problems. High-speed transients can damage memories, power supplies, and semiconductor components. Transients can also cause data errors in instrumentation, communication, and computing devices.

Typical utility problems include load switching, load shedding, accidents, and brownouts. Normal power network switching by a local utility can cause several hundred outages per year, each lasting a fraction of a second or more. The inability of utilities to meet power demands in peak periods forces them to schedule "brownouts" (i.e. a planned 3, 5, or 8% voltage reduction at the generating point). Such a major reduction could take the computer's voltage below its lower operating limit. Onsite power generation has many of the above problems, plus capacity limitations and frequency stability difficulties.

Typical electrical power requirements for most control system servers, workstations, and programmable logic controllers (PLCs) are 120 Volts AC, ±10%, measured at the equipment connections. This is important because voltage drops along the line from the service entrance to the equipment can cause up to a 9% loss. Also, large loads coming online can drive voltage down 20% or more for periods up to 30 ms.

Various types of devices may be installed to clean line power, eliminate noise, and provide backup power in emergencies. These include isolation transformers, voltage regulators, line conditioners, uninterruptible power supplies, and motor generator sets.

Use the following guidelines when setting up a power source for a City SCADA system:

1. Primary power should come from the most reliable source available.
2. The second power feed, if available, should come from a separate source.
3. PLCs should have battery backup or standby power. It is important to consider the size and power requirements of PLCs when using batteries as backup.
4. The SCADA system, including instrumentation power supplies, should be the only equipment fed from the branch feeder service.
5. Each instrument or power feed from the PLC power supply should have its own circuit protection utilizing a fused terminal connection with a blown fuse indicator.
6. Do not route the branch circuit close to other lines that supply noise-generating equipment. If circuits must run close together, keep parallel paths as short as possible (and where possible, route at a 90˚ angle).
7. The power source should be selected to:
    a. Reduce the effect of devices turning on and off.
    b. Supply lighting loads rather than equipment loads.
8. The feeder where the branch circuits originate should have enough capacity to accommodate future load increases.
9. All of the workstations, communications equipment and servers should be on the same power system.

10. Avoid using the power conditioned and distributed to SCADA equipment for supplying other non-SCADA related equipment.

10.2.1.1 Isolation Transformers

To protect the SCADA computer system workstations and servers from high-speed transients and high-frequency noise, an isolation transformer may be used along with an AC UPS system. Isolation transformers are necessary for facilities where a single UPS would not be sufficient for a long-term stable system. An isolation transformer has physically separated primary and secondary windings, and an electrostatic (Faraday) shield between the windings. The shield attenuates capacitive coupling between the windings and reduces common mode effects in the secondary winding.

Most modern shielding methods can achieve a common mode rejection ratio (CMRR) of 10,000,000:1 or 140 dB. Utilize the following specifications when selecting an isolation transformer:

- Input-to-output capacitance of 0.005 pF or less
- Leakage resistance of 1000 MOhms or greater between the primary and secondary windings, or between either winding or ground.

Some isolation transformers are available with normal mode rejection ratios (NMRR) of 100 dB or better. These transformers often use three shields: a primary shield, a secondary shield, and a Faraday shield between the two. This configuration provides maximum noise attenuation. Some common sources of isolation transformers include:

- Sola
- Tierney
- MagnaTec

10.2.1.2 Surge Suppression

Surge suppression devices are designed to absorb high voltage power fluctuations that can damage downstream control devices. A typical 3 phase system will have some type of Transient Voltage Surge Suppression (TVSS) along with a 120VDC TVSS after the step-down transformer.

Surge devices are typically a discrete input wired to a SCADA controller for counting surge pulses from the suppressor. Surge devices should only provide a pulse output when a surge has been encountered. A surge device will typically always be "on" when the device has failed.

For maximum protection, an isolation transformer may be installed upstream of the surge sensor. Another possibility is to install a line conditioner, a device that combines the characteristics of an isolation transformer and an AC voltage regulator. Such protection should be installed if line voltage fluctuations or site conditions that might cause a great deal of common-mode and normal-mode noise on the power lines are either suspected or detected. Site areas with large variable-speed motor drives are prime examples where noise on the power lines should be expected. Common manufacturers are PULS, SOLA, and Best Power.

10.2.1.3 Uninterruptible Power Supplies

If low line voltage or outages regularly occur, or could have serious consequences, the installation of an uninterruptible power supply (UPS) should be considered.

The UPS to be supplied should meet the following specifications:

- Harmonic distortion of 5% or less
- Frequency regulation of 60 Hz, + 1%
- Output voltage regulation of 120 Volts AC, + 2%

Because the line AC power may be used during inverter failure and when the UPS is being serviced, proper surge suppression equipment must be utilized on the line AC prior to the UPS. There are times when the UPS may be down for servicing or has failed and the power is being by-passed. It is important to have conditioned power or, at a minimum, proper surge suppression at all times. Due to power issues identified at several facilities, the recommended AC UPS device is currently the Minuteman Encompass models. These are “True Online” UPS systems where the output load is always running from the battery systems.

10.2.1.4 Motor Generator Sets

It is also possible to combine a UPS with a diesel engine or gas turbine generator set, which allows operation even if power is off for long periods. The UPS provides enough time for the generator to start and reach optimum speed. For example, a diesel generator typically takes about 10 to 20 seconds to respond to a power failure. In such a system, the generator should have about 2.5 times the power rating of the UPS to sustain the facility load.

10.2.2 Grounding and Shielding

This section presents standards and guidelines for grounding and shielding for the City SCADA systems.

10.2.2.1 General

Electromagnetic Interference (EMI) is unwanted time varying transient energy consisting of electric and magnetic field disturbances. *Radiated interference* is unwanted electromagnetic energy that emanates from a source into the surrounding area. *Conducted interference* utilizes power and communication lines/channels for propagation paths.

Conducted EMI is always a potential problem within control rooms. Modern computer and data processing systems use low level signaling internally and between units. In control rooms with both heavy power circuits and low-level signal wiring, attention to electrical isolation is necessary regarding electrical grounding and shielding. Lack of attention to this area can result in serious degradation of control system operation that is often very difficult to isolate and correct once installed.

NEC Article 250 covers general requirements for grounding and bonding of electrical installations. The NEC emphasizes safety for power circuits. Additionally, the problems of crosstalk and injection of unwanted signals into low-level data circuits and equipment must be considered.

To minimize interference between various equipment groups, City design standards recommend the single point ground (SPG) concept. The following definitions apply to SPG:

- Earth Ground: A high-quality earth ground of as low impedance as practical.

- Site Reference Ground: A central ground tie point consisting of a large copper plate heavily secured to earth ground. It serves as a single reference ground point for all parts of the system and the building.
- Grounding Circuits: With SPG, several independent insulated ground circuits are established by functional usage and all are terminated at the Site Reference Ground point. Except for structural rebar ground, the individual ground system circuits must be insulated from each other except at the Site Reference termination point. Computer panel and signal grounds must never share electric power ground circuits. Typically ground system circuits are established for:
  - Electric AC neutrals
  - Electrical equipment panel/conduit grounds
  - Computer/peripheral panel grounds
  - Signal ground
  - Facility/structure ground

Site-specific ground circuits can be established in different parts of a building. For example, all computer equipment in the Control Room may be connected by insulated cable to an isolated ground bar located in the communications room. This bar, in turn, is then terminated to the Site Reference Ground. Similar arrangements can be made in other areas.

10.2.2.2 Grounding Guidelines

In most cases, an isolated single point ground (SPG) system is used with electronic instrumentation and process control computers. This means that the system's ground connects to earth at only one point. This point may be a facility ground or a dedicated ground rod. If a dedicated ground rod is used, it must connect to the equipment or facility ground to be compliant with the NEC. This connection should be at only one point.

A SPG system has grounding branches that serve various parts of the computer and instrumentation system. Major branches connect to the system ground plate, while minor branches connect to analog, digital, or rack ground buses. Each ground branch must be connected at one end only; the far ends of each ground branch must be disconnected from ground.

The system ground plate should be an isolated ¼-inch thick copper plate that is centrally located to all system components. Dimensions should be such that the plate will have enough tapped holes to accommodate all the ground buses that need to be connected.

Conduit, cable raceways, or building steel must not be used to distribute the SPG from point to point. Distribution should be through a well-insulated, dedicated wire of appropriate size.

The earth ground for a SPG system should conform to the NEC, Section 250-81 and 250-83. The buried ground should:

- Be made of good electrical conductors
- Withstand mechanical abrasion
- Provide sufficient contact area with the soil to minimize grounding resistance

Ground resistance is measured using methods outlined in the Standard Handbook for Electrical Engineers, or by following procedures recommended by vendors of ground-measuring equipment.

The conductor connecting the earth ground to the system ground should be insulated and stranded copper wire, #2/0 AWG. This conductor should follow the most direct path between the ground points. Sharp turns decrease the conductor's ability to carry high currents, such as those encountered when lightning strikes nearby, and should be avoided.

10.2.2.3 Grounding PLC I/O Racks

Guidelines for setting up grounds for PLC I/O racks containing analog and digital signals are:

- Each I/O rack should have an isolated signal ground bus, 1-inch wide by ¼-inch thick, running from top to bottom in the rack. The bus should have tapped holes to accommodate ground connections from various devices in the rack. The signal ground bus should connect to the system ground plate at only one point, via a stranded, insulated copper wire of #8 AWG or larger. If the rack contains analog and digital signals, a separate bus should be provided for each.
- The rack frame must be connected to the system ground, via a connection that is kept isolated from the signal ground bus.
- Each chassis or panel in a rack should have internal grounding lines that connect to the signal ground bus. Connections should be via ring tongue connectors that bolt to the bus. If the chassis has several types of signals that need to be grounded, such as low-level sensor signals, high-level output modules, or noisy switching circuits-each should have a separate line to the signal ground bus. Only circuits of the same voltage level should share the same ground return line.
- Rack power should be supplied through an isolation transformer or UPS. This prevents ground loops between the instrument and electrical power grounds.

10.2.2.4 Grounding Computer Components

Grounding requirements for the SCADA system computer are similar to those for the PLC I/O racks. Grounding workstations and servers require the computer ground be an integral part of the UPS or isolation transformer ground.

The following are grounding requirements for computer components:

1. <u>The panels of the communications equipment must be connected to the system ground via a separate conductor</u>.
2. <u>Shell grounds for all computer peripherals or communication equipment must be connected to the system ground and not the building ground</u>. Special orange receptacles can be used to signify an isolated ground connection for computers and the peripherals.
3. <u>The computer ground bus (usually located with the UPS) must be connected to the system ground plate using an insulated #4 AWG (or larger) wire</u>. The ground conductor should run in conduit, using the shortest possible path to the ground plate. <u>This line must be separate from the panel frame ground</u>. Follow the guidelines noted in 10.2.2.3 Grounding PLC I/O Racks for the I/O signal bus ground.

4. In all cases the computer ground bus must connect to the building ground. Electrical codes and safety require all grounds be bonded together. The computer ground should be connected to the building ground at only one place. The location of the connection should be as close to the computer system ground rod as possible.
5. A full-sized neutral should be included on each power circuit serving computer components.

10.2.3 Electrical Installation

This section reviews general provisions for installation of electrical work that must be covered in a specification. The actual specification should conform to the city's standard format for electrical installation work. This section covers topics that must be reviewed before requirements are developed and incorporated into a contract document.

10.2.3.1 Codes and Standards

The contract documents should require that all work by the contractor conform to the applicable requirements of the current NEC NFPA 70 codes, together with the code and regulations of public utilities and all other authorities having jurisdiction where the PLC equipment is installed. Contract documents should require that all equipment be designed, constructed, installed, tested and be in conformity with all requirements and applicable standards. For general electrical codes required for the City electrical design and installation, see electrical design standards (Lynnwood Municipal Code, WCEC, NEC). In addition to these electrical codes, Underwriters Laboratories (UL) code compliance will be required for control system hardware and installation to pass inspection.

