EXHIBIT 11

SCADA GUIDLINES

FINAL

POLE BRIDGE WASTEWATER TREATMENT FACILITY SCADA ASSESSMENT PROJECT

DeKalb County, GA Department of Watershed Management SCADA Guidelines and Standards

B&V PROJECT NO. 409924
B&V FILE NO. 40.0500

PREPARED FOR

DeKalb County
GEORGIA

Department of Watershed Management

DeKalb County, Georgia

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BLACK & VEATCH

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Abbreviations and Acronyms

The following abbreviations and acronyms are used in this SCADA Guidelines and Standards:

12kV	12,470 Volts Alternating Current, 60Hz
480V	480 Volts Alternating Current, 60Hz
AC	Alternating Current
AI	Analog Input
ANSI	American National Standards Institute
AO	Analog Output
ATS	Automatic Transfer Switch
Bps	Bits per Second
CAA	Critical Alarm Alert
CAT-6	Category 6 Cable
CIP	Common Industrial Protocol
ControlLogix	PLC line manufactured by Allen-Bradley
CompactLogix	PLC line manufactured by Allen-Bradley
CMMS	Computerized Maintenance Management System
dB	Decibel
DLR	Device Level Ring
DI	Discrete Input
DO	Discrete Output
Ethernet/IP	Ethernet Industrial Protocol
FAT	Factory Acceptance Testing
Ft	Feet
HMI	Human Machine Interface
HOA	Hand-Off-Auto
I/O	Input Output
IP	Internet Protocol
ISA	International Society of Automation
LED	Light-emitting Diodes
mA	Milliampere
Mbps	Million Bits per Second
mm	millimeters
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NIC	Network Interface Card
nm	Nanometers
O&M	Operations and Maintenance
OIT	Touchscreen Operator Interface Terminal
OOS	Out of Service
OSC	Open-Stop-Close
PC/S	Plant Control/SCADA
PLC	Programmable Logic Controller
PM	Process Maintenance

RAID	Redundant Array of Independent Disks
RAS	Return Activated Sludge
RTD	Resistance Temperature Device
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
TIA/EIA	Telecommunications Industry Association/Electronics Industries Alliance
UL	Underwriters Laboratory
UPS	Uninterruptible Power Supply
VAC	Voltage, Alternating Current
VDC	Voltage, Direct Current
VFD	Variable Frequency Drive
WWTF	Wastewater Treatment Facility

1.0 Introduction

This document, ***DeKalb County, GA Department of Watershed Management SCADA Guidelines and Standards,*** consists of guidelines and standards related to the design, programming, and installation of equipment and instrumentation for control systems and provides standards and guidelines for automation systems implemented at DeKalb County, GA Department of Watershed Management (DWM) facilities including the water treatment, wastewater treatment and the conveyance system including pipelines and pumping facilities.

The Scope of this document covers

- operational modes and strategies for control of equipment
- hardware and software elements of control systems
- equipment and instrumentation interface
- process control system networks
- project guidelines for projects as related to automation

The Supervisory Control and Data Acquisition (SCADA) System deals collectively with all equipment utilized to measure the process and plant equipment. As such, the SCADA System is an integrated system consisting of many subsystems that function in coordination with each other. Operation and maintenance personnel interact with the SCADA System locally at equipment or OIT, and at SCADA workstations located in many process areas in the facilities and in the Operations Control Room. The SCADA workstations are computers that run special purpose SCADA software that provides graphical displays representing processes with values updating in near real time and which provide the capability for users to initiate supervisory control commands.

<u>This document is intended to be a living document to be updated and enhanced with each completed project.</u>

1.1 PURPOSE

The primary purpose of this document is to define standards to assure uniformity and consistency of design concepts, formats, methodologies, procedures and quality of work for automation control projects. Although the focus is on SCADA and Programmable Logic Controller (PLC) systems, this standard also covers process network equipment and installation, process equipment and valve interface requirements, enclosures, control system power requirements, and conduit penetrations. These standards will be implemented throughout control systems implemented at DWM.

Design engineers and programmers shall review this document prior to beginning work and adhere to the standards set forth in the design of the SCADA and PLC hardware and programs for which they are responsible. This document is intended to be reviewed before beginning any additions or modifications to the control system.

This approach, when used by consultants and DWM staff, will unify and standardize the control system equipment and design in contract specifications and serve as the guide for future upgrades. **<u>For any standard to be successful, it must be constantly and consistently applied to all projects that deal either directly or indirectly with process control.</u>**

The SCADA Guidelines and Standards furnish acceptable design practices and design standards that are in accordance with best industry practices and applicable codes. However, all users are expected to exercise good judgment and independent thought when applying the standards. When new automation is incorporated into DWM's facilities, or existing automation is upgraded, the work shall be designed in accordance with the design standards set out in this document.

1.2 SCADA SYSTEMS OVERVIEW

The SCADA systems are based on a distributed architecture. The PLCs and OITs are located throughout the plant, close to the controlled equipment. The SCADA servers are in a dedicated server room. The SCADA primary workstations are in the control room. Secondary SCADA workstations are located throughout the plant in critical process areas.

The SCADA servers and workstations are programmed to provide the operations staff with monitoring, control and alarming of all process system.

The PLCs and OITs shall be programmed to operate autonomously from the SCADA servers. In the event of a loss of communication from the SCADA system, the PLC will continue to provide process control based on the last good setpoint or control command.

The communications system shall support PLCs using Ethernet communications. All new systems shall communication over Ethernet.

2.0 Process and Instrumentation Diagrams (P&ID)

2.1 PURPOSE OF P&IDS

The purpose of the P&IDs is to represent the process, equipment, instrumentation and control functionality through defined symbols. The P&IDs are not meant to show all mechanical and piping detail, but to show the connection and interaction between components (mechanically, electrically, and digitally). P&IDs should show all piping and equipment that relate to the process, but not piping fittings, reducers, tees, etc. The following information should be contained on a P&ID:

- Process piping, tanks, equipment and structures
- Skid mounted equipment i.e. Chemical feed systems
- Primary elements, transmitters and analyzers
- Actuators and final control elements
- Local control panels
- Input/output signals
- Electrical interlocks

Information generally contained on the P&ID should include instrument electrical connection requirements i.e. Ethernet, 4-20mA, or Digital connection. Equipment nameplate and manufacturer information provided in the electronic format with the CAD drawings should be provided in database format. This information will need to be added to DWM Computerized Maintenance Management System (CMMS). DWM currently uses Oracle Utilities Work and Asset Management (OWAM).

2.2 DRAWING LAYOUT

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

2.2.1 Level 1 - Plant Control/SCADA (PC/S) System Interface

This level is located at the top of the drawing and contains the shared display human-machine interface (HMI) functions, computer functions, digital logic control functions (e.g. PLCs and RTUs), and input/output (I/O) signals. The functions should be orientated such that the interlocks, input/output signals and interaction between components are clear and unambiguous. It is not intended that this level of the P&ID show every detail of the control logic. Control logic text, Boolean, or other type logic coding should not be included on the P&ID. Detailed control descriptions should be provided in the contract document specifications to supplement the P&ID.

2.2.2 Level 2 - Process Control Panels

This level contains vendor package control panels, area panels and process control panels (e.g. filter consoles) that interface with the PC/S. The process control panel level shall be located directly below the PC/S System Interface level.

2.2.3 Level 3 – Process, Instrumentation, and Equipment

This level contains the process piping, equipment, structures, primary elements, field instrumentation, and local equipment control and monitoring functions. The process, instrumentation, and equipment level are located at the bottom of the drawing.

A typical P&ID layout is shown in figures at the end of this section.

2.3 EQUIPMENT PANEL REPRESENTATION

Equipment panels include vendor package panels, area control panels, process control panels, motor control centers, variable frequency drive (VFD) controllers, local control panels, and pushbutton stations. The following are guidelines for equipment control panel representation on P&IDs:

Panels and panel devices should only be shown if they interface directly or indirectly with the PC/S. This would primarily include devices used for controlling the equipment, but only when required to show the device's interaction with the PC/S. One example would be a packaged control system that has a Local-Off-Remote switch that allows PC/S control when switched to the "Remote" position.

Vendor package panels, area control panels and process control panels should be in Level 2. These panels should be represented with device bubbles with a light-line weight panel border.

Panels must be identified on the P&ID with a name designation and should occupy the least space possible.

Motor control center devices, VFDs, local equipment control, pushbutton stations or devices that are an integral part of the supplied equipment should not be shown with panel borders. Bubbles representing these devices should "float" in Level 3 near the related equipment. These devices should include a panel, MCC, or VFD designation in the seven o'clock position. See example in the figure below:

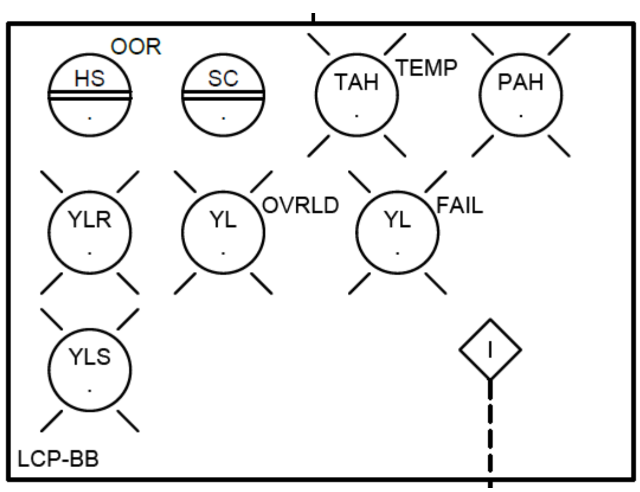


Figure 2-1 Equipment Panel Example

2.4 PROCESS LAYOUT AND PIPING

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

Equipment such as tanks, mixers, and conveyors should be depicted using light line weights. Structures such as basins, and wetwells should be shown using double lines in light line weight. Building boundaries are often used to indicate that a group of devices are located within a building. Building boundaries should be shown using a center dash line type.

Proper scaling or correct physical location is not a requirement in P&ID drawings. However, shape similarity is important to allow quick identification of a process being controlled. The process layout should be orientated such that the interaction between components is clear and unambiguous.

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

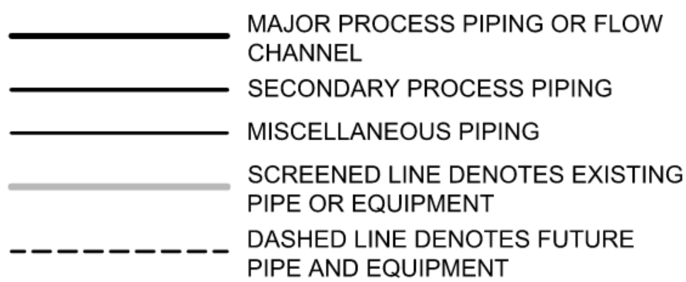


Figure 2-2 Process Flow Line Examples

Process lines that enter or leave a drawing are designated by the symbol shown in the figure below. The symbols include the source or destination drawing number.

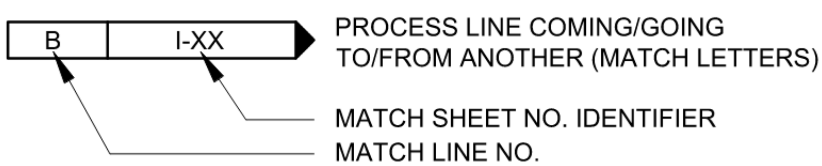


Figure 2-3 Process Continuation Symbology

Match line letters should use letters A through Z. If additional continuations are required, two letter match lines should be used beginning with AA, AB, AC, and so forth.

2.5 PIPING IDENTIFICATION

Process piping shown on the P&IDs should be identified to include pipe size, process code, sequence number, pipeline material code, insulation material code (if applicable), insulation thickness (if applicable), and special code. The figure below shows and example of pipeline identification.

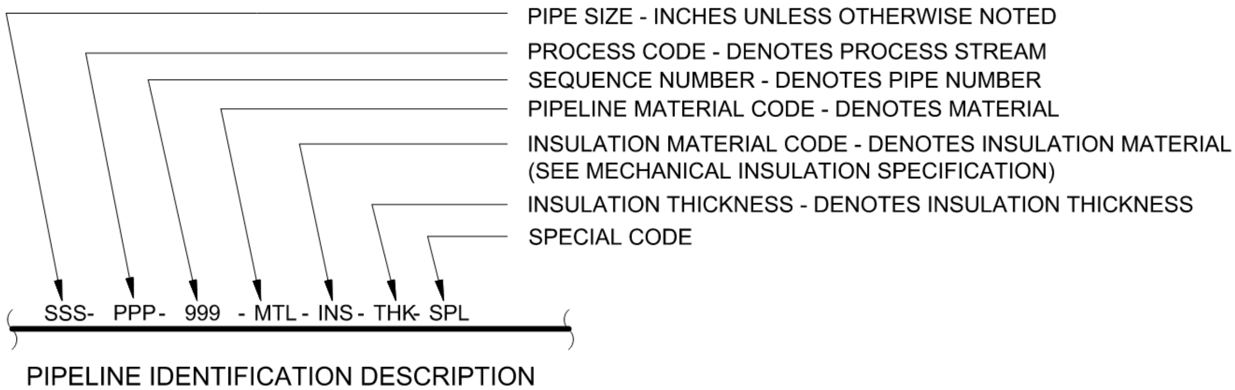


Figure 2-4 Process Continuation Symbology

Process codes are on the upper right side of sheet 3 of P&ID Legends & Abbreviations at the end of this section. Pipeline material codes are on the upper center of sheet 2 of P&ID Legends & Abbreviations at the end of this section.

2.6 PROCESS EQUIPMENT SYMBOLOGY

Symbols for process equipment include pumps, compressors, valves, gates, actuators, primary elements and miscellaneous devices. Process equipment symbology shall be as shown on sheet 1 of the P&ID Legends & Abbreviations at the end of this section.

2.7 INSTRUMENT AND CONTROL FUNCTION SYMBOLOGY

Instruments represented on P&IDs consist of primary or control element symbols connected to bubbles with identifiers that specify the type of instrument function. The symbols and identifiers are based on the Standards Library S5.1 of the Instrumentation, Systems, and Automation Society (ISA) Standards and Recommended Practices for Instrumentation and Control. Instrument symbols include lights, switches, relays and all instruments that measure, indicate, and transmit process information. Each instrument symbol includes an instrument identifier, loop number and additional fields for description of special instruments. Instrument identifiers, loop numbers and description fields are described in detail in the following sections. The figure below shows instrument and control function symbology that should be used on P&IDs.