Lynnwood Electrical Code:
https://www.codepublishing.com/WA/Lynnwood/#!/Lynnwood16/Lynnwood1610.html#16.10.

It is important to remember that projects involving the SCADA system may include many jurisdictions and cities other than Lynnwood. The local codes where the equipment is going to be installed must be reviewed to ensure the installation will be compliant. Codes for other jurisdictions and cities may involve the following standards.

- Institute of Electrical and Electronics Engineers (IEEE)
- Underwriters Laboratories, Inc. (UL)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Code (NEC)
- National Fire Protection Association (NFPA)
- National Electrical Contractors Association "Standard of Installation" (NECA)
- Instrument Society of America (ISA)
- Occupational Safety and Health Administration (OSHA)

In addition, all materials and equipment must be listed by Underwriters' Laboratories, Inc., except for classes of materials and equipment not available with such listing. In the case of conflicting standards or codes, mediation of the most applicable code rests with the City and the local jurisdiction if the work is not in the City of Lynnwood. National codes and standards take precedence when no other codes cover the work.

10.2.3.2 Clearances

The specification must require the contractor or the system integrator to maintain clearances in front of electrical panels and other electrical installations as required by the NEC. It is also important to maintain working clearances around electrical equipment required for proper maintenance, operation, and accessibility.

10.2.3.3 Separation of Signal and Power Circuits

This section describes measures that help prevent noise from entering the SCADA control system wires carrying low level signals. *Signal conduits* are conduits containing 4-20 mA analog signal circuits, thermocouple leads, or discrete input circuits to PLCs. Signal conduits also include conduits containing communication link cables between PLCs and remotely located I/O (Input/Output) modules. *Power conduits* are conduits containing power, light, or control circuits operating on AC, or on DC operating at more than 48 VDC or 20 mA DC.

The following are City standards for signal and power conduits:

1. Signal and power conduits must be separated in accordance with Table 10-1.

Table 10- 1
City Standards for Signal and Power Conduit Separation

Maximum Operating Voltage VAC (RMS) or VDC	Maximum Current Amperes (RMS)	Minimum Clearance between Signal and Power Conduits (inches)
0 - 125	Less than 30	2
0 - 125	30 to 100	4
0 - 125	100 or more	6
125 - 240	Less than 100	6
125 - 240	100 or more	6
More than 240	Less than 100	12
More than 240	100 or more	12

2. Signal and power conduits should be separated by 3 inches minimum where runs cross. The runs must cross at right angles.

The following are guidelines for signal and power conduits:

- Signal conduits should be separated from equipment generating high levels of electrical noise such as motors, solid state motor starters, transformers, inverters, etc. by 5 feet minimum.
- Signal circuits should not be contained in the same raceway or boxes with power, light, or control circuits.
- Signal circuits within equipment panels should be separated from power, light, or control circuits by:
  - Metal partitions
  - Containing the power, light, or control circuits in metal raceways

– Containing the signal circuits in metal raceways

10.2.4 Submittals

This section covers what should be included in an electrical submittal to maintain control over the final product.

10.2.4.1 Shop Drawings

AutoCAD format drawings must be provided in PDF format or 11-by-17-inch hardcopies. The following electrical shop drawings must be provided and defined in the contract documents as a minimum submittal list for all City SCADA projects.

- Overall site plans. Show exterior conduits and wiring to radio antennas, telephone poles, yard valves and meters, and all other related components.
- Interior power plans. Show interior conduits, wiring, junction boxes, all control system equipment, control panels, instruments, and all other related components.
- Interior and exterior wall elevations. Show mounting of PLCs, disconnect switches, power distribution panels, conduit connections to existing power distribution panels, light switches, emergency pull-switches in control centers, antenna feedline routing, and locations of all other electrical devices and conduit systems.
- Detail drawings for backup panel, interposing relay panel, relay control panel, PLC assembly and installation. Include conduit entry, exterior panel elevations, interior panel elevations, device and nameplate schedules, wireway and terminal block placement, electronic module and power supply placement, fans, heaters, thermostats, filters, and all other devices.
- Elementary control and wiring diagrams for all backup panels, interposing relay panels, relay control panels, PLC panels, PLC I/O panels, remote I/O panels.
- Elementary control diagrams for all switchgear, motor starters, and process equipment control circuits having interfaces with the project.
- Instrument loop diagrams per ISA S5.4 for all instruments, pump controls, valve and gate controls, solenoid valve controls, status contacts, and all other devices connected to PLC I/O systems. Include terminal designations for all wiring, including shields of instrumentation cables. Include wire and cable numbers.

The contractor must also be required to provide elementary control diagrams and must use the ladder diagram format incorporating line number, operation function statement, contact location line and a description of operation of each device. Each contact should be labeled with its function, as well as its number, e.g.: "LSH-1, SUMP HI LEVEL". Format and symbols require City approval. The contractor or integrator must show terminals for field wiring and field wiring as dashed lines.

10.2.4.2 Cable and Conduit Schedules

The contractor must provide an instrumentation cable and conduit schedule in format acceptable to the City, detailing each cable and conduit routing. This includes point-to-point conduit, wire, and cable lists in an industry standard database format for all conduit, wiring and cabling from field devices to and from I/O panels. Also include conduit, wiring, and cabling for all intermediate conduit runs to junction boxes, manholes, pullboxes, termination panels, interposing relay panels, backup panels, and all other points of access or termination for wiring and cabling. The schedule must include database fields shown in Table 10-2 for each cable or conduit:

Table10-2
Cable and Conduit Schedules

Cable	Conduit
Cable number	Conduit tag number
Cable type and conductor size	Conduit/raceway source
Conductor insulation color each cable conductor	Conduit/raceway destination
Instrument loop number served by each conductor group	Conduit/raceway length
Terminating instrument numbers (source and destination)	Conduit/raceway intersections name (name derived from conduits or raceways intersecting at that point)
Conductor numbers	Conduit/raceway size
Conduit number through which cable is routed	Wire sizes and types for all wires in that run
Power distribution panel schedules	Cable type and conductor sizes for all wires in that run
	Wire tag numbers for all wires in that run
	Cable tag numbers for all cables in that run
	Instrument loop numbers for all wires and cables in that run

10.2.4.3 Manuals

The specifications must require that all instruction booklets, operating manuals, manufacturer's recommended list of spare parts and parts lists be provided. The specifications should further require all information necessary to install and maintain equipment and to order replacement parts. The following manufacturers' data sheets are useful:

Conduit	Wire	Cable	Enclosures
Disconnect switches	Circuit breakers	Lighting equipment	Indicator lights
Pushbuttons	Selector switches	Relays	Sockets
Terminal blocks	Fuse blocks	Wireways	Control panels
Termination panels	Pullboxes	Heat tracing systems	Small UPS systems
Power line conditioners			

Where catalog data sheets describe more than one model or option, the contractor should circle the item that applies, or stamp the item with a bold arrow pointing to it. In addition, the contractor should draw a bold line through all text and pictorial information that does not apply to the item.

10.2.4.4 Submittal Approval

The specifications must require that detailed drawings, descriptive data and other data sheets showing design information that verifies that the equipment meets the technical requirements be provided.

Information submitted for approval must include:

- Specification section and paragraph number
- Manufacturer's name and product designation or catalog number

- Electrical ratings
- Standards or specifications of ANSI, ASTM, ICEA, IEEE, ISA, NEMA, NFPA, OSHA, UL, or other organizations, including the type, size, or other designation
- Assembly drawings in sufficient detail to identify every part of the specified equipment
- Dimensioned plan, sections, and elevations showing means for mounting, conduit connections, and grounding, and showing layout of components
- Materials and finish specifications, including paints
- List of components including manufacturers' names and catalog numbers

10.3 SCADA PANEL FABRICATION STANDARDS

This section describes City standards for panels used by control systems and general requirements for materials, type of construction, and construction guidelines. This standard must be used for all new control panels installed in City facilities. This standard does not apply to and is not intended for retrofit of existing panels and/or custom panels.

10.3.1 Approved Panel Types

Panel types must be compatible with and suitable for the environment of their installed location. NEMA area classification should be designated according to the environment by the city staff according to NFPA/NEC regulations. Only the following NEMA types are approved for installation in City water and wastewater facilities:

1. NEMA Type 4. **Watertight and Dust tight** - Indoor and Outdoor panels are intended for use indoors or outdoors to protect the enclosed equipment against splashing water, seepage of water, falling of hose-directed water, and severe external condensation.
2. NEMA Type 4X**. Watertight**, **Dust tight and Corrosion Resistant** -Indoor or outdoor panels have the same provisions as Type 4 panels and, in addition, are corrosion-resistant. Type 316 stainless steel boxes that utilize non-corrosive hinge and locking components must be used for outdoor locations. Use fiberglass panels for underground chambers. Use fiberglass panels for areas with chemical exposure, such as hypochlorite facilities.
3. NEMA Type 12. **Industrial Use** - **Dust tight and drip tight** - Indoor panels are intended for use indoors to protect the enclosed equipment against fibers, flyings, lint, dust and dirt, and light splashing, seepage, dripping and external condensation of non-corrosive liquids.

The City may approve the use of other NEMA types on a case-by-case basis.

PLC panels, local panels and termination panels must never be located in hazardous locations. These areas sometimes occur in water distribution systems near backup generators that utilize fuel and require fuel storage. These areas are defined by the NFPA and local codes, which may at times be more restrictive. Local panels consisting of a remote/local switch or limited start/stop control may be in a hazardous area only if all devices and the panel are rated for the hazardous area.

10.3.1.1 Underwriters Laboratories, Inc.

Electrical equipment and material must be listed and labeled for the purpose for which it is used by Underwriters Laboratories Inc. (UL). The equipment and control panel must be certified and labeled as compliant with UL508, Industrial Control Equipment.

10.3.2 Panel Construction

The following are City standards for panel construction:

1. Panels must be designed to accommodate all necessary accessories. These accessories include instrument air, power supplies, mounting hardware, terminal blocks and any signal conditioning or conversion equipment that may be necessary to make operational all monitored and controlled equipment to be mounted in the panel.
2. Panel layout and equipment spacing must be designed to allow for device removal, calibration and maintenance without disassembly of adjacent devices.
3. On larger panels, removable "eye" bolts must be provided to facilitate sling handling of each panel. Eyebolt mounting must be a part of the structural support bracing to distribute stresses and panel weight while sling handling panels during installation.

Panels shall be standardized to well-known suppliers such as Hoffman, Rittal, or equal will ensure that all panels have sufficient structural reinforcements to ensure a plane surface, limit vibration and to provide rigidity during shipment, installation and operation without distortion or damage to the panel or injury to any mounted instruments.

4. All panels must be provided with continuous flush hinges:
    a. Exterior panel doors less than 36 inches high must be equipped with a hasp and staple suitable for accepting a ⅜-inch padlock.
    b. All panel doors 36 inches high and larger must require 3- point latch assemblies with key-locking handle. The key lock assembly should be equipped with a Best key core. Panels should be constructed of a minimum of 12 gauge steel, with the exception of single door wall-mounted panels, which may be constructed of 14 gauge steel.
    c. Interior panel doors less than 36" must have a single-point latch with key-locking handle.

10.3.3 Panel Mounting

There are three basic mounting configurations that may be specified for City facilities: pedestal, wall-mounted, or free-standing.

1. All pedestal-mounted panels must be specified to be constructed of a minimum of 12-gauge stainless steel. Mounting must utilize either an existing pedestal, or the pedestal supplied with the panel must utilize the existing base mounting hardware.

2. Single door, wall-mounted panels must be specified up to a maximum of 48 inches high by 12 inches deep.

3. All free-standing panels must be specified to be constructed of a minimum of 12 gauge steel.

10.3.4 Environmental Requirements

10.3.4.1 Maximum Temperature

All panels must have ample cooling or be sized to prevent high temperatures from shortening the life of the equipment mounted inside. The specification must prohibit any location within the panel or interior of the equipment mounted inside reaching temperatures more than 15˚F above the ambient temperature outside of the panel. In some cases, outdoor panels will require sun shields. The requirement for sun shields should be included in the site surveys.

10.3.4.2 Intake Air Filters

If panels require air exchange for cooling, fans drawing air into the panel must be filtered. The filter surface area must be sized three times larger than the fan intake area for each fan. This sizing requirement lowers the velocity of the air moving through the filters and extends the period between filter changes.

10.3.4.3 Cooling without Air Exchange

Panels with excessive heat loads located in areas of heavy particulate contamination must be cooled without air exchange between the interior and the exterior of the panel. Either solid-state cooling equipment or refrigeration must be used to cool the panel. The heat dissipation portion of the cooling unit must be designed for use in areas with heavy particulate contamination and be capable of running extended periods without cleaning. Areas within water treatment facilities with high levels of particulate contamination may need carbon filtering or lime addition.

10.3.4.4 Enclosure Type Ratings

Enclosure type rating identified below identifies the specific environmental condition the control panel is designed to handle.

Enclosure Type Rating

Provides a Degree of Protection Against the Following Environmental Conditions	3	3R	3RX*	4*	4X	6
Incidental contact with the enclosed equipment	•	•	•	•	•	•
Rain, snow, and sleet [b]	•	•	•	•	•	•
Windblown dust	•			•	•	•
Hose-down				•	•	•
Corrosive agents			•		•	
Occasional temporary submersion						•

10.3.5 Panel Power Supply

Panel power supply refers to several components that provide a steady supply of DC voltage to control system equipment during normal and abnormal power conditions. Power supplies are designed for industrial applications and require equipment rated for this type of application.

10.3.5.1 Surge Protection

Surge protection equipment is used to isolate AC voltage surges from reaching control system components. These devices use clamping, diversion, and restriction circuitry to isolate power surges. All devices must be DIN rail mountable. Acceptable manufacturers include:

- Allen-Bradley 4983-DC120-20
- Cutler Hammer AGSHW CH-120N-15-XS
- Phoenix Contact SFP 1-20/120AC (2856702)

10.3.5.2 DC Power Supply with Battery Chargers

The AC-DC power supply is used to convert AC voltage to DC voltage using a switching power supply design with a battery backup system. The battery backup system can charge backup batteries and automatically use them for backup power when AC power is lost. All devices must be DIN rail mountable. Acceptable manufacturers include the following:

- PULS QS20.241
- Sola Hevi-Duty
- Phoenix Contact
- Rockwell Automation

10.3.5.3 DC to DC Power Supplies

DC to DC power supplies are typically used for converting 24 VDC from the main panel power supply to lower voltages such as 12 VDC and 5 VDC. These lower voltages are sometimes required for control panel devices that are not designed for the standard 24VDC used by most PLCs and their control loops. Some DC power supplies from manufacturers such as PULS allow for multiple voltages out of one power supply unit thereby eliminating the need for a DC to DC power supply. Acceptable DC to DC power supply manufacturers include:

- PULS CD10.241 or equal

10.3.5.4 DC to DC Isolators

DC to DC power supplies are also used as a method of isolating the DC power from the facility ground and noisy industrial equipment. These types of isolators are typically 24VDC to 24VDC units that act similarly to an isolation transformer. The city has been including these devices on all facility control system power supplies. Acceptable DC to DC isolator manufacturers include:

- PULS
- Sola
- Phoenix Contact

10.3.5.5 Backup Batteries

Backup DC batteries are used as backup power when AC power has been lost. The amp-hour size of the DC battery is dependent on the control panel power requirements and the amount of backup time required. An acceptable battery is the:

- PULS UZK12.261 or equal.

10.3.6 **Panel Wiring and Terminations**

All internal panel wiring and terminations must be designed in accordance with the latest applicable standards of the NEC and applicable state and local electrical codes.

10.3.6.1 General Requirements

The following are City standards for panel wiring and terminations:

1. Wire bundles must be secured using plastic wiring wraps, except within wiring ducts. The bundles must be securely fastened to the steel structure at suitable intervals, but not exceeding 12 inches in diameter. All wire retention devices, including wire ducts, must be mounted to the back plate with appropriately sized machine screws. The back plate must be drilled and tapped to accept machine screws. No double-faced tape is permitted.
2. Where shielding is required, only shields with continuous foil or metalized plastic providing 100% coverage must be permitted. The drain wire must not be used as a control signal conductor.
3. No wiring within a panel shall be spliced. Wire must be run in continuous lengths from terminal block to terminal block. Wire service loops must be provided to permit device removal. Terminal blocks should be the compression type with captive screws. The use of three tier terminal blocks or locating the terminal blocks where line-of-site is impaired, making insertion or removal of wires difficult is not acceptable. Fork-type lugs are not permitted. Internal raceways must be sized per NEC standards and have removable covers.
4. Power wiring insulation must be rated at 600 Volts at 90˚C and be copper type MTW. No wire smaller than 14 AWG must be used for power wiring. All other wiring insulation must be rated at not less than 300 Volts at 90˚C.

All individual wires that are a source of power to the instruments or contacts (wetting voltage) should be fused with indicating style fuse holders. Larger current conductors (>10 amps and 120 VAC) supplying individual instruments or equipment should have circuit breaker protection devices.

10.3.6.2 Signal Separation

1. Signal wiring must be segregated from control power wiring and arranged neatly to facilitate circuit tracing.
2. Low-level analog signals of 100 mV or less must not be run in the same bundle, duct, or wire duct as digital input or control output wiring.
3. All DC signal wiring must be segregated from wire conducting AC signals.

10.3.6.3 Loop Isolators

Loop isolators are used to provide galvanic isolation between instrument 4-20mA current loops. Acceptable manufacturers include AGM Electronics, Moore Industries or Phoenix Contact.

10.3.6.4 Terminal Blocks

See section 10.4.2.3 for terminal block specifications

10.3.6.5 Wire Colors

See Section 10.4.2.2 for wire specifications

10.3.6.6 Wire Identification

All wires and cable terminated within control panels, instrumentation panels and termination panels should be provided with identification tags to identify cables, terminations, and conductors. Wires must be identified in accordance with City's PLC Installation Standard in Section 10.4.2.2. A specific format has been developed that is supported by the SCADA database, instrumentation names and existing wiring. Allowing the contractor to randomly identify wires is not acceptable and complicates hardware and software maintenance.

10.3.6.7 Wastewater Wiring for Intrinsically Safe Environments

Any wiring that is installed into a Class 1, Division 1, Group D environment (wastewater) will require an intrinsically safe circuit according to the NEC Article 500 for methods and practice. The theory behind intrinsic safety is to ensure that the combined electrical and thermal energy in the system is always low enough that ignition of the hazardous atmosphere cannot occur. This is achieved by ensuring that only low voltages and currents enter the hazardous area, and that all electric supply and signal wires are protected by intrinsically safety barriers. Intrinsic safety also refers to installing physical barriers that isolate hazardous gases from non-intrinsically safe equipment and other sources of ignition.

10.3.6.8 Intrinsically Safe Guidelines for Enclosures

Field wiring of intrinsically safe circuits should be segregated from non-intrinsically safe wiring by use of suitable barriers, separate wire-ways, or trays.

Intrinsically safe and non-intrinsically safe connection points should be located sufficiently apart to prevent any possibility of by passing or mis-wiring during installation or servicing of equipment.

The following are City standards for intrinsically safe panels:

1. The panel must contain a cautionary statement as follows: CAUTION: ANY SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.
2. The mounting plate must be grounded to ensure intrinsic safety. Resistance between the plate and earth ground should be less than 1 Ohm.
3. UL 913 is the Underwriter Laboratories standard for Safety Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations. This standard must be followed for all intrinsically safe installations.

10.3.7 PLC Controller Devices

The City has standardized on Rockwell PLCs that are 24VDC powered. It is strongly suggested to default to a 1769-L33ER CompactLogix processor or future equivalent for standardization if it meets the design requirements. Any deviation must be approved by City SCADA management. All CompactLogix I/O configurations need to be reviewed to ensure they meet the Rockwell acceptable configurations. PLCs should be powered from a 24VDC power supply that is not powering any noisy or inductive type loads. PLCs shall be powered from a DC UPS using a backup battery to allow for 8 hours of SCADA communication over the network. Recommended standard I/O cards include 1679-IF41, 1769-OF4CI, 1769-OW16, and 1769-IQ16.

10.3.8 Panel Display Devices

Display devices consist of rectangular panel meters, edgewise panel indicators, analog controllers, recorders, annunciators, and graphic displays.

Instruments or devices furnished for front of panel mounting must be suitable for panel mounting and selected to match each other and present a coordinated, aesthetically pleasing and functional arrangement. The arrangement of devices on the panel must be as symmetrical as possible. Devices must be grouped functionally to enable operators to easily locate groups of devices or individual devices to control the process. Panel indication or display devices must be mounted between 48 and 60 inches above the floor to be easily operable and readable by the operator.

All display devices must have scales that indicate the actual process value with the measured variable reading in engineering units (i.e. 0 to 300 GPM). The full-scale range of the process being monitored must also be displayed. It is unacceptable for display devices to indicate the measured value as a percent of maximum (i.e. 0 to 100% full scale) except for those devices displaying position (i.e. % valve open, % valve closed). *Programming parameters for all display devices (such as Red Lion LED displays and programmable chart recorders) must be included in the as-built documentation*.

10.3.8.1 Analog Controllers

If required, analog controllers should be completely self-contained, stand-alone, microprocessor-based, and configurable by user through the use of internal software such as controllers manufactured by Red Lion, ABB, Moore or Foxboro. The controller must be configurable for all analog control applications. The internal programming should have a minimum of 70 function blocks stored in non-volatile memory. The controller must be designed for interfacing to a PLC. Controllers must also be capable of being tied together through the use of a local instrument link allowing communication between multiple controllers.

Controllers must be programmable by selection and interconnection of function blocks in order to establish the station type and control strategy. All configuration data must be stored in the non-volatile memory to prevent loss of data during an electrical power interruption. The controller must be programmable by using a personal computer (PC) to download the software configuration. The software in the PC must also be capable of uploading programs from the controllers to archive, modify and verify these programs. Programming parameters for all controllers must be included in the as-built documentation.

10.3.8.2 Display Devices

Video display devices from manufacturers such as Rockwell may be used in stations where local monitoring and control of the station is deemed appropriate. Before they fabricate panels, vendors must submit for City approval a colored copy of any video displays with a description of how the display functions. The preferred display is the Panelview Plus 7, 2711P-T10C22D9P. Smaller versions of the display can be used for small applications.

10.3.9 Switches, Pushbuttons and Lights

All selector switches, pushbuttons and indicating lights must match the NEMA rating of the panel in which they are installed, and be of the same series or model. Recommended manufacturers are Square D, Allen Bradley, or approved equal.

10.3.9.1 Switches and Pushbuttons

Selector switches and pushbuttons must be the type that are supplied with the add-on operator mechanisms so that the appropriate number of contact blocks and block type can be attached to the switch. Contact block terminals must be labeled for identification purposes and contain not less than one single pole, double throw contact.

Contacts must be specified as heavy-duty type, rated 10 Amp at 120 VAC breaking current.

In the case where the contact blocks are handling low level signal currents, the contacts must be rated for electronic duty and provide mechanical self-cleaning action for reliable operation on electronic loads where thermal cleaning action is not present. The contacts should be rated at 1 Amp at 28 VDC and be constructed of gold or gold flashing over silver.

Pushbuttons must match the existing function color. It is unacceptable to utilize color or styles that could create confusion.

10.3.9.2 Indicating Lights

The City requires use of light emitting diodes (LED) as indicating lights because they are less expensive than traditional lamps over the life of the equipment. Removal and replacement of indicating lights must be accessible through the panel front. A push-to-test-feature must be used on indicating lights to provide a positive test of light condition. All indicating lights must be oil-tight type operating from either 24 VDC or 120 VAC. Indicating lights operating on 120 VAC must be transformer type with the indicating lamps operating on 6 to 8 VAC. Indicating lights operating on 24 VDC must have lights rated for 28 VDC for longer life. Lights should meet the NEMA classification for the area and the panel that they are used on. Failure to use the right types of components within the rating of the panel will violate the UL listing.