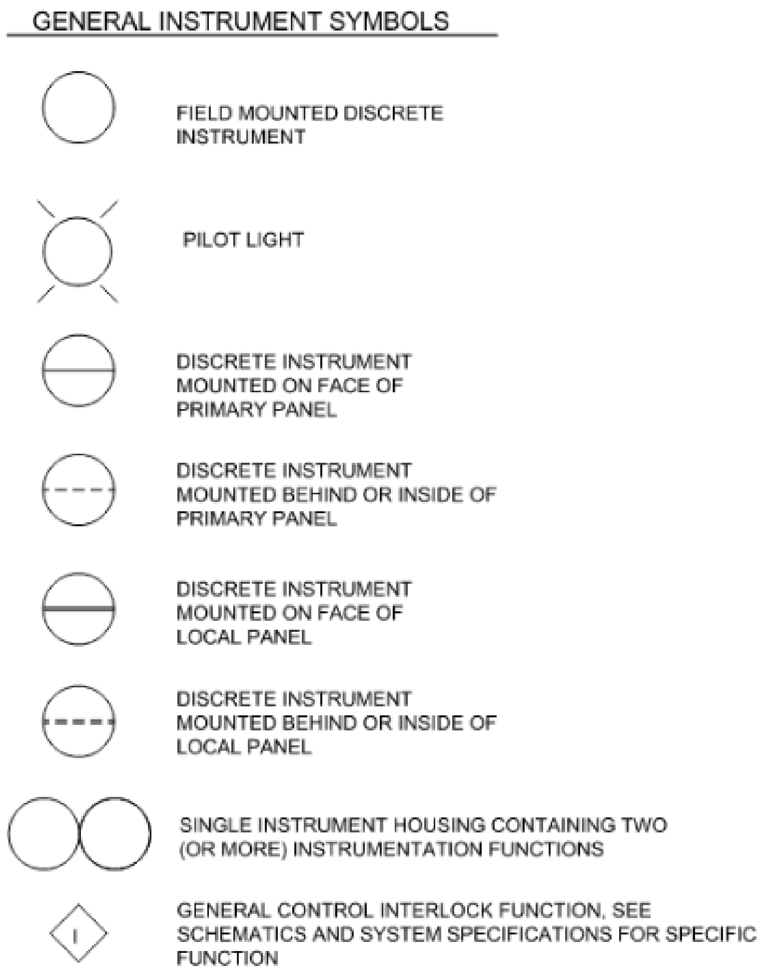


Figure 2-5 Instrument Function Symbols

2.7.1 Instrument Power

Instruments that require power from external sources (i.e. not loop-powered) should not include an external power source identification.

2.8 DIGITAL CONTROL, SHARED DISPLAY AND COMPUTER SYMBOLOGY

Symbols for distributed control, shared display, logic and computer symbology are based on the Standards Library S5.3 of the Instrumentation, Systems, and Automation Society (ISA).

Digital control functions include programmable logic controllers (PLCs), remote terminal units (RTUs) or other types of microprocessor-based field controllers. These symbols should be used for processors that are integral to the PC/S System.

Computer function symbols should be used where systems include components identified as computers, distinct from integral processors. Computer function symbols include pre-programmed algorithms, user-defined strategies, and software calculations.

Shared display functions include the graphic or alphanumeric display of data on the computer control system's human-machine interface (HMI).

Digital control, shared display and computer symbols also include function identifiers, loop numbers and additional description fields which are defined in detail in other sections. The figure below shows digital control, shared display and computer symbology.

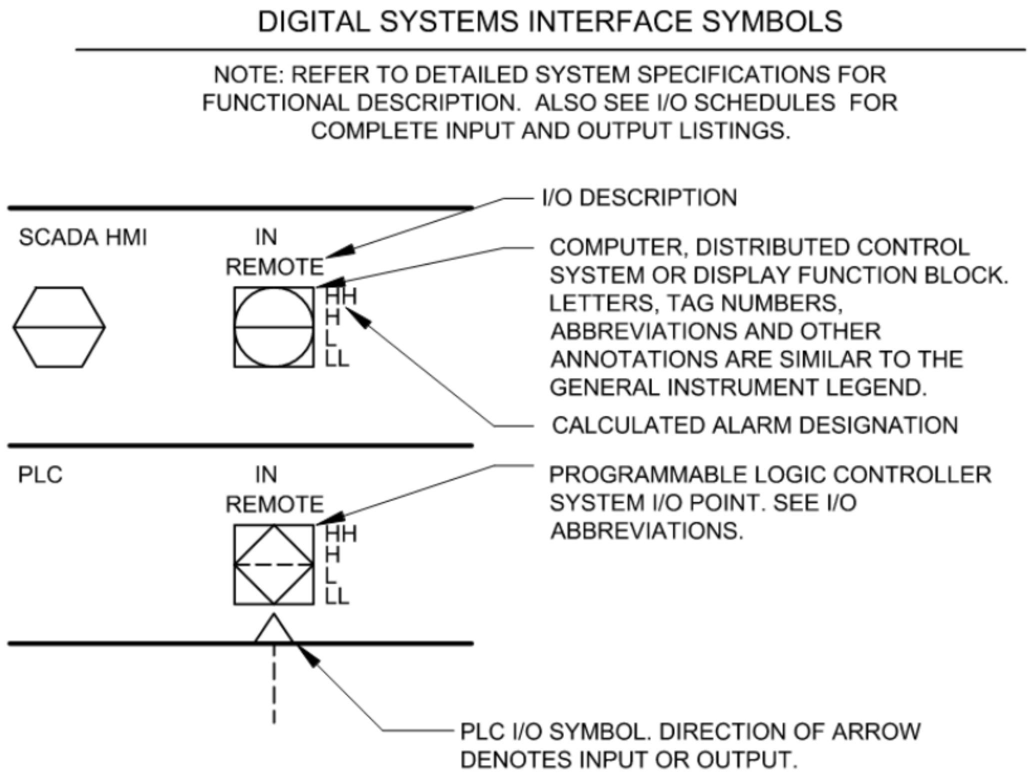


Figure 2-6 Digital Control, Shared Display and Computer Symbology

2.9 INPUT/OUTPUT (I/O) SYMBOLOGY

Control system I/O includes discrete inputs, discrete outputs, analog inputs, analog outputs, pulse inputs and modulating discrete outputs. The P&IDs shall use distinct symbols for each type of I/O as shown in the figure below.

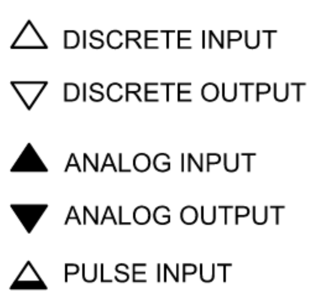


Figure 2-7 I/O Symbology

2.10 INSTRUMENT IDENTIFICATION TAGGING

Instrument symbols and digital control, shared display and computer symbols shall include identification tagging based on the Standards Library S5.1 of the Instrumentation, Systems, and

Automation Society (ISA). Identification tagging consists of an instrument identifier, control loop number and additional descriptors for special instruments.

2.10.1 Instrument Identifiers

Instrument and control system identifiers are in the upper left half of the instrument symbol and shall be as shown in a table on sheet 2 of P&ID Legends & Abbreviations at the end of this section. This table is based on ISA S5.1 standard with modifications in user-defined fields.

2.10.2 Control Loop Numbers

Control loop numbers are in the bottom half of the instrument symbol. A control loop is a collection of instruments or devices that control or monitor a single process parameter or item of equipment. The control loop number shall include a device (or process unit) tag, loop number, and device numbers that indicate trains and multiple units within a loop.

The designer shall coordinate instrument device tags with DWM staff and shall follow the unit process area number assignments listed in the table below.

Note: The following table reflects the Process Area Numbers currently used at Pole Bridge WWTF. There needs to be a project to standardize Process Area Numbers across all of the DWM facilities. Then the table below should be updated to reflect the new standards.

Table 2-1 Unit Process Area Number Assignments

PROCESS AREA NUMBER	RELATED PROCESS
2	Influent Pumping
3	Headworks
4	Aeration
5	Secondary Clarification
6	Flocculation
7	Final Clarification
8	Chlorine Contact
9	Chlorination
10	RAS/WAS Pumping
11	Sludge Aeration Blowers
13	Sludge
16	Solids Loading
17	Alum
18	Caustic

PROCESS AREA NUMBER	RELATED PROCESS
19	Polymer

2.10.3 Special Instrument Description Fields

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

Examples of special instrument descriptions include:

- **HOA** for Hand-Off-Auto
- **VFD** for Variable Frequency Drive
- **CL2** for Chlorine

A complete listing of common abbreviations used in the description field is shown in the center of sheet 2 of P&ID Legends & Abbreviations at the end of this section under the heading Instrument and I/O Abbreviation Definitions.

An example of instrument identification tagging is shown in the figure below.

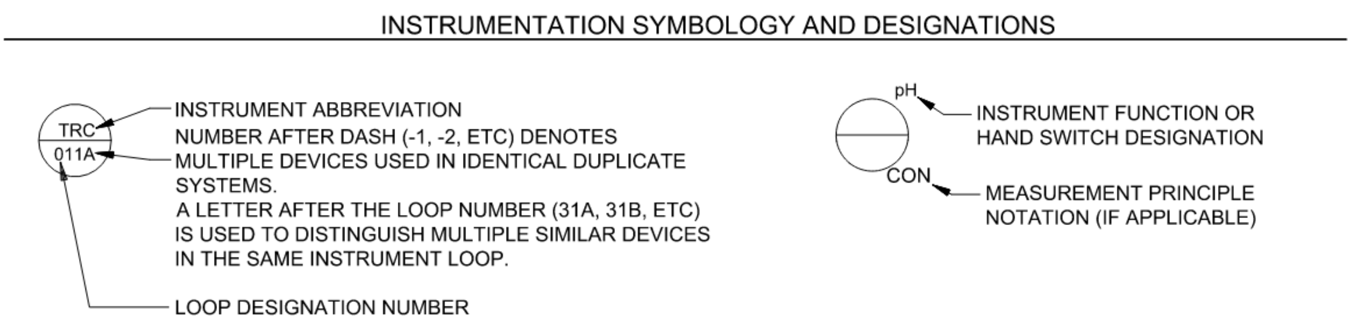


Figure 2-8 Instrument Identification Example

2.11 EQUIPMENT TAGGING

All equipment shown on the P&IDs shall include an equipment tag number. An example of equipment tagging representation is shown in the figure below.

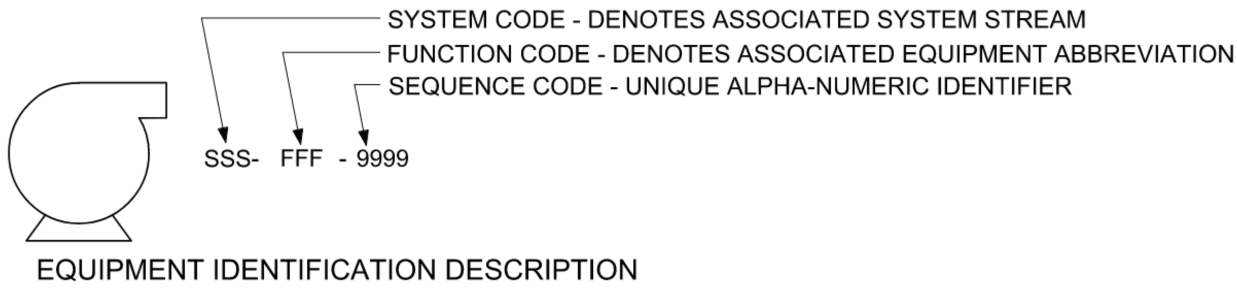


Figure 2-9 Equipment Tagging Example

System and function code abbreviations are listed on sheet 3 of P&ID Legends & Abbreviations at the end of this section.

Device (or unit process) tags shall be unique and shall not duplicate existing equipment tags. The device tag number used in the equipment tag should be identical to the instrument device tag number. The designer shall coordinate equipment device tags with DWM staff and shall follow the process number assignments listed in the table above.

The equipment loop number shall be identical to the instrument loop number.

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

2.12 ELECTRICAL INTERLOCKS

Electrical interlock circuitry used at the field level is represented on a P&ID with the symbol shown in the figure below. Electrical control schematics should be provided for all electrical interlocks shown on the P&IDs. Detailed control descriptions should also define these electrical interlocks. Examples of how interlock symbols are used are shown in the example P&ID at the end of this section.

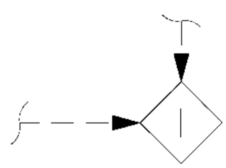


Figure 2-10 Electrical Interlock Example

2.13 DIGITAL COMMUNICATION REPRESENTATION

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

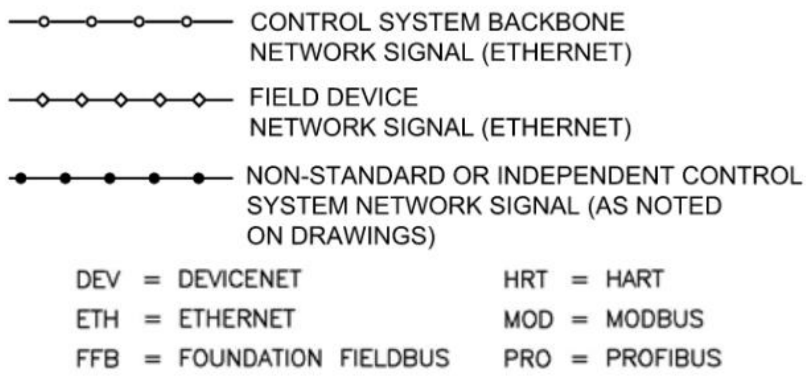


Figure 2-11 Fieldbus Symbology and Abbreviations

Often there is an increased number of status points generated by a PLC that are non-critical to process operation, but too numerous to show on a P&ID. These PLC generated points can be listed in spreadsheet form on the drawing, I/O listing, or control narratives. An example of digital communication representation is shown on the example P&ID at the end of this section.

2.14 TEXT, FONT AND LINE WEIGHT STANDARDS

Text size, font type and line weight standards used on P&IDs shall be as follows:

- Text Size: 0.10" (Minimum plotted text height for a full size (34"x22") sheet)
- Font Type: Arial
- Line Weights:
    - Pipe Lines (Major) – 0.0350"
    - Pipe Lines (Secondary) – 0.0250"
    - Pipe Lines (Misc) - 0.0200"
    - Equipment & Valves - 0.0200"
    - Instruments & IO – 0.0150"

2.15 PROCESS FLOW DIAGRAM (PFD)

The PFD should precede the P&IDs and should represent an overview of entire plants or entire process streams. PFDs should represent processes as blocks with arrows showing the direction of flow from one process to the next. An example PFD is shown in the next section – Example Drawings.