A. Nomenclature

The following is the nomenclature City prefers on indicating lights:

- TROUBLE/MALFUNCTION: Equipment has malfunctioned. Equipment is operating in a non-normal mode caused by the malfunction of other components. Equipment is not operating within its normal operating limits.
- STATUS: Status of components or mode of operation of equipment is within normal operating limits.
- RUNNING: Equipment is operating.
- OPEN: Circuit breaker, valve, gate, or switch is open.
- CLOSED: Circuit breaker, valve, gate, or switch is closed.
- STAND-BY/ENERGIZED: Power is applied to control equipment and is available to operate the motor.

B. Color Coding

Indicating lights must be color-coded as shown in Table 10-3.

Table 10-3
City Color Coding for Indicating Lights

Legend Nomenclature	Lens Color
General	
Trouble/malfunction	RED
Status	WHITE
Running	GREEN
Computer acknowledge	BLUE
Motors	
Stand-by/energized	WHITE
On/run	GREEN
Valves	
Open	GREEN
Closed	RED

10.3.10 Relays and Timers

This section presents City standards for relays and timers.

10.3.10.1 General

The following are City general standards for relays and timers:

1. Relays controlled by PLC outputs must provide an adequate burden. Adequate burden refers to a condition when the output is turned off the relay coil, the relay will de-energize even though a low-level leakage current may still flow from the PLC output through the relay coil. All relays must be UL recognized and have a minimum mechanical life of ten million operations. For applications requiring switching of very low current signals, such as 4-20mA control loops, relays must be hermetically sealed and use mercury wetted contacts.
2. All relays with similar functions must be supplied by the same manufacturer to ensure similar appearance and uniform operating characteristics. The operating temperature range must be compatible with the environment in which the relay will be installed.

10.3.10.2 Relay Control Logic and Interposing Relays

All control logic and interposing relays must be heavy-duty, machine tool industrial type with contacts rated not less than 10 Amperes at 240 VAC. Relay coils must be molded construction and operate on 24 VDC or 120 VAC 60 Hz +10% as required. All relays must have a clear polycarbonate dust cover and internal indication to show if the relay is energized and be continuous duty rated.

10.3.10.3 Timing Relays

The following are City standards for timing relays:

1. All timing relays must be of the solid-state pulse-count type using a high frequency RC oscillator and integrated circuit counter for timing. Electrolytic capacitors must not be used in the timing circuits. Solid state timing relays must be Allen Bradley 700 Type HR; IDEC GE1, RTE or GT3 Series; or equal
2. Time delays from 0.1 second to 48 hours must be available with each timer model, adjustable over a 20:1 range. The timer must reset in 0.03 second or less. Timer accuracy must be +2% under normal conditions. On-delay and/or off-delay must be supplied as required. Repeat accuracy must be +5% or better. Reset and recycle time must be 200 milliseconds maximum. All time delays must be adjustable via a digital selector switch on the timer body.
3. The timing relay must have 2 NEMA Form-C timed contacts and 1 Form-C instantaneous contact. Two additional NEMA Form-C timed contacts must be provided where required.

10.3.10.4 Intrinsically Safe Relays

Intrinsically safe relays are required for direct connection of float switch instrumentation installed in a Class 1, Division 1, Group D, hazardous wastewater environments.

10.3.11 Intrinsic Barriers

Intrinsic safety barriers are devices that limit the current, voltage, and total energy delivered to a sensor in a hazardous area or flammable environment in order to prevent an explosion. Zener barriers are passive devices that contain Zener diodes, resistors and fuses to limit excess voltage and current. They divert potentially dangerous energy to ground and are the basic building blocks for all other types of intrinsically safe barriers.

Intrinsic barriers must be used for direct connection of discrete or analog instrumentation installed in a Class 1, Division 1, Group D hazardous wastewater environments.

10.3.12 Nameplates and Identification Tags

Panels and all equipment within them must be identified by their name and function.

10.3.12.1 Nameplates

The following are City standards for nameplates:

1. Nameplates must be secured to equipment fronts using screws. Rivets or adhesive may be used for securing nameplates to the inside face of recessed panel doors in finished locations or other types equipment that are enclosed in panels.
2. Nameplates must be made of laminated plastic approximately 3/32 of an inch thick, beveled edge, white with black engraved lettering, attached with corrosion-resistant machine screws with self-locking nuts. Nameplates must be a minimum size of 1¼ inches high by 3½ inches wide.
3. Nameplates must identify the function, position, and/or condition indicated for each pushbutton, switch, indicating light, or other control device. Nameplates for pushbuttons, switches, indicating lights, and similar control devices must be the standard type furnished with the device.

4. Nameplates must be provided for the following equipment and match existing size, color and lettering height for similar applications:
    a. Each panel
    b. All individual equipment pieces within a panel
    c. All PLC panels
    d. All power supplies, UPS systems, and transfer switches
    e. All electrical distribution and control equipment, and loads served
    f. Individual circuit breakers, and switches, with identification of circuit and load served, including location
    g. Receptacles, with identification of panelboard and circuit number
    h. All junction boxes terminal boxes
5. Nameplates made of embossed tape are not permitted for any application, even temporary.

10.4 SCADA INSTALLATION STANDARDS

This section describes City standards and other requirements for installing new control equipment in City facilities.

10.4.1 General Requirements

These facilities include water distribution and wastewater facilities.

10.4.1.1 Installing PLC in Enclosures

The PLC and its I/O racks (if required) are to be installed within either an existing panel, or in a new panel.

A. New Panels

In most cases, the new PLC will be installed in a new panel located near the existing control panel. Stainless steel must be used for new panels to be installed in outdoor locations. If a new panel is required, the panel must conform to City standards for panel fabrication, refer to section 10.3.

B. All Cabinets

1. In all cases the backpanel must meet the following minimum requirements:
    a. ¼" thick, braced as required to prevent buckling.
    b. Mounting hardware must be 316 stainless steel.
    c. Surface must be prepared, primed and finish coated in accordance with the coating manufacturer's recommendations.
    d. Finish coat must be air-dry polyurethane or epoxy enamel.

e. Color must be Federal Standard 27722, white.

2. The PLC must be mounted to the backpanel(s) in accordance with the PLC manufacturer's recommendations. The placing of the PLC on the backpanel(s) must allow adequate space for installation of plastic raceways to route the I/O module cables to the existing terminal blocks, plastic raceways, and other PLC racks. The spacing must ensure that the minimum bending radius of all cables is not violated. All projects should attempt to standardize on panel sizes and mounting orientation in an attempt to keep the control systems similar between like facilities. This improves assembly and maintenance efficiencies.

10.4.1.2 Electrical Requirements

A. Power Supply

The PLC power supply will be a 24VDC. The PLC I/O modules operate on voltages required to interface with the field equipment. The PLC will be operated from a battery backed up uninterruptible DC power supply with the following characteristics:

Output voltage	24 VAC ±5%
Total Harmonic Distortion	Less than 2%

B. Grounding I/O Modules

The following are City standards for setting up grounds for I/O racks containing analog and digital signals:

1. Each PLC must have an isolated signal ground bus, 1-inch wide by ¼-inch thick, running across the bottom on the backpanel. The ground bus must be insulated from the panel and be sized to allow proper termination of shield drain wires. The bus must have tapped holes to accommodate ground connections from various instruments and low-level signal devices in the rack. The signal ground bus must connect to the system ground plate at only one point, via a stranded, insulated copper wire of #8 AWG or larger.
   a. Using the existing ground bus is acceptable if the instrument shields are already connected to the bus.
   b. If a new panel is used and the wires are extended from the existing panel to the new panel the ground should be extended to the isolated ground bus in the new panel.
2. The PLCs rack and I/O frame must be connected to the facility electrical system ground, via a connection that is kept isolated from the signal ground bus. The isolated ground must eventually connect to the building ground to be compliant with NEC Article 250.
3. Each I/O module or panel in a rack must have internal grounding lines that connect to the signal ground bus. Connections should be via ring tongue connectors that bolt to the bus. If the chassis has several types of signals that need to be grounded, such as low-level sensor signals, high-level output modules, or noisy switching circuits, each should have a separate line to the signal ground bus. Only circuits of the same voltage level should share the same ground return line.

4. Applications using small PLCs may use a grounding system composed of a terminal strip with a common connection bar substituting for the copper ground bus bar. The common connection bar must be tinned and provide ample material for the compression style terminal strip to make the proper low-resistance connections.

C. Isolating and Protecting I/O Modules

1. Analog optical isolation must be provided between PLC analog input module loops and field analog loops to prevent ground loops. All analog inputs must have isolated analog inputs, either per input or per group of four inputs. Separate I/O isolators may be used to prevent ground loops in applications utilizing small PLCs with less than four analog inputs.
2. All digital inputs must have optically isolated inputs, either per input or per group depending on I/O module.
3. Surge suppression must be provided for the AC power in the panel. Surge protection must be provided for analog loops between the PLC and field (remote) devices.

10.4.2 Wiring Control Panel I/O Modules

This section presents City standards for wiring I/O modules.

10.4.2.1 General

Each PLC I/O module must be wired to a terminal block using color-coded wire. The minimum acceptable wire gauge for cable conductors is 16 AWG. For 4-20 mA signals and other analog signals provide 18 AWG stranded copper, twisted pair, shielded cable, 80˚C rated, UL listed, 0.25 inches maximum outside diameter, with 100% coverage aluminum foil Mylar-lines shield and 22 AWG (minimum) stranded tinned copper ground drain.

Where additional power wiring is required, extending signal cables, or adding terminal blocks, the following sections apply.

10.4.2.2 Wiring

A. General

Each piece of equipment requiring AC power must be provided with an NFPA No. 70 Type SJ cord with a molded-on grounding type plug for AC power connection.

B. Panel Connection Wire

Connection wiring refers to all wires that have both ends terminated within the same panel. Panel wiring must be MTW. This wire provides high flexibility and easy routing within panels. TFF may be used to wire panels but it is a second choice since it is not as flexible as MTW.

Power and control wiring must be sized to meet all codes.

C. Signal Connection Wire

Signal wiring refers to all wires that are used to connect instrumentation to the control panel terminal blocks. Control wiring must be sized to meet all codes.

D. Wire Tagging

The contractor must tag all panel connection wiring at terminations with machine printed shrink fitted plastic sleeves.

The contractor must tag 120 VAC power circuit wires with the letters L, N, or PG as appropriate.

Tag numbers for control circuit wires consist of the equipment number followed by a dash, followed by the wire number. Match wire numbers with interconnection wire numbers when they are electrically identical.

E. Wire Colors

Power conductors in panels for 120VAC must be provided with the insulation colors shown in Table 10-4.

Table 10-4
Insulation Wire Colors for 120 VAC

Description Code	120 VAC Wire	Color
L	Power	Black
C	Control	Red
N	Neutral	White
PG	Ground	Green

Codes and associated wire colors for 24 VDC and less are shown in Table 10-5.

Table 10-5
Insulation Wire Colors for 24 VDC or Less

Code	DC Wire	Color
VDC	VDC Power Supply	Red
S	Signal, Analog	White or Clear
COM	Signal Common	Black
PG	Equipment Ground	Green
C	Discrete Events and Low-Voltage Control	Blue

10.4.2.3 Terminal Blocks

1. Cables from field instruments and from outside the panel must be landed on termination blocks prior to being routed within the panel.
2. Design of the terminal block layout must include a grounded barrier to segregate those terminals devoted to current type signals from others. The terminal blocks must be mounted on a channel and the channel bolted to the inside of the panel. Terminals must accept wire size 12 AWG and smaller.

3. Terminal blocks must be rated at least 300 Volts for general industrial control devices and 600 Volts for limited power circuits. Miniature terminal blocks for low-voltage signals are permitted if they are mounted with ample access for servicing. All terminals must have a continuous marking strip and each terminal block assembly must be labeled.

Acceptable manufacturers include Phoenix Contact, Allen-Bradley and Weidmuller.

Provide terminal blocks as specified in Table 10-6:

Table 10-6
Terminal Blocks

Description	Type	Application
120 VAC Power & Control		
Fuse terminal block w/blown fuse LED indicator	Phoenix or equal	Power Supply for Field Panels
Terminal Block	Phoenix or equal	Neutral & Control Wiring
Grounding Terminal Block	Phoenix or equal	Equipment Grounding Conductor
Disconnect Terminal Block	Phoenix or equal	Foreign Circuit Disconnect
24 VDC (and other voltage) Signals		
Fuse Terminal Block w/blown fuse LED indicator	Phoenix or equal	4-20 ma Current Loop (supply side)
Terminal Block w/Test Sockets	Phoenix Test Plug Socket, or equal	1-5 VDC Analog Signals
Terminal Block	Phoenix or equal	4-20 ma Current Loop (return side) Shield Drains
Terminal Block	Phoenix or equal	Splicing Cables where space is limited
Terminal Markers		
Terminal Marking Card	Phoenix or equal	All Terminal Blocks

10.4.2.4 Terminal Tags, Covers and Markers

Each terminal strip must be marked as follows:

1. Unique (for the panel) identifying alphanumeric code at one end.
2. Plastic marking strip running the entire length with a unique (for the terminal strip) number for each terminal.
3. Machine printed with ⅛-inch high numbers.
4. Terminal blocks carrying power circuits must include a transparent, hinged cover for personnel protection and accessibility.

10.4.2.5 Fuses and Fuse Holders

On 120 VAC circuits, ceramic tube type fuses must be used that have 25,000 Amperes interrupting capacity at 125 Volts and neon blown fuse indicator lamps. Drawout type fuse holders must be provided.

24V DC circuits must use fast acting glass tube type fuses rated as follows:

1. ⅛ or 1/10 Amp for 4-20 mA loops.
2. 3 Amp for the power supply to individual instruments.

10.4.2.6 Wiring Duct

Slotted plastic wiring duct with dust cover, Panduit Type E or NE, must be used between the PLC I/O racks, and wherever new wiring duct is required to complete the installation. Wiring duct must be mounted by drilling and tapping backpanel for appropriate screws. No double face tape may be used on equipment mounts or wiring supports.

10.4.2.7 Wiring Methods

1. Wiring must be routed in a manner that is mechanically safe with the wires supported by means other than the connections. Wires must not be supported by connections. Wires must be contiguous from connector to connector. Wire splices are not allowed. All connection must be within panels and must be completed using terminal strips.
2. Shield drain wires must not be used as a signal conductor. All shields must be terminated at a terminal strip or must be trimmed back to the jacket of the shielded cable. Shields that are connected to ground must either be tinned by solder or must have a piece of heat shrink insulation placed over the wires to prevent stray strands from either reaching ground or shorting to other terminals. Crimps on connectors, such as spade lugs, are unacceptable.

10.4.3 Operator Interface

New PLCs must include a graphics-based operator interface that connects to the new control system through an Ethernet TCP/IP connection. The operator interface devices chosen must have drivers written for all the most popular PLCs, allowing simple connection to any new PLC.

Typical manufacturers are Allen Bradley or equal.

The operator interface must provide the following features and capabilities:

1. Touchscreen LCD Display
2. Numeric touchscreen keypad function
3. Ethernet TCP/IP ports
4. NEMA 4/12, Class 1, Div. 2, CE approved
5. Minimum of 4”(h) x 6”(w) dimensions
6. Windows® compatible configuration tool and message editor
7. Support a minimum of 200 alarm messages
8. Color
9. Ability to view in outside conditions if located outside
10. 10 - 30 VDC power
11. Compatible with common PLC brands

Preferred models include 2711P-T10C22D9P.

10.4.4 Fabrication and Installation Test Requirements

Testing requirements must be part of every PLC installation. Testing specifications must require the contractor to provide tests for all equipment and software. If equipment or software does not have specific tests defined in the contract, then the contractor must develop testing procedures. All software and all equipment related to the PLC system must be tested.

The contractor must prepare and submit for review and approval:

- Factory Acceptance Test Plan and procedures
- Site Acceptance Test Plan and procedures
- Test Schedules
- Test Reports
- PLC program documentation

10.4.4.1 Test Plans

The contractor must prepare and document a separate test plan for each Factory Acceptance Test and Site Acceptance Test. The actual test procedures must be a formal submittal delivered to City for review and approval before the start of the tests.

The test procedures must be structured in a step-by-step, building block manner with checkpoints at critical functions. The procedures must facilitate the reporting of test results and the re-creation of error conditions.

Test data sheets must be used to record applicable drawing numbers, test equipment, discrepancies, corrective action(s) required, and test data. Data entries must be referenced to the applicable procedures and allowable limits for each entry must be indicated on the data sheets.

10.4.4.2 Test Reports

The contractor must develop, maintain, and update Test Reports of all test results and conditions that were recorded during the course of the testing. Test results must include:

- Identification of test being conducted
- Date and time of test
- Prerequisite tests and demonstrations
- Brief statement of test objective(s) and scope
- Brief test description
- List of test and monitoring equipment required to perform test
- Test results
- List of test deficiencies and their resolutions
- Retesting requirements (if required)
- Failure events
- Contractor's certification (as applicable)

10.4.4.3 Factory Acceptance Test

A Factory Acceptance Test and verification for all deliverable equipment, programs, and associated documentation must be performed before the system is shipped. Tests must verify that the equipment is manufactured and assembled correctly, is operating as designed, and complies with contractual requirements. The tests must verify that the software and hardware meet the functional and performance requirements of the project.

The Factory Acceptance Test must include the following major test and verification activities:

A. System Configuration Verification

Before Factory Acceptance testing, the system must be subjected to system deliverable configuration verification. A copy of the configuration and record of quantities of part numbers must be included with the Factory Acceptance Test Report. The City does not permit equipment replacement or substitutions without rigorous quality control accounting and re-testing of affected equipment.

B. Equipment Test and Verification

Factory Acceptance Testing for equipment consists of visual inspection and verification that the equipment is assembled in accordance with the approved drawings.

1. All hardware panels must be verified to determine the structural integrity. The following must be inspected and verified, as a minimum:
    a. Backpanel structure
    b. Paint work and finish
    c. Dimensions
2. The following verification of wiring and connections must be performed, as a minimum:
    a. Wire in terminal block, including correct connection, wiring installation and wire stripping.
    b. Cable runs, including correct connection, supports, routing, shielding, wire-way design, and terminal security.
    c. Fuse and breakers for correct rating and placement.
    d. Grounding strips, including layout, cables, connection security, and correct size.
3. The following must be visually inspected:
    a. Card wiring support
    b. I/O rack clearances
    c. I/O and equipment labeling
    d. I/O card type verification
    e. I/O card layout
    f. Power supply mounting
    g. Power cable routing

h. Data cable routing

C. Functional Test

The functional test must exercise every specified system function and must include, but not be limited to, the following:

- Rigorous exercising of all inputs and outputs both individually and collectively.
- Demonstrate analog input and analog output accuracy.
- Testing of all operator interface functions.
- Verification of all control operations to ensure they result in the correct sequence of operation at the PLC.
- Simulation of PLC communication error conditions and demonstration of error detection and handling.
- Demonstrate PLC power supply failure and recovery.
- Demonstrate the ability to remove and insert each I/O module.
- Provide certified test results for the deliverable equipment.
- Demonstration of correct calculation of totalized quantities.
- Demonstrate the proper operation of all application programs and control strategies using whatever simulations are necessary.
- Testing of typical and worst-case situations that would arise in the use of the system.

10.4.4.4 Site Acceptance Test

After the Factory Acceptance Tests are complete, the system must be packaged and shipped to City and designate for installation. The following tests must be performed once the system is installed:

- System installation test
- System operational test
- Final documentation acceptance

A. Installing New PLCs

The strategy for installing new PLCs is as follows:

1. Install the new PLC panel and run conduit where necessary. Install power, communications and the I/O cables.
2. Send dummy discrete and analog signals that duplicate the signals at the site to SCADA and verify the communication path and the software are working.
3. Verify all graphic displays used by the site are loaded and are responding to the new PLC.

4. Coordinate with the City and secure approval that the new PLC can be connected to the site's I/O.
5. Verify communications to the new SCADA System. Verify analog and discrete points are functional and transmission control from SCADA is operating where applicable.
6. Finalize the wiring between the new PLC and the I/O. Organize unused wiring to provide a neat and clean appearance.

B. System Installation Tests

System Installation Tests verify that equipment and all cables have been properly installed, have not been damaged, and have not failed in shipment or storage.

The Installation Test demonstrates stable operation of all PLC I/O modules, wiring and data transmission to the SCADA HMI under actual operating conditions. <u>The Installation test must also demonstrate proper operation of all digital or sequential control</u>. <u>All start/stop, open/close, up/down, and similar commands and all discrete status inputs must be tested for proper operation</u>. <u>In addition, all alarms, both analog and discrete must also be tested</u>.

C. System Operational Test

<u>A System Operational Test of the system functions, software, and performance must be performed after completion of all site Installation Tests</u>.

These tests verify complete operation of the site, including additional tests required to verify field-installed equipment, which was not available at the factory.

<u>The contractor is required to</u>:

- Verify the facility installation.
- Verify the System Installation Test.
- Verify proper operation of the PLC program under field operational conditions by repeating the tests performed during the Factory Acceptance Test.
- Verify proper data exchange and operation between the PLC and the new SCADA system.
- Verify operation of any local operator interface device.

D. Final Documentation Acceptance

<u>Final acceptance of any work must be linked to the proper operation and documentation of the controls installed by the contractor</u>. The following actions must be defined in the contract documents and be a prerequisite for final acceptance of the control system:

- Successful completion of the Site Acceptance Test.
- Delivery of all record (as-built) documentation and drawings.
- Resolution of all outstanding system deficiencies.

- Delivery of the record (as-built) PLC program and configuration documentation in print and an electronic copy.

10.4.5 SCADA Communications

SCADA communications design currently consists of communications within a remote facility and long-distance communications between remote facilities and City control locations. Some City SCADA communications standards are undisclosed for security reasons. This secrecy, along with the complexity and changing communications standards in the industry, require that the SCADA management staff be involved during communications design.

The selection of the type of communications protocol and physical wiring to implement should be left to the SCADA management staffto identify based on security concerns, existing facility equipment, existing SCADA communications infrastructure and industry standards.

The City uses the following types of communications within its facilities:

- Communication between instrumentation and control equipment. Control equipment could consist of a relay logic circuit or a PLC.
- Communication between PLCs and other peripheral equipment such as operator interfaces, local PLCs, or remote I/O equipment.
- Communication between instrumentation and control equipment is dependent on the instrumentation to be used and the application of this instrumentation. Instrument communications currently consists of the following standards:
- Discrete Switch connections for instruments such as float switches, flow meter pulse outputs, limit switches, pressure switches and intrusion switches. Communications wiring for these types of connections typically use shielded or unshielded wire pairs.
- 4-20mA based analog communications for input and output connections to instruments such as level sensors, pressure sensors, flow meters, chemical analyzers and dosing pumps and VFD motor monitoring and control. Shielded twisted wire pairs are typically used for analog instrumentation connections.
- Digital communications between instrumentation and PLC devices. This is typically used for more advanced instruments such as intelligent motor control systems, chemical analyzers, flow meters and environmental monitoring equipment. Communication protocols could be one of dozens of different industry standards. Wiring could be anything from twisted pair wire to fiber optic cable.

Communication between PLCs and peripheral equipment is dependent on the existing systems and the application of any system updates. PLC and peripheral equipment communications currently consists of the following standards:

- Serial digital communications using RS-232 or RS-485 wiring standards between equipment. This type of communications typically uses shielded twisted pair wiring and is heavily used in the industry but is slowly being replaced by high speed digital communications.