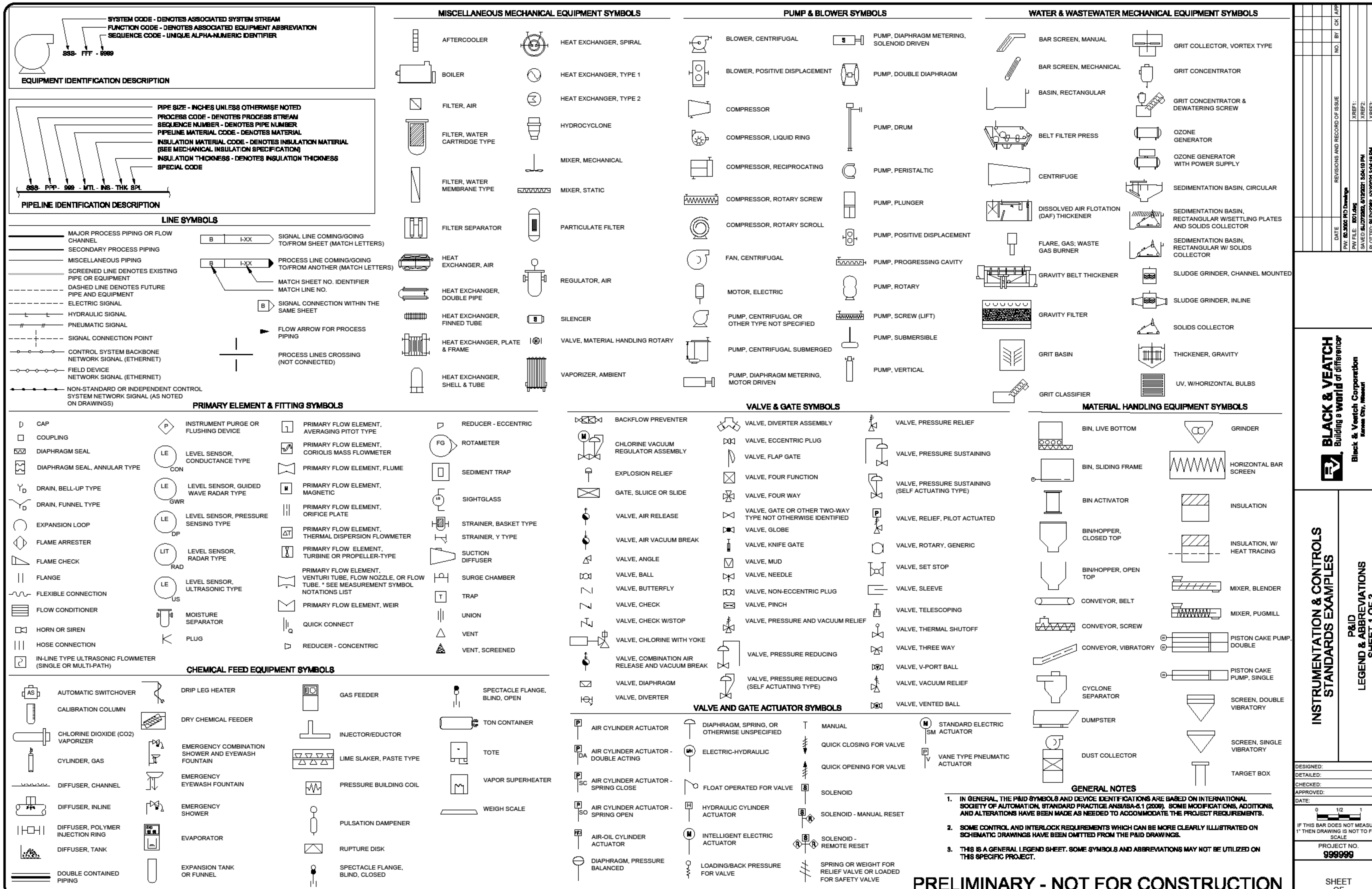
2.16 EXAMPLE DRAWINGS

The P&ID legend and abbreviations standards are shown on three sheets below. An example of a pump station P&ID is shown after the three standard sheets.

Figure 2-12 Instrumentation and Control Legend Sheet 1 through 3 – See Below

Figure 2-13 P&ID Example – See Below

Figure 2-14 PFD Example – See Below


SYSTEM CODE - DENOTES ASSOCIATED SYSTEM STREAM
FUNCTION CODE - DENOTES ASSOCIATED EQUIPMENT ABBREVIATION
SEQUENCE CODE - UNIQUE ALPHA-NUMERIC IDENTIFIER
SSS- FFF - 9999
EQUIPMENT IDENTIFICATION DESCRIPTION
PIPE SIZE - INCHES UNLESS OTHERWISE NOTED
PROCESS CODE - DENOTES PROCESS STREAM
SEQUENCE NUMBER - DENOTES PIPE NUMBER
PIPELINE MATERIAL CODE - DENOTES MATERIAL
INSULATION MATERIAL CODE - DENOTES INSULATION MATERIAL (SEE MECHANICAL INSULATION SPECIFICATION)
INSULATION THICKNESS - DENOTES INSULATION THICKNESS
SPECIAL CODE
PIPELINE IDENTIFICATION DESCRIPTION
LINE SYMBOLS
MAJOR PROCESS PIPING OR FLOW CHANNEL
SECONDARY PROCESS PIPING
MISCELLANEOUS PIPING
SCREENED LINE DENOTES EXISTING PIPE OR EQUIPMENT
DASHED LINE DENOTES FUTURE PIPE AND EQUIPMENT
ELECTRIC SIGNAL
HYDRAULIC SIGNAL
PNEUMATIC SIGNAL
SIGNAL CONNECTION POINT
CONTROL SYSTEM BACKBONE NETWORK SIGNAL (ETHERNET)
FIELD DEVICE NETWORK SIGNAL (ETHERNET)
NON-STANDARD OR INDEPENDENT CONTROL SYSTEM NETWORK SIGNAL (AS NOTED ON DRAWINGS)
SIGNAL LINE COMING/GOING TO/FROM SHEET (MATCH LETTERS)
PROCESS LINE COMING/GOING TO/FROM ANOTHER (MATCH LETTERS)
MATCH SHEET NO. IDENTIFIER
MATCH LINE NO.
SIGNAL CONNECTION WITHIN THE SAME SHEET
FLOW ARROW FOR PROCESS PIPING
PROCESS LINES CROSSING (NOT CONNECTED)
MISCELLANEOUS MECHANICAL EQUIPMENT SYMBOLS
AFTERCOOLER
BOILER
FILTER, AIR
FILTER, WATER CARTRIDGE TYPE
FILTER, WATER MEMBRANE TYPE
FILTER SEPARATOR
HEAT EXCHANGER, AIR
HEAT EXCHANGER, DOUBLE PIPE
HEAT EXCHANGER, FINNED TUBE
HEAT EXCHANGER, PLATE & FRAME
HEAT EXCHANGER, SHELL & TUBE
HEAT EXCHANGER, SPIRAL
HEAT EXCHANGER, TYPE 1
HEAT EXCHANGER, TYPE 2
HYDROCYCLONE
MIXER, MECHANICAL
MIXER, STATIC
PARTICULATE FILTER
REGULATOR, AIR
SILENCER
VALVE, MATERIAL HANDLING ROTARY
VAPORIZER, AMBIENT
PUMP & BLOWER SYMBOLS
BLOWER, CENTRIFUGAL
BLOWER, POSITIVE DISPLACEMENT
COMPRESSOR
COMPRESSOR, LIQUID RING
COMPRESSOR, RECIPROCATING
COMPRESSOR, ROTARY SCREW
COMPRESSOR, ROTARY SCROLL
FAN, CENTRIFUGAL
MOTOR, ELECTRIC
PUMP, CENTRIFUGAL OR OTHER TYPE NOT SPECIFIED
PUMP, CENTRIFUGAL SUBMERGED
PUMP, DIAPHRAGM METERING, MOTOR DRIVEN
PUMP, DIAPHRAGM METERING, SOLENOID DRIVEN
PUMP, DOUBLE DIAPHRAGM
PUMP, DRUM
PUMP, PERISTALTIC
PUMP, PLUNGER
PUMP, POSITIVE DISPLACEMENT
PUMP, PROGRESSING CAVITY
PUMP, ROTARY
PUMP, SCREW (LIFT)
PUMP, SUBMERSIBLE
PUMP, VERTICAL
WATER & WASTEWATER MECHANICAL EQUIPMENT SYMBOLS
BAR SCREEN, MANUAL
BAR SCREEN, MECHANICAL
BASIN, RECTANGULAR
BELT FILTER PRESS
CENTRIFUGE
DISSOLVED AIR FLOTATION (DAF) THICKENER
FLARE, GAS; WASTE GAS BURNER
GRAVITY BELT THICKENER
GRAVITY FILTER
GRIT BASIN
GRIT CLASSIFIER
GRIT COLLECTOR, VORTEX TYPE
GRIT CONCENTRATOR
GRIT CONCENTRATOR & DEWATERING SCREW
OZONE GENERATOR
OZONE GENERATOR WITH POWER SUPPLY
SEDIMENTATION BASIN, CIRCULAR
SEDIMENTATION BASIN, RECTANGULAR W/SETTLING PLATES AND SOLIDS COLLECTOR
SEDIMENTATION BASIN, RECTANGULAR W/ SOLIDS COLLECTOR
SLUDGE GRINDER, CHANNEL MOUNTED
SLUDGE GRINDER, INLINE
SOLIDS COLLECTOR
THICKENER, GRAVITY
UV, W/HORIZONTAL BULBS
PRIMARY ELEMENT & FITTING SYMBOLS
CAP
COUPLING
DIAPHRAGM SEAL
DIAPHRAGM SEAL, ANNULAR TYPE
DRAIN, BELL-UP TYPE
DRAIN, FUNNEL TYPE
EXPANSION LOOP
FLAME ARRESTER
FLAME CHECK
FLANGE
FLEXIBLE CONNECTION
FLOW CONDITIONER
HORN OR SIREN
HOSE CONNECTION
IN-LINE TYPE ULTRASONIC FLOWMETER (SINGLE OR MULTI-PATH)
INSTRUMENT PURGE OR FLUSHING DEVICE
LEVEL SENSOR, CONDUCTANCE TYPE
LEVEL SENSOR, GUIDED WAVE RADAR TYPE
LEVEL SENSOR, PRESSURE SENSING TYPE
LEVEL SENSOR, RADAR TYPE
LEVEL SENSOR, ULTRASONIC TYPE
MOISTURE SEPARATOR
PLUG
PRIMARY FLOW ELEMENT, AVERAGING PITOT TYPE
PRIMARY FLOW ELEMENT, CORIOLIS MASS FLOWMETER
PRIMARY FLOW ELEMENT, FLUME
PRIMARY FLOW ELEMENT, MAGNETIC
PRIMARY FLOW ELEMENT, ORIFICE PLATE
PRIMARY FLOW ELEMENT, THERMAL DISPERSION FLOWMETER
PRIMARY FLOW ELEMENT, TURBINE OR PROPELLER-TYPE
PRIMARY FLOW ELEMENT, VENTURI TUBE, FLOW NOZZLE, OR FLOW TUBE. * SEE MEASUREMENT SYMBOL NOTATIONS LIST
PRIMARY FLOW ELEMENT, WEIR
QUICK CONNECT
REDUCER - CONCENTRIC
REDUCER - ECCENTRIC
ROTAMETER
SEDIMENT TRAP
SIGHTGLASS
STRAINER, BASKET TYPE
STRAINER, Y TYPE
SUCTION DIFFUSER
SURGE CHAMBER
TRAP
UNION
VENT
VENT, SCREENED
CHEMICAL FEED EQUIPMENT SYMBOLS
AUTOMATIC SWITCHOVER
CALIBRATION COLUMN
CHLORINE DIOXIDE (CO2) VAPORIZER
CYLINDER, GAS
DIFFUSER, CHANNEL
DIFFUSER, INLINE
DIFFUSER, POLYMER INJECTION RING
DIFFUSER, TANK
DOUBLE CONTAINED PIPING
DRIP LEG HEATER
DRY CHEMICAL FEEDER
EMERGENCY COMBINATION SHOWER AND EYEWASH FOUNTAIN
EMERGENCY EYEWASH FOUNTAIN
EMERGENCY SHOWER
EVAPORATOR
EXPANSION TANK OR FUNNEL
GAS FEEDER
INJECTOR/EDUCTOR
LIME SLAKER, PASTE TYPE
PRESSURE BUILDING COIL
PULSATION DAMPENER
RUPTURE DISK
SPECTACLE FLANGE, BLIND, CLOSED
SPECTACLE FLANGE, BLIND, OPEN
TON CONTAINER
TOTE
VAPOR SUPERHEATER
WEIGH SCALE
VALVE & GATE SYMBOLS
BACKFLOW PREVENTER
CHLORINE VACUUM REGULATOR ASSEMBLY
EXPLOSION RELIEF
GATE, SLUICE OR SLIDE
VALVE, AIR RELEASE
VALVE, AIR VACUUM BREAK
VALVE, ANGLE
VALVE, BALL
VALVE, BUTTERFLY
VALVE, CHECK
VALVE, CHECK W/STOP
VALVE, CHLORINE WITH YOKE
VALVE, COMBINATION AIR RELEASE AND VACUUM BREAK
VALVE, DIAPHRAGM
VALVE, DIVERTER
VALVE, DIVERTER ASSEMBLY
VALVE, ECCENTRIC PLUG
VALVE, FLAP GATE
VALVE, FOUR FUNCTION
VALVE, FOUR WAY
VALVE, GATE OR OTHER TWO-WAY TYPE NOT OTHERWISE IDENTIFIED
VALVE, GLOBE
VALVE, KNIFE GATE
VALVE, MUD
VALVE, NEEDLE
VALVE, NON-ECCENTRIC PLUG
VALVE, PINCH
VALVE, PRESSURE AND VACUUM RELIEF
VALVE, PRESSURE REDUCING
VALVE, PRESSURE REDUCING (SELF ACTUATING TYPE)
VALVE, PRESSURE RELIEF
VALVE, PRESSURE SUSTAINING
VALVE, PRESSURE SUSTAINING (SELF ACTUATING TYPE)
VALVE, RELIEF, PILOT ACTUATED
VALVE, ROTARY, GENERIC
VALVE, SET STOP
VALVE, SLEEVE
VALVE, TELESCOPING
VALVE, THERMAL SHUTOFF
VALVE, THREE WAY
VALVE, V-PORT BALL
VALVE, VACUUM RELIEF
VALVE, VENTED BALL
VALVE AND GATE ACTUATOR SYMBOLS
AIR CYLINDER ACTUATOR
AIR CYLINDER ACTUATOR - DOUBLE ACTING
AIR CYLINDER ACTUATOR - SPRING CLOSE
AIR CYLINDER ACTUATOR - SPRING OPEN
AIR-OIL CYLINDER ACTUATOR
DIAPHRAGM, PRESSURE BALANCED
DIAPHRAGM, SPRING, OR OTHERWISE UNSPECIFIED
ELECTRIC-HYDRAULIC
FLOAT OPERATED FOR VALVE
HYDRAULIC CYLINDER ACTUATOR
INTELLIGENT ELECTRIC ACTUATOR
LOADING/BACK PRESSURE FOR VALVE
MANUAL
QUICK CLOSING FOR VALVE
QUICK OPENING FOR VALVE
SOLENOID
SOLENOID - MANUAL RESET
SOLENOID - REMOTE RESET
SPRING OR WEIGHT FOR RELIEF VALVE OR LOADED FOR SAFETY VALVE
STANDARD ELECTRIC ACTUATOR
VANE TYPE PNEUMATIC ACTUATOR
MATERIAL HANDLING EQUIPMENT SYMBOLS
BIN, LIVE BOTTOM
BIN, SLIDING FRAME
BIN ACTIVATOR
BIN/HOPPER, CLOSED TOP
BIN/HOPPER, OPEN TOP
CONVEYOR, BELT
CONVEYOR, SCREW
CONVEYOR, VIBRATORY
CYCLONE SEPARATOR
DUMPSTER
DUST COLLECTOR
GRINDER
HORIZONTAL BAR SCREEN
INSULATION
INSULATION, W/ HEAT TRACING
MIXER, BLENDER
MIXER, PUGMILL
PISTON CAKE PUMP, DOUBLE
PISTON CAKE PUMP, SINGLE
SCREEN, DOUBLE VIBRATORY
SCREEN, SINGLE VIBRATORY
TARGET BOX
GENERAL NOTES
1. IN GENERAL, THE P&ID SYMBOLS AND DEVICE IDENTIFICATIONS ARE BASED ON INTERNATIONAL SOCIETY OF AUTOMATION, STANDARD PRACTICE ANSI/ISA-5.1 (2009). SOME MODIFICATIONS, ADDITIONS, AND ALTERATIONS HAVE BEEN MADE AS NEEDED TO ACCOMMODATE THE PROJECT REQUIREMENTS.
2. SOME CONTROL AND INTERLOCK REQUIREMENTS WHICH CAN BE MORE CLEARLY ILLUSTRATED ON SCHEMATIC DRAWINGS HAVE BEEN OMITTED FROM THE P&ID DRAWINGS.
3. THIS IS A GENERAL LEGEND SHEET. SOME SYMBOLS AND ABBREVIATIONS MAY NOT BE UTILIZED ON THIS SPECIFIC PROJECT.
PRELIMINARY - NOT FOR CONSTRUCTION
BLACK & VEATCH
Building a world of difference
Black & Veatch Corporation
Kansas City, Missouri
INSTRUMENTATION & CONTROLS STANDARDS EXAMPLES
P&ID LEGEND & ABBREVIATIONS SHEET 1 OF 3
DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE:
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE
PROJECT NO.
999999
SHEET
OF