- High speed TCP/IP based communications between facility equipment such as PLC to PLC or PLC to Operator interface. This method of communications allows the designer to create a high-speed local area network (LAN) among the facility equipment. The City has a vast fiber optic network for high speed connection from remote sites to the SCADA system. All IP addresses are managed by City IT and addresses should be requested. Static IP addresses that have not been assigned by City IT should not be used. Duplicating IP addresses can take existing systems offline.

10.5 SCADA INSTRUMENTATION SIGNALS BY FACILITY TYPE

This section describes the City SCADA Field Equipment data and instrumentation requirements by City facility type.

10.5.1 All City Facility Control Panels

This section presents instrumentation signals that are universal standards for all City facility control panels.

10.5.1.1 Control Panel Signals

The standard control panel data signals include:

- Control Panel AC Power Failure Alarm
- Control Panel PLC Battery Low Voltage Alarm
- Control Panel PLC Battery Charging Status
- Control Panel Door Open Alarm
- PLC State (PROGRAM-REMOTE-RUN)
- PLC Communication Fail Alarm
- PLC Error Alarm
- Battery Voltage

10.5.1.2 Intrusion or Security

Intrusion devices for building and site entry should be added as required based on site configuration. Specific intrusion and security systems are undisclosed in this section for security reasons. For additional security information, refer to the City SCADA staff or the City Public Works management.

10.5.2 Storage Facilities

This section identifies recommended storage facility SCADA Data/Instrumentation signal standards for all existing reservoir sites, tank sites, standpipes, and reservoirs located at the City pump station sites. The instrumentation signals described monitor all storage level information, flows, system pressures, valves statuses, water quality and SCADA communication status data. Typical standard signals are described below.

10.5.2.1 Level Signals

Reservoir, Tank or Standpipe level signals should be provided on all of the existing SCADA systems at storage facilities.

Reservoir level signal fail alarm signals should also be provided at all storage facilities. High level and overflow float switches are required at storage facilities for alarming. SCADA operators are notified by the SCADA system of the level signal failure.

10.5.2.2 Distribution System Pressure

Distribution system pressure is measured on the distribution system side of any storage facility isolation valves. SCADA operators use pressure data to verify customer supply pressure. This verification is important during periods when the storage facility is isolated from the distribution system due to altitude valve closure or when manual valves are closed for storage facility maintenance.

10.5.2.3 Inflow/Outflow

Storage facility inflow and outflow instruments should be provided at storage facilities. Flow meters will provide flow data that can be used to calculate water losses, zone transfer flows, and pump efficiencies.

Storage facility inflow meters and outflow meters must be installed at storage facilities where piping space is available. Piping space must allow for a spool piece magnetic flow meter to be installed with manufacturer’s recommended upstream and downstream distances to provide a +/- 0.5 to 1.0% accuracy reading over the expected flow range.

10.5.2.4 Reservoir Bypass Flow

Reservoir bypass flow meters are required to provide flow data that can be used to calculate water losses, zone transfer flows and pump efficiencies.

Where the reservoir configuration allows water to bypass the reservoir inlet piping, and where the piping allows, a spool piece magnetic flow meter should be installed with manufacturer’s recommended upstream and downstream distances to provide a +/- 0.5 to 1.0% accuracy reading over the expected flow range.

10.5.2.5 Overflow Alarm

The City provides overflow detection and alarms on some of its storage facility overflow lines. The overflow alarm is used by the PLC to calculate the overflow rate and total based on inflow rate, outflow rate, and bypass flow rate.

Overflow alarm Instruments should be float switches.

10.5.2.6 Overflow Flow Rate Measurement

Storage facility piping should be evaluated to determine the most economical way to measure the water that is overflowing from a storage facility.

- Alternative 1: The overflow alarm could be used by PLC logic to trigger the calculation of the overflow rate based on inflow rate, outflow rate, and bypass flow rate.
- Alternative 2: The overflow flow rate could be measured with a spool piece magnetic flow meter installed downstream of the valves. The flow meter must be installed in a piping configuration that maintains a full pipe under conditions of flow and no flow. If an overflow meter is installed, the PLC can calculate the overflow alarm based on the overflow flow rate.

10.5.2.7 Reservoir Under Floor Drain Flow Rate Measurement

Reservoir under floor drains direct water that leaks through the reservoir liner or from the external water table to a drain. The storage facility piping should be evaluated to determine the most economical way to measure the water that is pumped or drained from the reservoir under floor drain system.

10.5.2.8 Chlorine Residual Monitoring

The City provides chlorine residual monitoring instruments for internal water on its large, covered storage facilities. These instruments use recirculation of water with sodium hypochlorite injection. Chlorine residual measurement is a very important water quality parameter required for compliance with regulations.

The chlorine analyzer should be connected to the PLC with an analog input point. High and low chlorine residual alarms should be generated by the chlorine analyzer and transmitted to the PLC.

10.5.2.9 Bypass Valve Open/Close Command

Storage facility bypass valves should be monitored and controlled as a basic data requirement.

10.5.2.10 Altitude Valve Control and Monitoring

City provides altitude valve status monitoring at many of its storage facilities. PLC control of the altitude valve is provided at some City storage facilities.

10.5.2.11 Inlet/Outlet Valves

Some City storage facility sites are configured with inlet and/ or outlet valves. All inlet and outlet valves should include the standard PLC interface signals noted in the storage facility standard equipment list:

- Valve open limit switch
- Valve closed limit switch
- Valve open command
- Valve close command
- LOCAL-OFF-REMOTE in REMOTE switch status
- LOCAL-OFF-REMOTE in LOCAL switch status
- Valve motor run

- Valve high torque alarm on close
- Valve high torque alarm on open
- Valve position 0 to 100% status analog input
- Valve position 0 to 100% analog output command (optional)

10.5.3 Remote-Controlled Valve Stations

This section describes City signal standards for remote-controlled valve stations. The goal at remote controlled valve sites is to monitor all valve pressure information, valve flow, site security, and SCADA communication status data. Typical standard signals are described below.

10.5.3.1 Upstream Pressure

Upstream pressure monitoring at a remote-controlled valve station measures the pressure at the upstream or lower pressure zone side of the valve. Upstream pressure monitoring provides an indication of local zone pressure when the valve is closed and provides a dynamic pressure indication while the valve is open and water is flowing from a high elevation zone to a lower elevation zone. Pressure comparisons at more locations in the distribution and transmission systems will provide valuable information about the system hydraulic conditions to SCADA operators and optimization applications.

Low upstream pressure alarms can be set to advise the operator that customer low-pressure complaints could occur.

10.5.3.2 Downstream Pressure

Downstream pressure monitoring at a valve station measures the pressure at the downstream or low-pressure zone side of the valve. Downstream pressure monitoring provides the following:

- An indication of local downstream zone pressure when the valve is closed
- A dynamic pressure indication while the valve is open and water is flowing from a high elevation zone to a lower elevation zone

Pressure comparisons at more locations in the distribution and transmission system will provide valuable information about the dynamic distribution system hydraulic conditions to SCADA operators and for optimization applications.

High downstream pressure alarms can be set to advise the operator that customer high-pressure complaints could occur.

10.5.3.3 Downstream Pressure High Alarm

A pressure switch connected to the downstream side of the valve will provide a downstream pressure high alarm. This alarm is used as a backup alarm when a failure or calibration error occurs with the downstream pressure transmitter. This is a basic data requirement that is used to provide additional high-pressure protection at valve stations.

10.5.3.4 Valve Station Flow to Zone

Flow monitoring of the water flow to the low-pressure zone is measured at some City remote-controlled valve stations. The City monitors valve station flow at remote controlled valve stations with larger sized valves, or where remote-controlled valves are used on transmission lines. Valve station flow should be provided at all remote-controlled valve stations and added as basic data at stations that do not currently have flow monitoring.

Flow monitoring at all valve stations will provide the benefit of tracking water flows and aid in detection of water leaks and losses. Flow monitoring will also allow operators and SCADA users to reduce the cost of water delivery by finding the lowest cost delivery strategy.

10.5.3.5 Remote-Controlled Valves

Water systems use three types of motor operated remote-controlled valves: ball, butterfly, and gate valves. Remote-controlled valves include different control and monitoring signals at different sites. The preferred configuration for remote-controlled valves used for flow or no-flow control is the following discrete open/close control interface:

- Valve Open and Close commands are generated by PLC logic and sent from discrete outputs to the valve actuator. Open and close commands are sent from the operator SCADA workstation if the operator control is in SCADA manual mode, or by the local PLC logic if the operator control is in SCADA Auto mode.
- Valve Open and Closed status signals are sent from limit switches on the valve to discrete inputs to be used by PLC logic and sent to the SCADA operator workstation for display.
- The preferred configuration for remote-controlled valves used to provide modulating or variable flow rates is control by an analog position signal from the PLC. These valves should also monitor the analog valve position signal and send the position signal to the operator SCADA workstation. Currently valves are controlled by varying pulse width durations to the open or close command relays.
- One option to control valve position is by 0 to 100% analog output commands generated by PLC logic. The position commands can be sent from the operator SCADA workstation if the operator control is in SCADA manual mode, or by the local PLC logic if the operator control is in Auto mode.
  - The valve position signal of 0 to 100% is monitored by an analog input channel to be used by PLC logic and sent to the SCADA operator workstation for display.
  - Remote controlled valves with discrete open/close control interface can be used in modulating control applications, but the position feedback should always be monitored by the PLC and sent to the operator’s SCADA workstation.
- Valve Local-Off-Remote switch in remote. The Remote status of the valve local control switch is an input to the PLC, used by the PLC logic, then sent to the SCADA operator to confirm the valve is ready to accept commands from a remote location. The Local status of the valve control switch is also an input to the PLC and is provided to the SCADA operator.
- Valve fail to open/close alarm. The PLC should generate a valve fail to open or close alarm that is based on the comparison of the open or close command with the open or closed position status. If the command does not match the status after an adjustable time delay, the valve fail alarm is generated.

10.5.4 Pressure Regulating Valve (PRV) Stations

Pressure regulating valve (PRV) station data/instrumentation standards include only pressure regulating valve sites for the distribution system. The City currently has 2 main PRV stations that are to control the flow from AWWD.

The City-recommended PRV station signal standards include upstream pressure monitoring, downstream pressure monitoring and flow to each zone with monitoring by the SCADA system. SCADA users will require flow measurement to account for most of the water flow from zone to zone to effectively detect leaks and determine the most efficient method to move water to each distribution area.

Typical recommended standard signals are described below.

10.5.4.1 Upstream Pressure

Upstream pressure monitoring at a PRV station measures the pressure at the upstream or high-pressure zone side of the valve. Upstream pressure monitoring provides an indication of local zone pressure when the valve is closed and provides a dynamic pressure indication while the valve is open and regulating pressure from a high elevation zone to a lower elevation zone. Pressure comparisons at more locations in the distribution system will provide valuable information about the system hydraulic conditions to the SCADA operators and SCADA users.

Low upstream pressure alarms can be set to advise the operator that customer low-pressure complaints could occur.

10.5.4.2 Downstream Pressure

Downstream pressure monitoring at a PRV station measures the pressure at the downstream or low-pressure zone side of the valve. Downstream pressure monitoring provides an indication of local zone pressure when the valve is closed and provides a dynamic pressure indication while the valve is regulating water pressure from a high elevation zone to a lower elevation zone.

High downstream pressure alarms can be set to advise the operator that customer high-pressure complaints could occur.

10.5.4.3 Downstream Pressure High Alarm

A downstream pressure high alarm is provided with a pressure switch connected to the downstream side of the valve. This is provided as a backup pressure alarm if the pressure is high when a failure or calibration error occurs with the downstream pressure transmitter. This is a basic data requirement that can provide additional high-pressure protection at valve stations.

10.5.4.4 PRV Station Flow to Zone

Monitoring of the water flow to the low-pressure zone is an option for critical PRV stations. Valve station flow should be provided at all large- and medium-sized PRV stations and added as basic data at stations that do not currently have flow monitoring.