INSTRUMENT AND I/O ABBREVIATIONS

MEANINGS OF IDENTIFICATION LETTERS

LETTER	FIRST LETTER: MEASURED OR INITIATING VARIABLE	FIRST LETTER: VARIABLE MODIFIER	SUCCEEDING LETTERS: READOUT OR PASSIVE FUNCTION	SUCCEEDING LETTERS: OUTPUT OR ACTIVE FUNCTION	SUCCEEDING LETTERS: FUNCTION MODIFIER
A	ANALYSIS		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
C	USER'S CHOICE			CONTROL	CLOSE
D	USER'S CHOICE	DIFFERENTIAL			DEVIATION
E	VOLTAGE (EMF)		SENSOR, PRIMARY ELEMENT		
F	FLOW, FLOW RATE	RATIO (FRACTION)			
G	USER'S CHOICE		GLASS, GAUGE, VIEWING DEVICE		
H	HAND (MANUALLY INITIATED)				HIGH
I	CURRENT (ELECTRICAL)		INDICATE		
J	POWER		SCAN		
K	TIME OR TIME-SCHEDULE	TIME RATE OF CHANGE		CONTROL STATION	
L	LEVEL		LIGHT		LOW
M	USER'S CHOICE	MOMENTARY			MIDDLE OR INTERMEDIATE
N	USER'S CHOICE		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
O	USER'S CHOICE		ORIFICE (RESTRICTION)		OPEN
P	PRESSURE OR VACUUM		POINT (TEST CONNECTION)		
Q	QUANTITY	INTEGRATE OR TOTALIZE	INTEGRATE OR TOTALIZE		
R	RADIATION		RECORD		RUN
S	SPEED OR FREQUENCY	SAFETY		SWITCH	STOP
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	
V	VIBRATION OR MECHANICAL ANALYSIS			VALVE, DAMPER OR LOUVER	
W	WEIGHT OR FORCE		WELL, PROBE		
X	UNCLASSIFIED	X-AXIS	ACCESSORY DEVICES OR UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED
Y	EVENT, STATE, OR PRESENCE	Y-AXIS		AUXILIARY DEVICES	
Z	POSITION, DIMENSION	Z-AXIS		DRIVE, ACTUATOR OR FINAL CTRL ELEMENT	

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PIPELINE MATERIAL CODE ABBREVIATIONS [1]

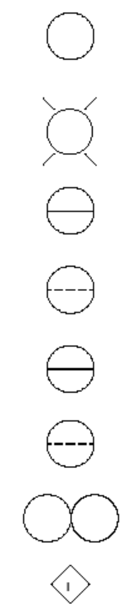
	PIPE MATERIAL	SPECIFICATION NO.
BR	BRASS	40 05 41
CBCP	CONCRETE BAR-WRAPPED STEEL CYLINDER PIPE	40 05 39.16
CCFP	CENTRIFUGALLY CAST FIBERGLASS PIPE	40 05 36.11
CCP	CONCRETE CULVERT PIPE	33 42 16
CI	CAST IRON SOIL PIPE	22 13 16
CMP	CORRUGATED METAL PIPE	33 42 14
CPVC	CPVC	40 05 32
CS	MISCELLANEOUS STEEL PIPE	40 05 24.43
CSG	GALVANIZED STEEL PIPE	40 05 24.43
CSP	COMPOSITE SEWER PIPE	40 05 43
CU	COPPER TUBING	40 05 17
DIP	DUCTILE IRON PIPE	40 05 19
FRP	FRP	40 05 32
FRPA	FRP EXHAUST AIR PIPE	40 05 36.11
HDPE	HDPE PRESSURE PIPE	40 05 33.11
HS	HOSE	40 05 41
LHCP	LOW-HEAD CONCRETE PRESSURE	40 05 39.18
LWSP	LIGHT WALL STEEL PIPE	40 05 24.14
PCCP	PRESTRESSED CONCRETE CYLINDER PIPE	40 05 39.14
PE	POLYETHYLENE	40 05 32
PP	POLYPROPYLENE	40 05 32
PVC	PVC	40 05 32
PVCFJ	PVC FUSED JOINT PIPE	40 05 31.13
PVCPP	PVC PRESSURE PIPE	40 05 31.12
PVCSP	PVC SEWER PIPE	40 05 31.16
PVDF	PVDF	40 05 32
RCP	CONCRETE SEWER PIPE	40 05 39.24
RPT	REINFORCED PLASTIC TUBING	40 05 32
SP	STEEL PIPE	40 05 24
SS	STAINLESS STEEL PIPE	40 05 23
TG	TEMPERED GLASS	40 05 41
VCP	VITRIFIED CLAY PIPE	40 05 44

1. ABBREVIATION EXTENSIONS ARE ADDED AS NEEDED TO IDENTIFY THE MATERIAL SUB-CLASSIFICATION IN THE SPECIFICATION, SUCH AS "SS-1" FOR DIGESTER GAS PIPING.

INSTRUMENT AND I/O ABBREVIATION DEFINITIONS

AAH	ANALYZER ALARM HIGH
AAHH	ANALYZER ALARM HIGH-HIGH
AAL	ANALYZER ALARM LOW OR STROBE ALARM LIGHT
AALL	ANALYZER ALARM LOW-LOW
AAX	ALARM HORN
AE	ANALYZER SENSOR
AI	ANALYZER INDICATION
AIT	ANALYZER INDICATING TRANSMITTER
ASH	ANALYZER SWITCH HIGH
ASHH	ANALYZER SWITCH HIGH-HIGH
CB	CONTROL BLOCK REFERENCE (SCADA LEVEL)
FAH	FLOW ALARM HIGH
FAL	FLOW ALARM LOW
FC	FLOW CONTROLLER
FE	PRIMARY FLOW ELEMENT/SENSOR
FG	FLOW SIGHT GAUGE
FI	FLOW DIGITAL INDICATOR (LED OR SCREEN)
FIC	FLOW INDICATING CONTROLLER
FIT	FLOW INDICATING TRANSMITTER
FQG	FLOW TOTALIZING GAUGE
FQIT	FLOW TOTALIZING INDICATING TRANSMITTER
FSH	FLOW SWITCH HIGH
FSL	FLOW SWITCH LOW
FY	FLOW SIGNAL CONVERTER, REPEATER, OR ISOLATOR
HIC	HAND INDICATING CONTROLLER
HMS	MOMENTARY PUSHBUTTON OR SELECTOR SWITCH
HS	HAND SWITCH
IAH	CURRENT ALARM HIGH (MOTOR OVERLOAD)
IE	CURRENT ELEMENT/SENSOR
ISH	CURRENT SWITCH HIGH USED TO DETECT HIGH TORQUE
JA	POWER FAILURE ALARM
JI	POWER INDICATOR
JIT	POWER INDICATING TRANSMITTER
JL	POWER INDICATING LIGHT
KQI	TIME TOTALIZING INDICATOR
LAH	LEVEL ALARM HIGH
LAHH	LEVEL ALARM HIGH-HIGH
LAL	LEVEL ALARM LOW
LALL	LEVEL ALARM LOW-LOW
LE	PRIMARY LEVEL ELEMENT/SENSOR
LG	LEVEL SIGHT GAUGE
LI	LEVEL INDICATOR (LED OR SCREEN)
LSH	LEVEL SWITCH HIGH
LSHH	LEVEL SWITCH HIGH-HIGH
LSL	LEVEL SWITCH LOW
LSLL	LEVEL SWITCH LOW LOW
LY	LEVEL SIGNAL CONVERTER, ISOLATOR, OR REPEATER
OAH	TORQUE ALARM HIGH
OAHH	TORQUE ALARM HIGH HIGH
OSH	TORQUE SWITCH HIGH
OSHH	TORQUE SWITCH HIGH-HIGH
PAH	PRESSURE ALARM HIGH
PAHH	PRESSURE ALARM HIGH-HIGH
PAL	PRESSURE ALARM LOW
PALL	PRESSURE ALARM LOW-LOW
PDAH	DIFFERENTIAL PRESSURE ALARM HIGH
PDAHH	DIFFERENTIAL PRESSURE ALARM HIGH-HIGH
PDG	DIFFERENTIAL PRESSURE GAUGE
PDI	DIFFERENTIAL PRESSURE INDICATOR (LED OR SCREEN)
PDIT	DIFFERENTIAL PRESSURE INDICATING TRANSMITTER
PDSH	DIFFERENTIAL PRESSURE SWITCH HIGH
PDSHH	DIFFERENTIAL PRESSURE SWITCH HIGH-HIGH
PDSL	DIFFERENTIAL PRESSURE SWITCH LOW
PDSLL	DIFFERENTIAL PRESSURE SWITCH LOW-LOW
PE	PRESSURE SENSOR
PG	PRESSURE GAUGE
PI	PRESSURE INDICATOR (LED OR SCREEN)
PIT	PRESSURE INDICATING TRANSMITTER
PSH	PRESSURE SWITCH HIGH
PSL	PRESSURE SWITCH LOW
SC	SPEED CONTROL
SI	SPEED INDICATION (LED OR SCREEN)
SIT	SPEED INDICATING TRANSMITTER
SSL	SPEED SWITCH LOW
TAH	TEMPERATURE ALARM HIGH
TAHH	TEMPERATURE ALARM HIGH-HIGH
TAL	TEMPERATURE ALARM LOW
TDI	DIFFERENTIAL TEMPERATURE INDICATOR (LED OR SCREEN)
TDIT	DIFFERENTIAL TEMPERATURE TRANSMITTER
TE	TEMPERATURE SENSOR/RESISTANCE TEMPERATURE DETECTOR
TG	TEMPERATURE GAUGE
TI	TEMPERATURE INDICATOR (LED OR SCREEN)
TIT	TEMPERATURE INDICATING TRANSMITTER
TSH	TEMPERATURE SWITCH HIGH
TSHH	TEMPERATURE SWITCH HIGH HIGH
TSL	TEMPERATURE SWITCH LOW
UA	MULTIVARIABLE/COMMON ALARM/COMMON FAULT
UCR	RUN COMMAND
UCS	STOP COMMAND
VAH	VIBRATION ALARM HIGH
WE	PRIMARY WEIGHT SENSOR/LOAD CELL
WG	WEIGHT GAUGE
WIT	WEIGHT INDICATING TRANSMITTER
YA	GENERAL ALARM EVENT
YI	EVENT INDICATION (LED OR SCREEN)
YIR	RUNNING INDICATION
YIS	STOPPED INDICATION
YL	EVENT INDICATING LIGHT
YLR	RUNNING INDICATING LIGHT
YLS	STOPPED INDICATING LIGHT
ZI	POSITION INDICATOR
ZIC	CLOSED INDICATION
ZIO	OPEN INDICATION
ZIT	POSITION INDICATING TRANSMITTER
ZLC	CLOSED INDICATING LIGHT
ZLO	OPEN INDICATING LIGHT
ZSC	CLOSED POSITION SWITCH
ZSO	OPEN POSITION SWITCH
ZT	POSITION TRANSMITTER

GENERAL INSTRUMENT SYMBOLS



FIELD MOUNTED DISCRETE INSTRUMENT

PILOT LIGHT

DISCRETE INSTRUMENT MOUNTED ON FACE OF PRIMARY PANEL

DISCRETE INSTRUMENT MOUNTED BEHIND OR INSIDE OF PRIMARY PANEL

DISCRETE INSTRUMENT MOUNTED ON FACE OF LOCAL PANEL

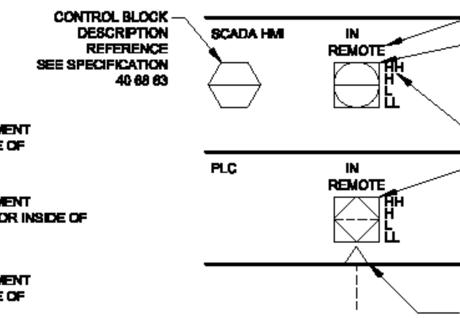
DISCRETE INSTRUMENT MOUNTED BEHIND OR INSIDE OF LOCAL PANEL

SINGLE INSTRUMENT HOUSING CONTAINING TWO (OR MORE) INSTRUMENTATION FUNCTIONS

GENERAL CONTROL INTERLOCK FUNCTION, SEE SCHEMATICS AND SYSTEM SPECIFICATIONS FOR SPECIFIC FUNCTION

DIGITAL SYSTEMS INTERFACE SYMBOLS

NOTE: REFER TO DETAILED SYSTEM SPECIFICATIONS FOR FUNCTIONAL DESCRIPTION. ALSO SEE I/O SCHEDULES FOR COMPLETE INPUT AND OUTPUT LISTINGS.



I/O DESCRIPTION

COMPUTER, DISTRIBUTED CONTROL SYSTEM OR DISPLAY FUNCTION BLOCK. LETTERS, TAG NUMBERS, ABBREVIATIONS AND OTHER ANNOTATIONS ARE SIMILAR TO THE GENERAL INSTRUMENT LEGEND.

CALCULATED ALARM DESIGNATION

PROGRAMMABLE LOGIC CONTROLLER SYSTEM I/O POINT. SEE I/O ABBREVIATIONS.

PLC I/O SYMBOL. DIRECTION OF ARROW DENOTES INPUT OR OUTPUT.

- △ DISCRETE INPUT
- ▽ DISCRETE OUTPUT
- ▲ ANALOG INPUT
- ▼ ANALOG OUTPUT
- △ PULSE INPUT

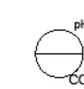
INSTRUMENTATION SYMBOLOGY AND DESIGNATIONS

INSTRUMENT ABBREVIATION

NUMBER AFTER DASH (-1, -2, ETC) DENOTES MULTIPLE DEVICES USED IN IDENTICAL DUPLICATE SYSTEMS.

A LETTER AFTER THE LOOP NUMBER (31A, 31B, ETC) IS USED TO DISTINGUISH MULTIPLE SIMILAR DEVICES IN THE SAME INSTRUMENT LOOP.

LOOP DESIGNATION NUMBER



INSTRUMENT FUNCTION OR HAND SWITCH DESIGNATION

MEASUREMENT PRINCIPLE NOTATION (IF APPLICABLE)

FUNCTION DESIGNATIONS AND ABBREVIATIONS

MEASUREMENT PRINCIPLE NOTATIONS

CON	CONDUCTANCE
DP	DIFFERENTIAL PRESSURE SENSING
FLN	FLOW NOZZLE
FLT	FLOW TUBE
GWR	GUIDED WAVE RADAR
RAD	RADAR
US	ULTRASONIC
VENT	VENTURI TUBE

CALCULATED ALARM DESIGNATIONS

H	HIGH
HH	HIGH-HIGH
L	LOW
LL	LOW-LOW

INDICATING LIGHT/ALARM DESIGNATIONS

OVRLD	OVERLOAD
TRQ HI	TORQUE HIGH
TRQ HI-HI	TORQUE HIGH HIGH

INSTRUMENT FUNCTIONS

Δ	SUBTRACT (DIFFERENCE)
Σ	ADD OR SUM (ADD AND SUBTRACT)
$\sqrt{\ }$	EXTRACT SQUARE ROOT
$\div$	DIVIDE
>	HIGH-SELECT
<	LOW-SELECT
$\times$	MULTIPLY
$\int$	INTEGRATE (TIME INTEGRAL)
CH4	METHANE
CL2	CHLORINE RESIDUAL
CO2	CARBON DIOXIDE
COND	CONDUCTIVITY
DO	DISSOLVED OXYGEN
DWPT	DEWPOINT
F(X)	CHARACTERIZE SIGNAL
H2S	HYDROGEN SULFIDE
K	GAIN OR ATTENUATE (INPUT:OUTPUT)
-K	GAIN AND REVERSE
LEL	LOWER EXPLOSIVE LIMIT
MCC	MOTOR CONTROL CENTER
MLSS	MIXED LIQUOR SUSPENDED SOLIDS
02	OXYGEN (PURITY)
03	OZONE
pH	pH

HAND SWITCH DESIGNATIONS

FR	FORWARD-REVERSE
HOA	HAND-OFF-AUTO
HOR	HAND-OFF-REMOTE
LOA	LOCAL-OFF-AUTO
LOR	LOCAL-OFF-REMOTE
LR	LOCAL REMOTE
OC	OPEN-CLOSE
OCA	OPEN-CLOSE-AUTO
OO	ON-OFF
OOA	ON-OFF-AUTO
OOR	ON-OFF-REMOTE
OSC	OPEN-STOP-CLOSE

TRANSDUCER & CONVERTER DESIGNATION

E	VOLTAGE
FSK	FREQUENCY SHIF KEYING
H	HYDRAULIC
I	CURRENT
P	PNEUMATIC PULSE
PD	PULSE DURATION
PF	PULSE FREQUENCY
R	RESISTANCE (ELECTRICAL)

EXAMPLE: I/P = CURRENT TO PNEUMATIC TRANSDUCER

POWER SUPPLY ABBREVIATIONS

—— 120V POWER SUPPLY SOURCE LABEL. USED ONLY WHERE NECESSARY TO HELP CLARIFY AN INSTRUMENT OR SYSTEM FUNCTION.

120V	120VAC
AS	AIR SUPPLY
ES	ELECTRIC SUPPLY
GS	GAS SUPPLY
HS	HYDRAULIC SUPPLY
NS	NITROGEN SUPPLY
SS	STEAM SUPPLY
WS	WATER SUPPLY

PRELIMINARY - NOT FOR CONSTRUCTION

DATE	REVISIONS AND RECORD OF ISSUE	NO.	BY	CK	APP

PW: 50.3000 PID Drawings | XREF1:
PW FILE: I002.dwg | XREF2:
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PLOTTED: BJJ72262, 8/12/2021 3:09:47 PM | XREF4:
USER: BJJ72262 | DWG VER: 1000

BLACK & VEATCH
Building a world of difference
Black & Veatch Corporation
Kansas City, Missouri

INSTRUMENTATION & CONTROLS STANDARDS EXAMPLES

P&ID
LEGEND & ABBREVIATIONS
SHEET 2 OF 3

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE:

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
999999

SHEET
OF

FD8000
D8000

SYSTEM CODE ABBREVIATIONS

ACE	ACETIC ACID
ACT	ACETYLENE
AER	AERATION SYSTEM
AIR	AIR, AERATION OR PROCESS
ALS	ALUMINUM SULFATE
ARG	ARGON
ARW	AIR WASH
AS	ANTI-SEALANT
ASH	ASH
BAL	BALLASTED FLOCCULATION
BIO	BIOSOLIDS
BIT	BIOTOWER
BLS	BLENDED SLUDGE
BNR	BNR
BRN	BRINE
BWH	BACKWASH FOR MEMBRANE OR FILTER
CA	CITRIC ACID
CACL	CALCIUM HYPOCHLORITE
CAH	LIME, HYDRATED
CAI	COMPRESSED AIR, INSTRUMENT
CAO	LIME, QUICKLIME
CAS	CARBON SLURRY
CATS	CALCIUM THIOSULFATE
CDW	CONDENSATE WATER
CEB	CHEMICAL ENHANCED BACKWASH FOR MEMBRANE
CEN	CENTRATE
CI	CORROSION INHIBITOR
CIP	CLEAN IN PLACE
CL2	CHLORINE
CLO2	CHLORINE DIOXIDE
CMS	COMPRESSED AIR, SERVICE
C02	CARBON DIOXIDE
COA	COAGULATION
COLW	COOLING WATER
CUS	COPPER SULFATE
DAF	DISSOLVED AIR FLOTATION
DCB	DISINFECTION CONTACT BASIN
DCL	DECHLORINATION
DEW	DEIONIZED WATER
DET	DETERGENT
DGA	DIGESTION, AEROBIC
DGM	DIGESTER GAS MIXING
DGG	DIGESTER GAS
DGS	DIGESTER SLUDGE
DIG	DIGESTION, ANAEROBIC
DRN	DRAINAGE
DW	DISTILLED WATER
DWT	DEWATERING
EFP	EFFLUENT PUMPING
EQB	EQUALIZATION BASIN
EXH	ENGINE EXHAUST
FE	FILTER EFFLUENT
FEC	FERRIC CHLORIDE
FES	FERRIC SULFATE
FLC	FLOCCULATION
FLT	FILTRATION
FO	FUEL OIL
FRC	FERROUS CHLORIDE
FRS	FERROUS SULFATE
FUE	DIESEL FUEL
FW	FIRE WATER
GAC	GRANULAR ACTIVATED CARBON
GOX	GASEOUS OXYGEN
GRS	GREASE
GRT	GRIT
GSL	GASOLINE
HCL	HYDROCHLORIC ACID
HCO3	CARBONIC ACID
HEL	HELIUM
HFL	HYDRAULIC FLUID
HFS	HYDROFLUOSILICIC ACID (FLUORIDE)
HSO4	SULFURIC ACID
HW	HOT OR HEATING WATER
HYD	HYDROGEN
INC	INCINERATION
INFP	INFLUENT PUMPING
INT	INTAKE
IRW	IRRIGATION WATER
KMN	POTASSIUM PERMANGANATE
LAG	LAGOON STORAGE
LAP	LAND APPLICATION
LIM	LIME, STABILIZATION
LOX	LIQUID OXYGEN
LPG	LP GAS OR PROPANE GAS
MEG	METHANE GAS
MEM	MEMBRANE
MGOH	MAGNESIUM HYDROXIDE
MTH	METHANOL
MXL	MIXED LIQUOR
NAC	SODA ASH
NAF	SODIUM FLUORIDE
NAL	SODIUM ALUMINATE
NAOH	SODIUM HYDROXIDE
NAM	SODIUM ALUMINATE
NASF	SODIUM SILICOFLUORIDE
NAX	SODIUM HEXAMETAPHOSPHATE
NBC	SODIUM BICARBONATE
NCL	SODIUM CHLORIDE
NCL2	SODIUM CHLORITE
NG	NATURAL GAS
NH3	ANHYDROUS AMMONIA
NHOH	AQUA AMMONIA
NHS	SODIUM BISULFITE
NIO	NITROUS OXIDE
NIT	NITROGEN
NOCL	SODIUM HYPOCHLORITE
NPW	NON-POTABLE WATER
NSO4	AMMONIUM SULFATE
ODC	ODOR CONTROL
OIL	OIL
OZD	OZONE DESTRUCT
OZN	OZONE
OZW	OZONATED WATER
PAC	POWDERED ACTIVATE CARBON
PACL	POLYALUMINUM CHLORIDE
PAR	PRE-AERATION
PER	HYDROGEN PEROXIDE
PEW	PLANT EFFLUENT WATER
PO4	PHOSPHORIC ACID
POLY	POLYMER
PPP	PHOSPHATE
PRC	PRIMARY CLARIFICATION
PRS	PRIMARY SLUDGE
PSC	PRIMARY SCUM
PSD	PRESEDIMENTATION
PW	POTABLE WATER
RAS	RETURN ACTIVATED SLUDGE
RCS	RECIRCULATED SLUDGE
RCW	RECLAIMED WATER
REF	REFRIGERANT
RES	RESIDUALS
ROS	REVERSE OSMOSIS
RW	RAW WATER
RWP	RAW WATER PUMPING
RWS	RAW WATER STORAGE
SCL	SECONDARY CLARIFICATION
SCR	SCREENINGS
SEP	SEPTAGE
SET	SETTLED WATER
SEW	SEWAGE
SO2	SULFUR DIOXIDE
SSC	SECONDARY SCUM
STM	STEAM
STS	STORM SEWER
STW	STORM WATER
SW	SURFACE WASH
SWT	SEAL WATER
TERT	TERTIARY TREATMENT
TF	TRICKLING FILTER
THCK	THICKENING
TPRS	THICKENED PRIMARY SLUDGE
TW	TREATED WATER
TWAS	THICKENED WASTE ACTIVATED SLUDGE
UV	ULTRAVIOLET
VAC	VACUUM
WAS	WASTE ACTIVATED SLUDGE
WW	WASH WATER
WWP	RAW WASTEWATER PUMPING
WWT	WET WEATHER TREATMENT
WWW	WASTE WASH WATER
ZOP	ZINC ORTHOPHOSPHATE

PROCESS CODE ABBREVIATIONS

ACE_X	ACETIC ACID
ACT_X	ACETYLENE
AER_X	AERATION SYSTEM
AIR_X	AIR, AERATION OR PROCESS
ALS_X	ALUMINUM SULFATE
ARG_X	ARGON
ARW_X	AIR WASH
AS_X	ANTI-SEALANT
ASH_X	ASH
BAL_X	BALLASTED FLOCCULATION
BIO_X	BIOTOWER
BIT_X	BLENDED SLUDGE
BLS_X	BNR
BNR_X	BIOSOLIDS
BRN_X	BRINE
BWH_X	BACKWASH FOR MEMBRANE OR FILTER
CA_X	CITRIC ACID
CACL_X	CALCIUM HYPOCHLORITE
CAH_X	LIME, HYDRATED
CAI_X	COMPRESSED AIR, INSTRUMENT
CAO_X	LIME, QUICKLIME
CAS_X	CARBON SLURRY
CATS_X	CALCIUM THIOSULFATE
CDW_X	CONDENSATE WATER
CEB_X	CHEMICAL ENHANCED BACKWASH FOR MEMBRANE
CEN_X	CENTRATE
CI_X	CORROSION INHIBITOR
CIP_X	CLEAN IN PLACE
CL2_X	CHLORINE
CLO2_X	CHLORINE DIOXIDE
CMS_X	COMPRESSED AIR, SERVICE
COA_X	COAGULATION
C02_X	CARBON DIOXIDE
COLW_X	COOLING WATER
CUS_X	COPPER SULFATE
DAF_X	DISSOLVED AIR FLOTATION
DCB_X	DISINFECTION CONTACT BASIN
DCL_X	DECHLORINATION
DEW_X	DEIONIZED WATER
DET_X	DETERGENT
DGA_X	DIGESTION, AEROBIC
DGG_X	DIGESTER GAS
DGM_X	DIGESTER GAS MIXING
DGS_X	DIGESTER SLUDGE
DIG_X	DIGESTION, ANAEROBIC
DRN_X	DRAINAGE
DW_X	DISTILLED WATER
DWT_X	DEWATERING
EFP_X	EFFLUENT PUMPING
EQB_X	EQUALIZATION BASIN
EXH_X	ENGINE EXHAUST
FE_X	FILTER EFFLUENT
FEC_X	FERRIC CHLORIDE
FES_X	FERRIC SULFATE
FLC_X	FLOCCULATION
FLT_X	FILTRATION
FO_X	FUEL OIL
FRC_X	FERROUS CHLORIDE
FRS_X	FERROUS SULFATE
FUE_X	DIESEL FUEL
FW_X	FIRE WATER
GAC_X	GRANULAR ACTIVATED CARBON
GOX_X	GASEOUS OXYGEN
GRS_X	GREASE
GRT_X	GRIT
GSL_X	GASOLINE
HCL_X	HYDROCHLORIC ACID
HCO3_X	CARBONIC ACID
HEL_X	HELIUM
HFL_X	HYDRAULIC FLUID
HFS_X	HYDROFLUOSILICIC ACID (FLUORIDE)
HSO4_X	SULFURIC ACID
HW_X	HOT OR HEATING WATER
HYD_X	HYDROGEN
INC_X	INCINERATION
INFP_X	INFLUENT PUMPING
INT_X	INTAKE
IRW_X	IRRIGATION WATER
KMN_X	POTASSIUM PERMANGANATE
LAG_X	LAGOON STORAGE
LAP_X	LAND APPLICATION
LIM_X	LIME STABILIZATION
LOX_X	LIQUID OXYGEN
LPG_X	LP GAS OR PROPANE GAS
MEG_X	METHANE GAS
MEM_X	MEMBRANE
MGOH_X	MAGNESIUM HYDROXIDE
MTH_X	METHANOL
MXL_X	MIXED LIQUOR
NAC_X	SODA ASH
NAF_X	SODIUM FLUORIDE
NAL_X	SODIUM ALUMINATE
NAM_X	SODIUM ALUMINATE
NAOH_X	SODIUM HYDROXIDE
NASF_X	SODIUM SILICOFLUORIDE
NAX_X	SODIUM HEXAMETAPHOSPHATE
NBC_X	SODIUM BICARBONATE
NCL_X	SODIUM CHLORIDE
NCL2_X	SODIUM CHLORITE
NG_X	NATURAL GAS
NH3_X	ANHYDROUS AMMONIA
NHOH_X	AQUA AMMONIA
NHS_X	SODIUM BISULFITE
NIO_X	NITROUS OXIDE
NIT_X	NITROGEN
NOCL_X	SODIUM HYPOCHLORITE
NPW_X	NON-POTABLE WATER
NSO4_X	AMMONIUM SULFATE
ODC_X	ODOR CONTROL
OIL_X	OIL
OZD_X	OZONE DESTRUCT
OZN_X	OZONE
OZW_X	OZONATED WATER
PAC_X	POWDERED ACTIVATE CARBON
PACL_X	POLYALUMINUM CHLORIDE
PAR_X	PRE-AERATION
PER_X	HYDROGEN PEROXIDE
PEW_X	PLANT EFFLUENT WATER
PO4_X	PHOSPHORIC ACID
POLY_X	POLYMER
PPP_X	PHOSPHATE
PRC_X	PRIMARY CLARIFICATION
PRS_X	PRIMARY SLUDGE
PSC_X	PRIMARY SCUM
PSD_X	PRESEDIMENTATION
PW_X	POTABLE WATER
RAS_X	RETURN ACTIVATED SLUDGE
RCS_X	RECIRCULATED SLUDGE
RCW_X	RECLAIMED WATER
REF_X	REFRIGERANT
RES_X	RESIDUALS
ROS_X	REVERSE OSMOSIS
RW_X	RAW WATER
RWP_X	RAW WATER PUMPING
RWS_X	RAW WATER STORAGE
SCL_X	SECONDARY CLARIFICATION
SCR_X	SCREENINGS
SEP_X	SEPTAGE
SET_X	SETTLED WATER
SEW_X	SEWAGE
SO2_X	SULFUR DIOXIDE
SSC_X	SECONDARY SCUM
STM_X	STEAM
STS_X	STORM SEWER
STW_X	STORM WATER
SW_X	SURFACE WASH
SWT_X	SEAL WATER
TERT_X	TERTIARY TREATMENT
TF_X	TRICKLING FILTER
THCK_X	THICKENING
TPRS_X	THICKENED PRIMARY SLUDGE
TW_X	TREATED WATER
TWAS_X	THICKENED WASTE ACTIVATED SLUDGE
UV_X	ULTRAVIOLET
VAC_X	VACUUM
WAS_X	WASTE ACTIVATED SLUDGE
WW_X	WASH WATER
WWP_X	RAW WASTEWATER PUMPING
WWT_X	WET WEATHER TREATMENT
WWW_X	WASTE WASH WATER
ZOP_X	ZINC ORTHOPHOSPHATE