Flow monitoring at all large and medium size PRV stations will provide the benefit of tracking water flows and aid in detection of water leaks and losses. The flow monitoring will also allow operator and SCADA users to reduce the cost of water delivery by finding the lowest cost delivery strategy.

Flow measurement equipment for PRVs are based on the Spool Piece Magnetic Flow meter. Spool piece magnetic flow meters can provide better than +/- 0.5% accuracy and can be installed within pipes with 5 diameters of undisturbed flow upstream and 5 diameters of undisturbed flow downstream of the flow element. Magnetic flow meters will provide the most accurate flow measurements at PRV stations. The meter cost is high for large pipe metering, and the piping and the vaults may require modification to install the large diameter equipment. Spool piece magnetic flow meters should be used where the pipeline is less than 24 inches in diameter.

10.5.4.5 Vault Flood Alarm

A float switch should be installed and connected to the PLC to provide a vault flood alarm.

10.5.4.6 Sump Pump

A sump pump should be installed to pump water from the vault to a drain line if the water table is ever above the bottom of the vault. A sump pump is not necessary if the bottom of the vault is always above the water table and the drain has been properly engineered for drainage.

10.5.5 Pressure or Flow Monitoring Station

Remote monitoring stations are installed at strategic locations in the distribution system to provide real-time pressure and flow data to the SCADA system operator. These monitoring stations provide pressure and flow data the operator can use to view the dynamic conditions within a zone to detect high- or low-pressure conditions to make operational decisions to correct the condition. The stations also provide data used for SCADA users to review and analyze.

Additional pressure and flow monitoring stations may be required to provide sufficient data to develop the system simulator and optimizer application. The pressure or flow monitoring station signal standards should be used to design and install new monitoring stations.

10.5.5.1 Pressure Equipment

Pressure monitoring at a remote monitoring station measures the pressure at the pipeline tap where the monitoring site is located.

10.5.5.2 Flow Equipment

Flow monitoring at a remote monitoring station measures the transmission line flow or zone to zone flow at that location.

10.5.6 Water Distribution Pump Stations

This section describes the City water pump station signal standards for all City water pump stations in the distribution system. The City currently has a single 680 Zone Booster pump station that is operational in the distribution system. The design goal for each water pump station is to monitor pump run status for each pump, pump station suction pressure, discharge pressure, discharge flow, bypass valve flow, pump station power consumption, site security, and SCADA communication status data. Typical pump station standard signals are described below.

10.5.6.1 Suction Pressure

Suction pressure monitoring at a water distribution pump station measures the pressure at the upstream side of the pump suction connections, and downstream of the station inlet or storage facility connection.

Low-suction pressure alarms should be programmed in PLC logic based on value of the suction pressure input signal to alert the SCADA operator and shutdown the facility pumps.

10.5.6.2 Discharge Flow

Pump station discharge flow rate is measured by a flow meter between the pump discharge header and the discharge zone. The pump station discharge flow rate provides flow data that is used to track water transfer from zone to zone, calculate and monitor pump efficiency, and detect water leakage on a system wide basis.

Discharge flow meters should be added as basic data to all pump stations that do not currently have the discharge flow rate measured.

10.5.6.3 Discharge Pressure

A pump station discharge pressure transmitter measures the pump station discharge pressure and sends the signal to the PLC and subsequently the SCADA operator. Discharge pressure provides data that can be used to calculate pump efficiency, provide high pressure alarm for the discharge zone before damage occurs, and provide data for SCADA users and management.

Discharge pressure transmitters should be installed as basic data at all pump stations that currently do not have the pressure monitored.

10.5.6.4 Electrical Power Consumption

Electrical power total consumption in kilowatts (kW) and energy consumption rate in kilowatt hours (kW-h) should be measured at the pump station, input to the PLC and sent to the SCADA system and operator at less than 15-minute intervals. Electrical power consumption data can be used to check the power company billing information on a monthly interval and is required at one to five-minute intervals to calculate the pump efficiency.

The standard for monitoring facility power at pumping plants will include one facility power monitor unit and individual power monitoring units in the MCC for each pump motor.

This type of power monitoring provides the following advantages:

- Much more accurate total and rate power consumption information.
- Electrical Variables (e.g. KW, KWH, voltage and power factor) and alarms (e.g. high voltage, power failure and low voltage) can be monitored to help resolve pump station electrical problems.
- Ability to diagnose individual motor/pump failures.

10.5.6.5 Discharge Pressure High Alarm

For water distribution pump stations, the discharge pressure high alarm signal is provided by a pressure switch connected to the pump station discharge line or by PLC logic that monitors the analog signal from the discharge pressure transmitter. The alarm can be used to provide only an alarm to the SCADA operator, or stop the pumps with either PLC logic or a hardwired interlock.

Discharge pressure high switches should be added at all stations as basic data at all pump stations that currently do not have the pressure alarms monitored.

10.5.6.6 Flood Alarm

The water distribution pump station flood alarm detects a high-water level or flood condition in the pump station building.

10.5.6.7 Fire Alarm

The pump station fire alarm detects a fire in the pump station building.

10.5.6.8 Electrical Power Fail Alarm

The pump station power fail condition is detected with a power fail relay or a more sensitive phase failure relay that monitors the incoming power at the pump station. Power failure can be detected with the new power monitor equipment that was recommended in the electrical power consumption section, 10.5.6.4.

10.5.6.9 Pump Running

The pump running status is monitored by a run contact in each pump motor starter. The run status signal is sent to the PLC, then to the SCADA operator workstation.

10.5.6.10 Hand-Off-Auto Switch Status

The PLC monitors the pump Hand-Off-Auto (HOA) switch position status for each pump. When this HOA switch is in the Remote position, the signal is a permissive to permit a pump start command to each respective pump.

10.5.6.11 Start Signal

The PLC sends a pump start signal to each water distribution pump motor control center (MCC) when the pump is required to run. The PLC outputs the pump start command when the pump HOA switch is in the AUTO position and a command is received from the master station.

10.5.6.12 Pump Available Status

For water distribution pump stations, the pump available status is calculated by the PLC and is true when the HOA switch is in Remote position and there are no pump alarms.

10.5.6.13 Motor and Pump Alarms

For water distribution pump stations, the following motor and pump alarms are recommended:

- **Pump and Motor Bearing High-Temperature Alarm**. Bearing high-temperature switches will be interfaced to the PLC. An additional relay may be required to add a dry contact for PLC input.
- **Motor Overload Alarm.** Motor overload relays will be interfaced to the PLC. An additional relay may be required to add a dry contact for PLC input.

10.5.6.14 Pump Discharge Valve Status

For water distribution pump stations where pump discharge valves are installed, the open and closed status can be monitored by the SCADA system PLC to provide an alarm if the valve is not open when the pump is running.

10.5.7 Wastewater Lift Stations

The following section outlines City signal standards for wastewater lift stations. The design goal for wastewater lift stations is to monitor pump status for each pump, wet well level, effluent flow, site alarms, and SCADA communication status data. There are currently 2 types of wastewater lift stations.

- Wet Well/Dry Well
- Submersible

10.5.7.1 General

A. Wet Well/Dry Well and Submersible Lift Stations

Wet well/dry well pump stations consist of a storage well for wastewater and a dry vault adjacent to the storage well for pumps, motors, valves and sometimes electrical equipment. Submersible pump stations have the motors, pumps and sometimes valves submerged in the wastewater storage vault with the electrical equipment located in a dry vault or above ground.

Setpoints are used to control the pumps based on wet well levels. The setpoints include lead level for a first pump run, lag level for a second pump run, and an off level to shut off both pumps. After each pump run, the pumps will alternate lead and lag selection. If one pump becomes locked out due to a pump failure or has been turned off, then the other pump will always become the lead pump. When the remote facility pumps are in AUTO mode, they can be controlled from the central SCADA system via setpoints. Most new or upgraded wastewater lift stations have been of the submersible type.

10.5.7.2 Station Discharge Flow

Wastewater lift station discharge flow rate is measured by a flow meter between the pump discharge header and the discharge zone.

10.5.7.3 Wet Well Level

Level signals should be provided for wet well storage tanks. Wet well level is primarily used for automatic wastewater pump control and primary high/low and overflow level alarming. Some existing wastewater lift stations may use wet well level sensors to identify flow rate but future new and upgraded facilities will standardize on magnetic flow meters.

Level signal fail alarm signal should also be provided at all City wastewater lift station facilities. The alarm signal is calculated by the PLC and is used in the data quality monitor and for disabling the automatic level control strategy so that the wet well floats will be used for pump control. SCADA operators will be notified of the level signal failure.

10.5.7.4 High Level Float

Wastewater lift station facilities have high level floats located above the level sensor high level setpoint. These floats identify when the wet well level has reached a high point that could possibly cause an overflow condition.

10.5.7.5 Station Flood Alarm

The wastewater lift station flood alarm detects a high-water level or flood condition in the pump station building.

10.5.7.6 Electrical Power Fail Alarm

The wastewater lift station power fail condition is detected with a power fail relay or a more sensitive phase failure relay that monitors incoming power at the lift station.

10.5.7.7 Pump Running

The wastewater pump running status is monitored by a run contact in each pump motor starter. The run status signal is sent to the PLC, then to the SCADA operator workstation. The location of this run contact is dependent on the Motor Control panel design.

10.5.7.8 Pump Hand-Off-Auto Switch

Each pump in the wastewater lift station must be equipped with a Hand-Off-Auto switch. The status of each pump must be monitored by the SCADA PLC.

When this switch is in the Auto position, the signal is a permissive for a pump auto start command to the respective pump. All City pump stations currently include this status signal.

10.5.7.9 Pump Available Status

The wastewater pump available status is calculated by the PLC and is true when the HOA switch is in Auto position and there are no pump alarms.

10.5.7.10 Motor Overload Alarm

Motor overload relays must be interfaced to the PLC. An additional relay may be required to add a dry contact for PLC input.

10.5.7.11 Pump Discharge Valve Status

Where pump discharge valves are installed, the open and closed status must be monitored by the SCADA system PLC to provide an alarm if the valve is not open when the pump is running. The pump discharge valve position status switches should be added as a basic data requirement.

10.5.7.12 Electrical Power Consumption

Electrical power consumption monitoring standards are the same for water and wastewater lift stations. Refer to section 10.5.6.4: Electrical Power Consumption.

10.5.7.13 Start Signals

Wastewater lift station pump call start signals are used to control the level of the facility wet well. For wetwell/drywell and submersible facilities, the pumps are called to lower the wet well level by pumping the wastewater into the next wastewater basin or interceptor. The PLC outputs the start command when the pump HOA switch is in the Auto position.

10.6 SYSTEM INTEGRATION STANDARDS

10.6.1 VFD

VFD when controlling a critical part of a process should come with ethernet network capabilities for easy access for SCADA. This allows monitoring of Energy, Power, Amps, Voltages, and alarms and also ease of parameter monitor and editing. VFDs should be added as part of the I/O configuration and configured with Datalinks.

VFD configuration should be set up to avoid any alarms (Comm Alarms, HIM, etc.) from unnecessarily stopping the VFD especially in lift station pump applications.

10.6.2 Alarming

10.6.2.1 PLC Inputs

All discrete and analog inputs should be monitored and generate alarms when not in the expected state or range. Analog inputs typically should have a HiHi, Hi, Lo, Lolo, and Instrument Fail Alarms with the proper operator level having access to the setpoints and alarm delays with being able to disable. A delay of 0 seconds implies the alarm should be disabled. All alarms need to be tested through to the phone auto-dialer system (Win911), which is typically managed by the SCADA/HMI integrator which is typically the on-call contractor.

10.6.3 Communication Failures

Any device that communicates on the SCADA network must include a communication fail alarm annunciated by the SCADA HMI system.

10.6.4 HMI Integration

The City has an on-call SCADA HMI integrator. The system integrator should interface with the designated City HMI integrator to gain alignment on tag naming, structures, alarming standards, statistical data, time clock synchronization, and a communication heartbeat.