X = PROCESS CODE SUFFIX USED TO FURTHER SPECIFY A PROCESS STREAM (I.E. CL2_G FOR CHLORINE GAS OR CL2_S FOR CHLORINE SOLUTION)

FUNCTION CODE ABBREVIATIONS

ACD	AERATOR, COARSE BUBBLE DIFFUSED
ACMB	ACTIVATION CHAMBER
AD	AIR DRYER
AEFD	AERATOR, FINE PORE DIFFUSED
AES	AERATOR, SURFACE
AF	AIR FILTER
AFC	AFTERCOOLER
AFD	ADJUSTABLE FREQUENCY DRIVE
AFS	AERATOR, FLOATING SURFACE
AR	AIR RECEIVER OR REGULATOR
AS	AIR SEPARATOR
AST	AIR STRIPPER
B	BIN (STORAGE - ALL TYPES)
BA	BIN ACTIVATOR
BDZ	BULLDOZER
BFP	BACKFLOW PREVENTER
BFPS	BELT FILTER PRESS
BL	BLOWER, POSITIVE DISPLACEMENT
BLC	BLOWER, CENTRIFUGAL
BLR	BOILER
BNR	BASIN, BNR
BSNA	BASIN, AERATION
BSNC	BASIN, CHLORINE CONTACT
BSNO	BASIN, OXIC
BSNS	BASIN, SEDIMENTATION
BSNX	BASIN, ANOXIC/OXIC
CAB	COVER, ALUMINUM DOME BASIN
CCLM	CALIBRATION COLUMN
CDG	COVER, GAS HOLDER
CFD	COVER, FIXED DIGESTER
CFG	CENTRIFUGE
CFL	COVER, FLOATING DIGESTER
CGR	CLASSIFIER, GRIT
CGS	CHLORINE GAS SCRUBBER
CHF	CHEMICAL FEEDER
CMB	COVER, MEMBRANE
CML	COMPRESSOR, LIQUID RING
CMP	COMPRESSOR
CMPS	COMPRESSOR, STEAM
CMR	COMPRESSOR, ROTARY SCREW
COB	CONVEYOR, BELT
COS	CONVEYOR, SCREW
CRG	CRANE, GANTRY
CRJ	CRANE, JIB
CRN	CRANE
CRP	CRANE, PORTABLE GANTRY
CRT	CRANE, TRAVELING BRIDGE
CTR	CONTAINER, PROCESS
CW	CLEARWELL
CYG	CYLINDER, GAS
CYLC	CYLINDER, CHLORINE
DAF	DISSOLVED AIR FLOTATION THICKENER
DFB	DIFFUSER BANK
DFP	DIFFUSER, PIPELINE
DFT	DIFFUSER, TANK
DGAP	DIGESTER, ANAEROBIC PRIMARY
DGAS	DIGESTER, ANAEROBIC SECONDARY
DGE	DIGESTER, AEROBIC
DIF	DIFFUSER, CHANNEL
DPS	DIAPHRAGM SEAL
DSUV	DISINFECTION UNIT, UV
DUC	DUST COLLECTOR
DWS	DEWATERING SCREW
EDC	EDUCTOR
EEWF	EMERGENCY EYE WASH FOUNTAIN
EQPB	EQUIPMENT, BUILDING SERVICES
EQPE	ELECTRICAL EQUIPMENT, GENERAL
EQPG	EQUIPMENT, GENERAL OR UNSPECIFIED
ESEW	EMERGENCY SHOWER AND EYEWASH
ESHR	EMERGENCY SHOWER
EXC	EXPANSION CHAMBER
EV	EVAPORATOR
FAN	FAN, CENTRIFUGAL
FAR	FLAME ARRESTER
FAX	FAN, AXIAL FLOW
FC	FLAME CHECK
FD	FLOOR DRAIN
FGP	FILTER, GAS PARTICULATE
FL	FORKLIFT
FLC	FILTER, CARTRIDGE TYPE
FLCH	FLOCCULATOR, HORIZONTAL
FLCV	FLOCCULATOR, VERTICAL
FLG	FLARE, GAS
FLM	FLUME, PARSHALL
FLT	FILTER, UNDERDRAINS OR PRESSURE
FMSP	FOAM SEPARATOR
FS	FLOW SPLITTER
FST	FENCE STIRRER
FSW	FILTER. SURFACE WASH EQUIPMENT
FTNG	FITTING, MISCELLANEOUS
GBT	GRAVITY BELT THICKENER
GEN	GENERATOR, ENGINE (BACKUP POWER)
GFD	GAS FEEDER
GFL	GATE, FLAP
GRB	GRIT BASIN, VORTEX TYPE
GRC	GRIT SCREW CONCENTRATOR
GRD	GRINDER PULVERIZER
GRI	GRINDER, INLINE SEWAGE
GSD	GATE, SLIDE
GSL	GATE, SLUICE
GVT	GRAVITY THICKENER
GWH	GAS WATER HEATER
GWR	GATE, WEIR
HEX	HEAT EXCHANGER
HSC	HOIST, CHAIN
HST	HOIST
HSW	HOIST, WIRE ROPE
HYC	HYDROCYCLONE
HYDF	HYDRANT, FIRE
HYDW	HYDRANT, WALL
INJ	INJECTOR, CHEMICAL
LS	LIME SLAKER
M	MOTOR
MBMF	MEMBRANE, MICROFILTRATION
MBNF	MEMBRANE, NANOFILTRATION
MBR	MEMBRANE
MBRO	MEMBRANE, REVERSE OSMOSIS
MBUF	MEMBRANE, ULTRAFILTRATION
MFL	MIXER, FLOCCULATION
MXC	MIXER, CARBON
MXI	MIXER, IN-LINE
MXP	MIXER, SUBMERSIBLE, PROP OR BLENDER
MXPG	MIXER, PUGMILL
MXR	MIXER, RAPID
MXS	MIXER, STATIC
ODU	OZONE DESTRUCT UNIT
OGEN	OZONE GENERATOR
OPSU	OZONE POWER SUPPLY UNIT
ORD	OVERFLOW ROOF DRAIN
P	PUMP, POSITIVE DISPLACEMENT, ROTARY, DRUM OR BELL MOUNTED
PAD	PUMP, AIR DIAPHRAGM
PBC	PRESSURE BUILDING COIL
PCL	PUMP, CENTRIFUGAL
PCLR	PRIMARY CLARIFIER
PCN	PARTICLE COUNTER
PD	PULSATION DAMPENER
PDM	PUMP, DIAPHRAGM METERING
PHE	PUMP, HORIZONTAL END SUCTION
PHW	PUMP, HOT OR HEATING WATER
PINJ	POLYMER INJECTOR RING
PIPE	PIPE
PLT	PELLETIZER
PNS	PENSTOCK
PP	PACKAGED PLANT
PPC	PUMP, PROGRESSING CAVITY
PPL	PUMP, PLUNGER
PPS	PUMP, PERISTALTIC
PSC	PUMP, HORIZONTAL SPLIT CASE
PSCH	PUMP, SUBMERSIBLE CHOPPER
PSE	PUMP, SCREW ENCLOSED
PSL	PUMP, SUBMERSIBLE
PSO	PUMP, SCREW OPEN
PSP	PUMP, SUMP
PSS	PUMP, SUBMERSIBLE SUMP
PST	PLATE SETTLER
PVD	PUMP, VERTICAL DIFFUSION VANE
PVE	PUMP, VERTICAL END SUCTION
PVW	PUMP, VERTICAL WET PIT
RCO	RESIDUAL COLLECTOR
RD	RUPTURE DISK
RM	ROTAMETER
RSV	RESERVOIR
SAMP	SAMPLER
SBL	SOLIDS BLENDER, INLINE
SC	SCALE, WEIGHT
SCB	SCRUBBER
SCC	SLUDGE COLLECTOR, CIRCULAR
SCFC	SLUDGE COLLECTOR, FLOC-CLARIFYING
SCL	SCALE
SCLC	SLUDGE COLLECTOR, CROSS
SCLR	SECONDARY CLARIFIER
SCRB	SCREEN, MANUAL OR MECH CLEANED BAR
SCRH	SCREEN, HORIZONTAL
SCRI	SCREEN, INLINE SLUDGE
SCRS	SCREEN, STEP
SCRT	SCREEN, TRAVELING WATER
SCRV	SCREEN, VIBRATORY
SCSC	SLUDGE COLLECTOR, SOLIDS CONTACT
SCSE	SLUDGE COLLECTOR, SEC CLARIFIERS
SCSL	SLUDGE COLLECTOR, STRAIGHT LINE
SCW	SCUM WEIR, ROTATING
SEP	SEPARATOR, MOISTURE OR CYCLONE
SG	SIGHT GAUGE
SGR	SLUDGE GRINDER, INLINE OR CHANNEL
SGT	SIGHT GLASS, TALL
SIL	SILENCER
SMC	SCUM COLLECTOR
SRCH	SURGE CHAMBER
STR	STRAINER
STRB	STRAINER, BASKET TYPE
STRY	STRAINER, Y TYPE
TB	TURBINE
TBC	TURBINE COMPRESSOR
TBE	TURBINE ENGINE
TCC	TANK, CHLORINE CONTACTOR
TCN	TANK, AMMONIA STORAGE
TCP	TANK, METHANOL
TCR	TANK, CRYOGENIC STORAGE
TDW	TANK, DOUBLE WALL
TNK	TANK, GENERAL OR UNSPECIFIED
TNKC	TANK, FRP CHEMICAL STORAGE
TRK	TRUCK
TRP	TRAP, DRIP
TRPS	TRAP, SEDIMENT
TSA	TANK, STORAGE, ABOVE GROUND
TSE	TANK, ELEVATED STORAGE
TSMP	TANK, SAMPLER
TSW	TANK, STEEL WATER
TX	TANK, EXPANSION
UPS	UNINTERRUPTIBLE POWER SUPPLY
UVR	UV REACTOR
V	VALVE, GENERAL OR UNSPECIFIED
VAG	VALVE, ANGLE
VAP	VAPORIZER
VAR	VALVE, AIR RELEASE
VAVB	VALVE, AIR VACUUM BREAK
VBA	VALVE, AWWA BALL
VBF	VALVE, AWWA BUTTERFLY
VBFI	VALVE, INDUSTRIAL BUTTERFLY
VBFP	VALVE, BACKFLOW PREVENTER
VBM	VALVE, BALL MISCELLANEOUS
VCAV	VALVE, COMBINATION AIR RELEASE AND VACUUM BREAK
VCK	VALVE, CHECK
VCN	VALVE, CONE
VDG	VALVE, DIAPHRAGM OPERATED
VER	VALVE, EXPLOSION RELIEF
VFG	VALVE, FLAP GATE
VFW	VALVE, FOUR WAY
VG	VALVE, GATE
VGD	VALVE, DOUBLE DISC GATE
VGL	VALVE, GLOBE
VGR	VALVE, RESILIENT SEATED GATE
VKG	VALVE, KNIFE GATE
VMD	VALVE, MUD
VMR	VALVE, MATERIAL HANDLING ROTARY
VND	VALVE, NEEDLE
VP	VALVE, PROCESS
VPE	VALVE, ECCENTRIC PLUG
VPL	VALVE, NON-ECCENTRIC PLUG
VPN	VALVE, PINCH
VPO	VALVE, PISTON OPERATED
VPRD	VALVE, PRESSURE REDUCING
VPRL	VALVE, PRESSURE RELIEF
VPS	VALVE, PRESSURE SUSTAINING
VPT	VALVE, PILOT
VPVR	VALVE, PRESSURE/VACUUM RELIEF
VRG	VACUUM REGULATOR
VS	VALVE, SAFETY
VSL	VALVE, SOLENOID
VSLB	VESSEL, BOOT
VSLV	VALVE, SLEEVE
VTLS	VALVE, TELESCOPING
VTS	VALVE, THERMAL SHUTOFF
VTW	VALVE, THREE WAY
VVB	VALVE, VACUUM BREAKER
VVP	VALVE, V-PORT BALL
VVR	VALVE, VACUUM RELIEF
WC	WEIR, CIPOLLETTI
WLHC	WELL, HORIZONTAL COLLECTOR
WLV	WELL, VERTICAL
WR	WEIR, RECTANGULAR
WV	WEIR, V-NOTCH

PRELIMINARY - NOT FOR CONSTRUCTION

REVISIONS AND RECORD OF ISSUE

NO.	DATE	BY	CK	APP

BLACK & VEATCH
Building a world of difference.
Black & Veatch Corporation
Kansas City, Missouri

INSTRUMENTATION & CONTROLS STANDARDS EXAMPLES

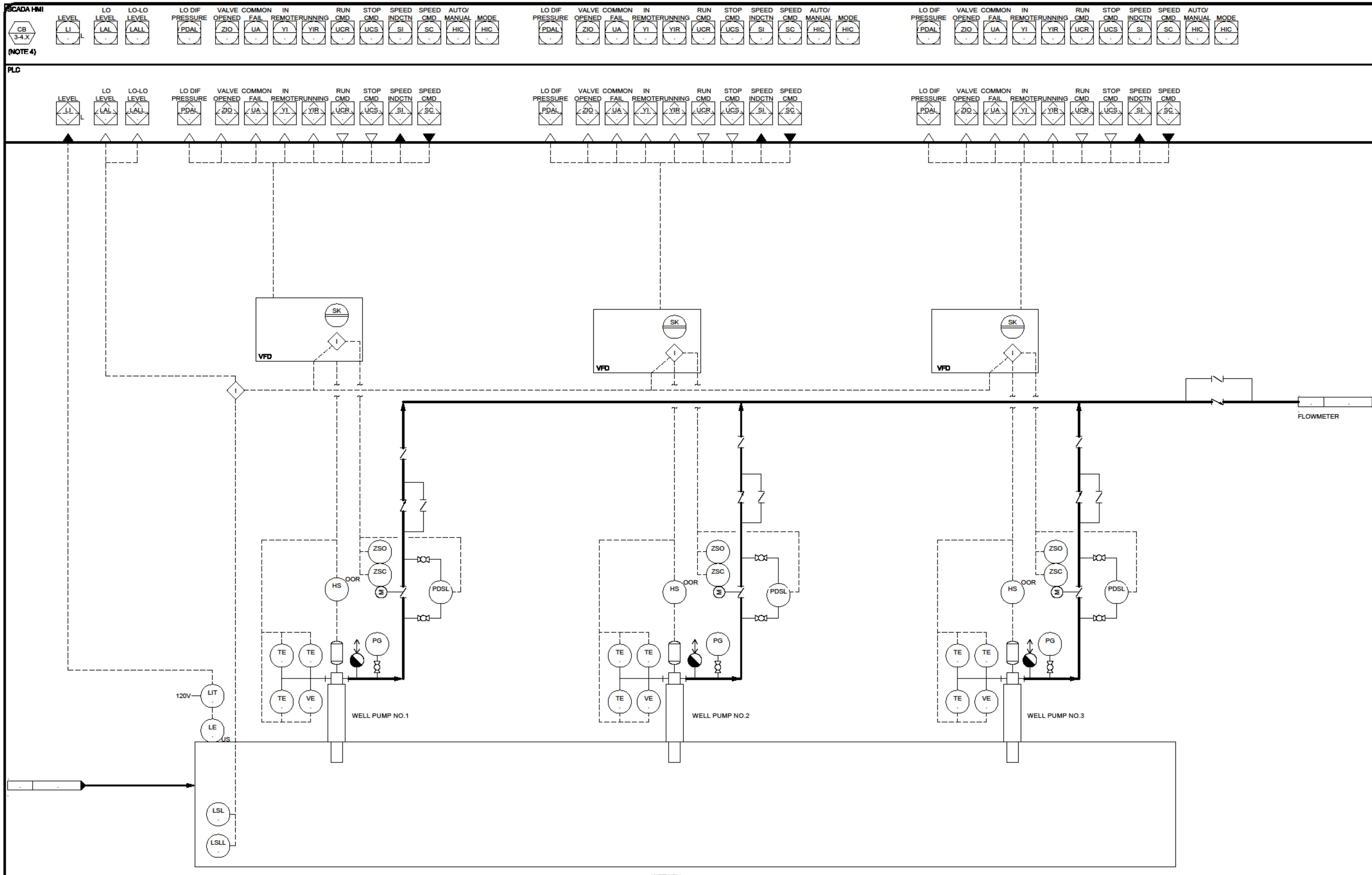
P&ID
LEGEND & ABBREVIATIONS
SHEET 3 OF 3

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE:

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
999999

SHEET
OF



NOTES:

1. SEE LEGEND ON DRAWINGS I-00-001, I-00-002, AND I-00-003.
2. UNLESS OTHERWISE NOTED, SYSTEM CODE ON INSTRUMENTATION AND VALVES IS "AIR."
3. LOCAL CONTROL DEVICES, SUCH AS INDICATING LIGHTS AND SWITCHES LOCATED ON MCCs OR ON EQUIPMENT, MAY NOT BE INDICATED ON THIS P&ID.
4. NOT ALL FUNCTIONS ARE SHOWN AT THE SCADA HMI OR PLC LEVEL. REFER TO CONTROL BLOCK LOOP NUMBER PARAGRAPHS IN SECTION 40 66 63 FOR FURTHER DETAIL ON PLC, SCADA CONTROL AND MONITORING.

FD7000
D6000

PRELIMINARY- NOT FOR CONSTRUCTION

NO.	BY	CK	APP	REVISIONS AND RECORD OF ISSUE	DATE

PW: BLS000 PID Drawings
PW FILE: VERTICAL TURBINE PUMPS WITH AFD.dwg
SAVED: BUD72682, 2/15/2021 6:18:47 AM
PLOTTED: BUD72682, 2/15/2021 6:19:09 AM
USER: BUD72682
DWG VER: 1000
XREF1:
XREF2:
XREF3:
XREF4:

BLACK & VEATCH
Building a world of difference
Black & Veatch Corporation
Kansas City, Missouri

INSTRUMENTATION & CONTROLS STANDARDS EXAMPLES

P&ID
VERTICAL TURBINE PUMPS WITH AFD

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE:

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
999999

SHEET
OF

SUMMARY OF DESIGN PARAMETERS

FACILITY NO.2
INFLUENT PUMP STATION

NO.OF PUMPS 5
FIRM CAPACITY 51 mgd
DRIVE TYPE 2 CONSTANT SPEED, 3 VARIABLE SPEED
CAPACITY
- CONSTANT SPD. 14400 gpm AT 52' TDH; 18000 gpm AT 39' TDH
- VARIABLE SPD. 2400-9200 gpm AT 47' TDH; 6000-10,600 gpm AT 39' TDH

MOTOR SIZE 250 Hp(CONST.), 150 Hp (VARIABLE)

FACILITY NO.3
HEADWORKS

NO. OF SCREENS 3 (2 mechanical, 1 manual)
BAR SPACING 0.5"
GRIT CHAMBER DIAMETER 20'
DETENTION TIME
- ANNUAL AVG. 108 sec
- PEAK DAY 39 sec

FACILITY NO.4
AERATION BASINS

ORGANIC LOADING (lb/1000ft^3)
- ANNUAL AVG. 15
- PEAK WEEK 29.6

DETENTION TIME 20 (hr) = ANNUAL AVG
MLSS (mg/l)
- ANNUAL AVG. 1950
- PEAK WEEK 3500

FACILITY NO.5
SECONDARY CLARIFIERS

DIAMETER 110'
SINGLE STAGE
- OVERFLOW RATE (gpd/ft^2)
  - ANNUAL AVG. 351
  - PEAK WEEK 632
- SOLIDS LOADING (lb/day/ft^2)
  - ANNUAL AVG. 8.6
  - PEAK WEEK 27.6

TWO STAGE
- OVERFLOW RATE (gpd/ft^2)
  - ANNUAL AVG. 526
  - PEAK WEEK 947
- SOLIDS LOADING (lb/day/ft^2)
  - ANNUAL AVG. 12.8
  - PEAK WEEK 41.5

FACILITY NO.6
RAPID MIX/FLOCCULATION BASINS

RAPID MIX
DETENTION TIME
- ANNUAL AVG. 73 sec
- PEAK DAY 26 sec

CAPACITY 5610 gal (each)

FLOCCULATION BASINS
DETENTION TIME
- ANNUAL AVG. 35.8 min
- PEAK DAY 12.8 min

CAPACITY 163,600 gal (each)

FACILITY NO.7
CHEMICAL CLARIFIERS

DIAMETER 110'
SINGLE STAGE
SAME AS SECONDARY CLARIFIERS

TWO STAGE
- OVERFLOW RATE (gpd/ft^2)
  - ANNUAL AVG. 702
  - PEAK WEEK 1264

FACILITY NO.10
RAS/WAS PUMP STATION

RAS PUMPS
- NO.OF PUMPS 4
- CAPACITY 5300 gpm
- FIRM CAPACITY 22mgd
- MOTOR SIZE 100 Hp

WAS PUMPS
- NO.OF PUMPS 4
- CAPACITY 200 gpm
- FIRM CAPACITY 600 gpm
- MOTOR SIZE 1.5 Hp

FACILITY NO.9
EFFLUENT CONTROL STRUCTURE

CHLORINE CONTACT BASINS

LENGTH TO WIDTH RATIO 40:1
CONTACT TIME
- ANNUAL AVG. 45 min
- PEAK HOUR 15 min

FLOW BALANCE (mgd)

STREAM ID	ANNUAL AVG.	PEAK WEEK	PEAK DAY
1	20	36	56
3	20	36	56
5	20	36	56
6	10	18	28
7	30	54	84
8	30	54	84
10	20	36	56
11	20	36	56
13	20	36	56
14	20	36	56
17			

CHEMICAL DOSAGE

	DOSAGE lbs/day		
	ANNUAL AVG.	PEAK WEEK	PEAK DAY
CHLORINE	1334	2402	3736
POLYMER	333	600	934
CAUSTIC	6,672	12,010	18,682
ALUM	16,680	30,024	46,704

SOLIDS PRODUCTION

STREAM ID		ANNUAL AVG.	PEAK WEEK	PEAK DAY
1	RAW SEWAGE TSS(lbs/day)	33,360	60,048	83,400
2	SCREENINGS (ft^3/day)	140	252	392
4	GRIT (ft^3/day)	80	144	224
6	RAS (mgd)	10	18	28
9	BIOLOGICAL WAS (lbs/day)	39,600	71,280	110,880
12	CHS (mgd) (lbs/day)	15,200	27,360	42,560
15	TOTAL WS (lbs/day) (APRIL THROUGH OCT)	54,800	98,600	153,440
16	SLUDGE TO LAND APPLICATION (lbs/day)	50,933	91,700	142,600

PLANT INFLUENT WASTEWATER LOADINGS

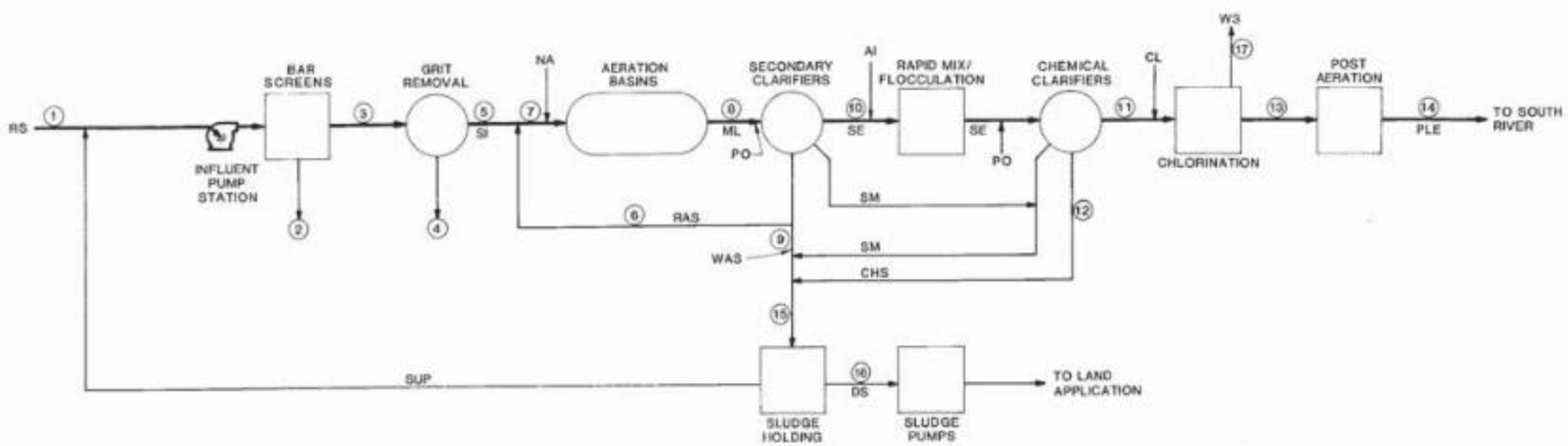
FLOW (mgd)
- ANNUAL AVG. 20
- PEAK WEEK 36
- PEAK DAY 56
- PEAK HOUR 60

TSS (lb/d)
- ANNUAL AVG. 33,360
- PEAK WEEK 60,048
- PEAK DAY 83,400

BOD_5 (lb/day)
- ANNUAL AVG. 33,360
- PEAK WEEK 60,048
- PEAK DAY 83,400

AMMONIA (lb/d)
- ANNUAL AVG. 2836
- PEAK WEEK 5104
- PEAK DAY 7090

TKN (lb/d)
- ANNUAL AVG. 5338
- PEAK WEEK 9608
- PEAK DAY 13,345



LEGEND

AI	ALUM	SE	SECONDARY EFFLUENT
CHS	CHEMICAL SLUDGE	SI	SECONDARY INFLUENT
NA	CAUSTIC	SM	SCUM
CL	CHLORINE	SUP	SUPERNATANT
DS	DIGESTED SLUDGE	WAS	WASTE ACTIVATED SLUDGE (BIOLOGICAL)
ML	MIXED LIQUOR	W3	NO.3 WATER SYSTEM
PLE	PLANT EFFLUENT	○	STREAM IDENTIFICATION
PO	POLYMER		
RAS	RETURN ACTIVATED SLUDGE		
RS	RAW SEWAGE		

DSGN		NO.	DATE	REVISION	BY	APVD
DR	F ZSEBEHAZY					
CHK						
APVD						

Dekalb County Public Works Department
Dekalb County Project No. SB 06-8-4

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

POLE BRIDGE CREEK
WASTEWATER TREATMENT PLANT
DEKALB COUNTY, GEORGIA

GENERAL
FLOW DIAGRAM AND DESIGN CRITERIA

SHEET
DWG NO. G-10
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PRELIMINARY

3.0 Control System Hierarchy

The control system hierarchy utilized at DWM is broken down by individual pieces of equipment and process strategies. For each level in the hierarchy, there are control modes and operational status.