10.7 DATA/INSTRUMENTATION STANDARDS BY INSTRUMENT TYPE

This section identifies equipment required at remote facilities by instrument type to interface between field processes and the City SCADA system. The data is used by the system operators and City public works management.

10.7.1.1 SCADA Data/Instrumentation Standards and Catalog

This section presents data/instrumentation standards and a catalog of recommended manufacturers and part numbers for each type of instrument. The manufacturer names and part numbers recommended in this section are a guideline for the instrument accuracy, quality and features the City requires for the SCADA system. To minimize spare parts inventory and technician training, it is recommended by the City operations department that standardized equipment not be substituted if possible.

A. Pressure Transmitters

Water Distribution Facilities

The City currently specifies pressure transmitters with a +/- 0.1% accuracy specification for both pressure measurement and elevated tank level measurement. The standard 4-20 mA signal is used to interface the pressure transmitter to the PLC and SCADA system.

The City has standardized on the following pressure transmitter models. Range of device should be set for 200% of maximum pressure expected.

Application	Model Type	Calibration Range
All Pressure Measurements	Foxboro or Equal	(depends on range of application)
Elevated Tank Level Measurements	Foxboro or Equal	(depends on range of application)

The pressure transmitter's +/- 0.1% accuracy specification is adequate for most pressure measurement and elevated tank level applications. The elevated tank level transmitters could be upgraded to pressure transmitters with +/- 0.025% accuracy to improve the tank level accuracy, but this is not a high priority upgrade requirement.

B. Differential Pressure Transmitters

Water Distribution Facilities

City standards recommend the Rosemount model 3051S series with +/- 0.025% accuracy for differential pressure transmitters. The improved accuracy will provide more accurate flow readings when used as a differential pressure transmitter for the Cla-Val flow meter conversion applications.

C. Level Transmitters

Water Distribution & Wastewater Facilities

The City uses non-contact sensors such as ultrasonic or radar for level measurement. These transmitters are designed to be mounted at the top of the reservoir or wet well and identify level by bouncing ultrasonic or microwave signals off the top of the water and measuring the travel time.

D. Ultrasonic Flow (Level) Sensor

Wastewater Facilities

Ultrasonic level sensors are typically used to identify open channel flow by measuring the water level over Parshall flumes and weirs. These are non-contact level measurement instruments that measure the traveling time for ultrasonic sound waves off a water/wastewater surface. City standards recommend the Endress Hauser FMU90-N12CB111AA1 Ultrasonic Prosonic Level transmitter.

E. Flow Meters

1) Spool Piece Magnetic Flow Meter

Water Distribution & Wastewater Facilities

The spool piece magnetic flow meters are available in sizes from 2 to 120 inches in diameter.

Advantages	Disadvantages
• Accuracy is +/- 0.5% of full scale when installed per the manufacturer's recommendations. • Meters can be installed as close as 5 pipe diameters upstream and downstream of flow disturbances such as tees, elbows, and valves and still provide the specified accuracy. The meter body averages the flow velocity in the cross section of the pipe diameter to provide flow measurement that is not noticeably affected by changes in the flow velocity profile. • Very low maintenance. There are no moving parts or bearings to wear out in the flow sensor. The measurement technology is long proven and optimized with internal diagnostic features. The cost has been reduced. • Flow meter transmitters can be calibrated easily and quickly without access to the magnetic flow element. • Spool piece magnetic flow meters are extremely reliable, and the flow measurement readings can be used with confidence if the transmitter is regularly checked for calibration. • Can measure and indicate bi-directional flow.	• Installed cost of Spool piece magnetic flow meters is higher than most other types of flow meters.

The City recommends spool piece magnetic flow meters for all water and wastewater lift stations, remote controlled valves, and storage facility flow meter applications with pipe diameters up to 60 inches.

2) Insertion Averaging Magnetic Flow Meters

Water Distribution Facilities

Insertion averaging magnetic flow meters use the same principle as a spool piece magnetic flow meter, except the magnetic coil and electrodes are embedded in a probe that is inserted directly into the pipe through a tap in the pipe wall. The insertion averaging magnetic flow meter can be installed in pipes from 4 inches to 120 inches in diameter.

Advantages	Disadvantages
• Accuracy is +/- 1.0% of full scale when installed per the manufacturer's recommendations.	• Meter equipment cost is higher than most flow meters except spool piece magnetic flow meters.

• Installation cost is low because the meter sensor probe can be installed in the pipeline through a tap in the pipe wall. The pipeline does not require shutdown and draining to install the tap and probe. • Meter probe can be removed for maintenance or repair without dewatering the pipeline.	• Sensitive to upstream and downstream pipe flow disturbances. Based on the manufacturer's application notes, the flow meter may not operate within the accuracy specifications in a location where the flow profile is skewed. The manufacturer recommends the meter be installed at least 25 pipe diameters downstream from an open or closed butterfly valve. A modulating butterfly valve located 25 pipe diameters upstream of the flow meter can cause up to 100% error. The meter requires more than 10 pipe diameters upstream from an open butterfly valve. • The meter requires a large vault with careful design to permit the full pipe diameter probe to be removed from the side of the pipeline without obstruction.

3) PRV Flow Meter

Water Distribution Facilities

The PRV flow measuring system is a specialized flow measurement system for use with certain PRV valves. Cla-Val and Singer have valve flow meter systems based on this technology. This system consists of a valve position transmitter connected to the valve position stem and a differential pressure transmitter connected between the valve inlet and outlet ports. The SCADA PLC receives the valve position signal and the differential pressure signal with analog inputs and calculates the flow based on a comparison to a valve coefficient (Cv) table stored in the PLC. Alternatively, a hardware flow computing module can be used to calculate the flow based on valve position, valve differential pressure and a valve Cv curve in tabular format from the Cla-Val factory. This flow measurement system is available for globe valve sizes from 3 inches to 24 inches in diameter.

Advantages	Disadvantages
• No external flow meter needs to be installed. • Moderate accuracy of +/- 3.0 % of actual flow. • Minimum installation cost in a PRV flow measurement retrofit application because the pipeline does not require dewatering if the existing PRV is used. • PRV vault does not require modification.	• Minimum flow rate accuracy may be 100 to 200 gpm of total flow. • Not available for 2-inch PRVs that are installed at many City sites with dual range PRVs. • Not accurate when differential pressure is less than 0.5 psid which could occur if valve is 100% open • Not accurate if valve position is less than 5% (almost fully closed).

The City recommends installing the Endress Hauser 5W4C3H (Proline Promag W 400) flow measuring sensor on the large PRV in a dual PRV station assuming the following two conditions are met:

1. The valve meets the manufacturer’s flow metering criteria of operating between 5% and 100% open.
2. Differential pressure across the valve is greater than 0.5 psid.

The small PRV in the dual valve station should have a spool piece magnetic flow meter installed because the upstream and downstream distances from the meter can be obtained without vault modifications or an additional vault.

4) Ultrasonic Flow Meters

Water Distribution and Wastewater Facilities

Transmissive ultrasonic flow meters use an ultrasonic transducer on each side of the pipe to calculate the flow velocity based on the time difference between reception of an ultrasonic signal sent upstream and that of an ultrasonic signal sent downstream. Ultrasonic flow meters can be used on water and wastewater applications. Single path ultrasonic flow meters provide one pair of transducers and multi-path ultrasonic flow meters use as many as 4 pairs of transducers to provide more accuracy for large diameter pipelines with full or partially full lines.

Advantages	Disadvantages
• Single path ultrasonic flow meters are moderate cost for pipelines of less than 36-inch diameter. • Multi-path ultrasonic flow meters can provide better **than +/- 1.0%** accuracy for pipelines larger than 36 inches in diameter with full or partially full conditions.	• Single path meters are very sensitive to upstream flow disturbances such as elbows, tees and open valves. • Single path meters should be installed with caution when required to be downstream of t pump discharge headers or flow control valves because of flow disturbances. • Multi-path ultrasonic flow meters are expensive and require special training for maintenance.

The City now recommend replacing ultrasonic flow meters for all applications with spool piece magnetic flow meters for sizes of 60 inches or less in diameter. For wastewater overflow pipelines, the City has standardized on hybrid ultrasonic Flo-Dar units from Hach. Lift Station 12 currently has one of these devices for identifying overflow flow into the King County interceptor system.

F. Float Type Level Switches For Emergency Backup

Water Distribution Facilities

Water level float switches should be specified as one of the following models from Gems Sensor & Controls:

Application	Model	Model Description
All tank level measurements	LS-52100	Float on an arm, all stainless steel
Where conduit is installed for float mounting	LS-1 850	Ball Float, all stainless steel
All sub-drains level measurements	LS-270	Bracket mounted with "slosh guard"

Lift Station Facilities

Float switch shall be non-mercury switch-type enclosed in a sealed polyurethane float. A weight shall be on the cord near the float switch. 2/C # 16 flexible type SJO oil-proof, 300-volt cord shall be integral with the float switch and shall be of sufficient length to reach the splice handhole with an additional five feet of slack cord.

Switches shall be by manufactured by Anchor Scientific, Inc., Roto-Float Type S, or equal.

G. Valve Position Transmitters

Water Distribution Facilities

Valve position transmitters convert the mechanical valve position into a 4-20 mA signal that is transmitted to the SCADA PLC. The City has standardized on the standard Cla-Val valve position transmitter to retrofit the valve position function on existing valves that do not include the position transmitter in the existing valve electric actuator.

For facilities with ball valves, a set of micro limit switches are typically used to identify the full open or full close status of the valves.

H. Valve Electric Actuators

Water Distribution Facilities

Valve Electric actuators should include open/close service models and modulating service models.

EIM, Limitorque and Rotork electric valve actuators have been installed at sites and have operated with minimal failures.

Valve electric actuators must provide the following functions as a minimum standard requirement:

- Hand-Off-Auto selector switch with a dry contact for "Auto" status and a dry contact for "Hand" status.
- Opened and closed status signals with dry contacts and isolated commons.
- Valve motor running status signal with a dry contact.
- Valve position 4-20 mA analog signal to the PLC.
- Remote open and close commands from the PLC.
- Remote valve position command with 4-20 mA signal from the PLC.

The following standard features can be specified to ensure the electric valve actuators are reliable and maintenance friendly:

- Integral Digital Display on the valve actuator to allow non-intrusive display of all valve calibration functions without removing the valve covers.
- Configuration changes should be made using infrared wireless communication from either the manufacturer's setting tool or a laptop with an infrared communication interface. The following functions should be configured and monitored via the wireless infrared communications link:
  - Electronic torque limit alarm
  - Position limits
  - Torque history for troubleshooting assistance

I. Water Quality Analyzers

Water Distribution Facilities

Water quality analyzers are used to monitor water chemistry, including the following parameters:

- Free and Residual Chlorine
- pH Levels
- Turbidity

The City has implemented several different water quality analyzers in the past but currently has no standards. Because water quality analyzer standards change quickly, any design that requires water quality monitoring equipment should check with City Water Quality staff to identify the current standards.

J. Pump Station Power Monitors

Water Distribution and Wastewater Lift Stations

Pump station power usage data such as kilowatts (kW) and kilowatt-hour (kW-h) should be monitored by the SCADA system to permit remote pump efficiency testing. Power billing records can also be checked by comparing the power company kW readings from the billing meter to the kW readings from the station power monitor.

Pump station power monitors with network communication to the PLC should be installed. The following power monitors should be specified for monitoring power usage data and to provide additional data to improve the electrical maintenance data at pump stations:

- **Facility Power.** Allen-Bradley Power Monitor 5000 with Powermonitor II display module and Ethernet communications interface to the water system PLCs. The Ethernet signal should connect to an existing port on the Ethernet Switch in the PLC panel. The Ethernet interface will permit basic electrical power data to be monitored by the PLC and additional data from the power monitor to be sent directly from the power monitor to the SCADA network.

The kW-h, kW and power factor data should be transferred from the power monitors to the PLC. The PLC will send the power data to the SCADA master station when polled for the data.