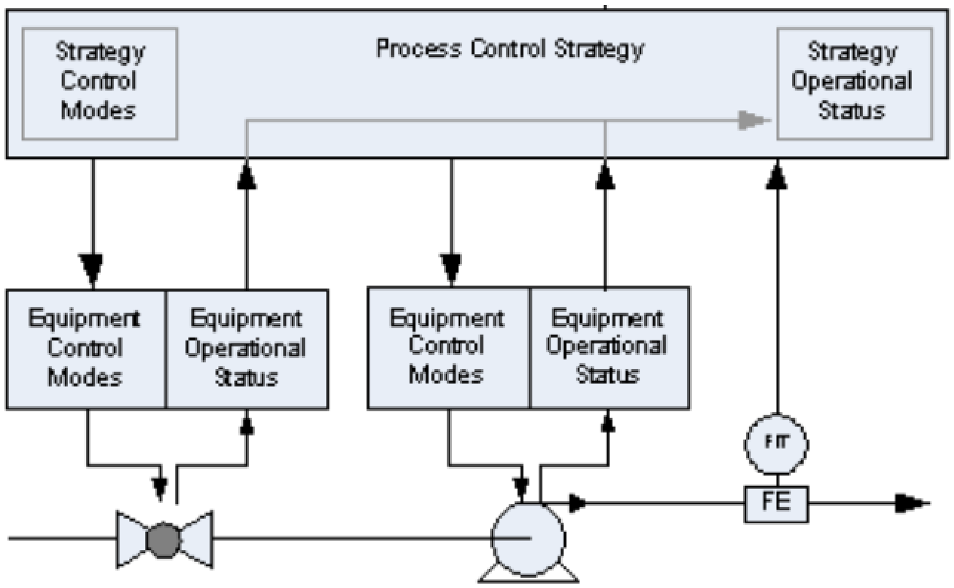


Figure 3-1 General Control System Hierarchy

Control Modes define what controls the equipment or process, while Operational Status defines the status of the equipment or process and its availability for control. This is described below.

3.1 EQUIPMENT CONTROLS MODES AND OPERATIONAL STATUS

Each device or piece of equipment that can be controlled from a PLC is always in one of three control modes: Local Manual, Remote Manual, or Remote Auto. This is depicted in the figure below.

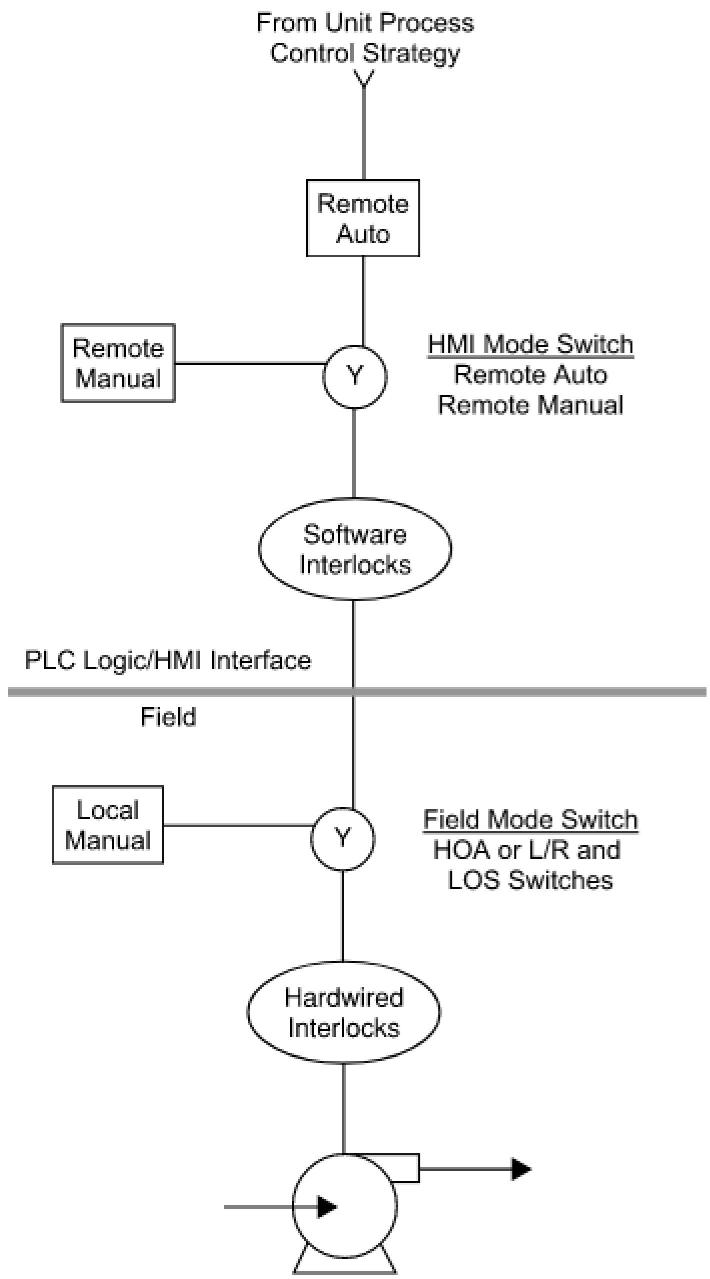


Figure 3-2 Equipment Control Modes

3.1.1 Local Manual

Equipment is in "Local Manual" mode when the Field Mode Switch is *not* in the "Remote" or "Auto" position or if the Lockout Stop button is engaged. In the Local Manual mode, equipment is controlled manually by operators from hand switches located at the equipment or on control panels in the process area. "Local Manual" control of any device overrides commands issued from the PLC.

The field control devices for all new installations shall be as shown below.

Table 3-1 Field Control Devices

TYPE OF EQUIPMENT	FIELD MODE SWITCH	LOCAL CONTROL DEVICES
Open/Close Valves/Gates	Local-Remote	Open-Stop-Close Switch
Throttling Valves	Local-Remote	Open-Stop-Close Switch
Modulating Valves	Local-Remote	Typ. On Actuator
Constant Speed Motors/ Pumps	Hand-Off-Auto	Lockout Stop Button, Reset Button, Remote Reset
VFDs	Hand-Off-Auto	Speed Pot, Lockout Stop Button, Reset Button, Remote Reset, Keypad[1]

[1] Keypad devices shall be located inside the VFD panel without operator access and shall be equipped with an Enable/Disable switch.

As an example, when the Local/Remote switch for a valve is placed in the “Local” position or when a Hand/Off/Auto switch for a pump is not in the “Auto” position, the equipment is in “Local Manual” control. When in this control mode, the corresponding PLC output commands are disabled both in the PLC logic and in the hardwired circuits associated with that piece of equipment.

3.1.2 Remote Manual

Equipment is in “Remote Manual” mode when the Field Mode Switch is in the “Remote” or “Auto” position, and Remote Manual control has been selected from the HMI screens.

Changes to equipment operation when in this mode occur only in response to operator action, not PLC automated control strategies. Operational changes to equipment while in “Remote Manual” mode is made by calling up the SCADA graphic corresponding to the equipment to be controlled and selecting the desired function in the appropriate display object, such as “Valve Open Command,” followed by confirming the action.

3.1.3 Remote Auto

Equipment is in “Remote Auto” mode when the Field Mode Switch is in the “Remote” or “Auto” position, and Remote Auto control has been selected from the HMI screens.

In this mode, equipment is controlled automatically by the PLC logic. Operation in this mode is based upon defined Process Control Descriptions.

3.1.4 Interlocks

Equipment Control may include interlocks, as shown in the diagram above. These impact multiple modes of operation and are typically included to prevent a safety or operational hazard.

Interlocks are defined as safeties that will shut off equipment when the interlock condition occurs. Interlocks include:

- Hardwired Interlocks: These interlocks are wired independently of the PLC and will shut the equipment off regardless of the Equipment Control Mode. Examples of these include motor over-temperature trips, thermal overloads, etc. Note: all equipment that includes hardwired interlocks will be accompanied by a field mounted reset button and a remote discrete output for interlock reset; the remote and local reset will be capable of clearing any interlocks.

- Lockout Stop LOS: This is a hardwired interlock that prevents the equipment from operating regardless of mode. This switch will typically be located within the vicinity of the equipment and can be pressed under an emergency situation.
- Software Interlocks: These interlocks are handled within the PLC, and will shut the equipment off when the condition occurs, and the Equipment is being operated by the PLC.
- Remote Auto Mode Interlocks: If these conditions occur, the equipment will be automatically changed from "Remote Auto" mode to "Remote Manual" mode.

Note: additional interlocks may be included in the Process Control Descriptions; however, any defined there will not impact "Remote Manual" or "Local Manual" operation.

3.1.5 Permissives

Equipment Control may include permissives, as shown in the diagram above.

Permissives are defined as conditions that must be met before a given control action or sequence can begin. Permissives will not shut off equipment for a sequence that has already started.

For the Equipment Control Hierarchy, there may be permissives that must be met for the PLC to be changed to Remote Auto Mode.

Note: additional permissives may be included in the Process Control Descriptions; however, any defined there will not impact "Remote Manual" or "Local Manual" operation.

3.1.6 Equipment Operational Status

The Equipment Operational Status is displayed on the SCADA screens. The Equipment Operational Status is determined by the state of the PLC inputs from the equipment. Tables are included below which show several examples of Equipment Operational Status based upon the associated PLC inputs. For these examples, an 'x' means the input is active, a 'o' means the input is not active, and a '-' means that the input can be in either condition for the defined status. The figure below shows examples include:

Open/Close Valves or Gates

PLC Inputs					
In Local	In Remote	Fault	Opened LS	Closed LS	Operational Status
-	-	-	x	-	Fully Opened
-	-	-	-	x	Fully Closed
-	-	x	-	-	Alarm
-	-	o	o	o	In Travel

Throttling or Modulating Valves or Gates

PLC Inputs						
Valve Pos	In Local	In Remote	Fault	Opened LS	Closed LS	Operational Status
-	-	-	-	x	-	Fully Opened
-	-	-	-	-	x	Fully Closed
-	-	-	x	-	-	Alarm
-	-	-	-	o	o	% Open

Constant Speed Pumps

PLC Inputs					
In Hand	In Off	In Auto	Running	Overload	Operational Status
-	-	-	x	-	Running
-	-	x	o	-	Stopped
-	-	-	o	x	Alarm
-	x	-	-	-	Off

Variable Frequency Drives (VFD)

PLC Inputs						
In Hand	In Off	In Auto	Running	Overload	VFD Fault	Operational Status
-	-	-	x	o	o	Running
-	-	x	o	o	o	Stopped
-	-	-	-	x	-	Alarm
-	-	-	-	-	x	Alarm
-	x	-	-	-	-	Off

Figure 3-3 Example Equipment Operational Status Tables

3.2 PROCESS CONTROL DESCRIPTIONS

Process Control Descriptions implement the Remote Auto control logic for a Unit Process or Process Area. The Process Control Descriptions typically coordinate the operation of several pieces of equipment that operate together.

3.2.1 Strategy Control Mode

Some Process Control Descriptions include more than one mode of operation. For example, Waste Activated Sludge may include Flow Control, Volume Control, and Mass Control modes. This is determined on a strategy-by-strategy basis.

3.2.2 Strategy Operational Status

The Strategy Operational Status can include one or two overall Operational Status Definitions. This includes the Strategy Control Status and/or the Service Modes.

3.2.2.1 Strategy Control Status

Strategy Control Status provides a convenient way to determine the Control Modes of all equipment associated with the Control Strategy. Not all control strategies display this information on the SCADA screens. Potential statuses include:

- Remote Auto: This means that all equipment required to operate the Control Strategy is in Remote Auto mode, thus the Control Strategy can automatically control the unit process.

- Remote Manual: This means that one or more of the pieces of equipment are in Remote Manual, thus the Control Strategy will not use the equipment that is in Remote Manual will not be used in the automatic control the unit process.
- Local Manual: This means that one or more of the pieces of equipment are in Local Manual, thus the Control Strategy will not automatically control the unit process.

3.2.2.2 Strategy Control Status

Service Modes define the operational status of processes with respect to the treatment process. Each process that has been integrated into the SCADA System is typically in one of four service modes or is transitioning between these. The Process Service Mode is derived from equipment inputs such as the positions of valves, the running status of pumps are running, and/or other appropriate conditions monitored by the control system.

- In Service: A Unit Process is “In Service” or “IS” Service when it is performing its normal process function.
- Standby: A Unit Process is in “Standby” when it is currently not operating but is ready for service.
- Out-of-Service: A Unit Process is “Out-of-Service” (OOS) when it is not operating and is not available for service until operators take specified actions.
- Process Maintenance: A Unit Process is in “Process Maintenance” or “PM” when operators take a given equipment or system through a specified procedure, typically as defined in an approved Standard Operating Procedure.

It is important to note that the Service Mode is not determined by the Control Mode that the equipment or strategy is in. An example for determining the service of a Filter is provided in the following table with the process maintenance being a filter backwash.

Table 3-2 Example Service Modes for a Filter

CONTROL ELEMENT	IN SERVICE	IN STANDBY	OUT OF SERVICE	PROCESS MAINTENANCE (BACKWASH)
Influent Valve	Open	Closed	Closed	Closed
Effluent Valve	Throttling	Closed	Closed	Closed
Backwash Valve	Closed	Closed	Closed	Opened/Closed[1]
Backwash Pump	Off	Off	Off	On/Off[1]
Filter to Waste Valve	Closed	Closed	Closed	Throttling
Air Wash Valve	Closed	Closed	Closed	Opened/Closed[1]
Air Wash Blower	Off	Off	Off	On/Off[1]

[1] Control elements will be both opened/closed or on/off based on the step of the backwash sequence.

A control strategy may include PLC logic to transition from one service mode to another. For example, the filter control strategy might include logic to put a filter in service.

Some specific unit processes may have additional status indications. For example, a filter may be valved for draining or filling. This type of operational status would be defined on a case-by-case basis. An example for determining the status of draining a filter is provided in the table below.

Table 3-3 Example Status when Backwashing a Filter

CONTROL ELEMENT	PROCESS MAINTENANCE (DRAINING)	PROCESS MAINTENANCE (FILLING)
Influent Valve	Closed	Opened
Effluent Valve	Opened	Closed
Backwash Valve	Closed	Closed
Backwash Pump	Off	Off
Filter to Waste Valve	Closed	Closed
Air Wash Valve	Closed	Closed
Air Wash Blower	Off	Off

3.3 RELATED DEFINITIONS

The following terms are defined here for clarification.

- Shared Control Strategy: A shared control strategy is a strategy that is the same as another strategy.
- Elementary Control Method: An elementary control method is a defined pre-programmed module for a specific task. An elementary control method is used in multiple places within the plant. For example, an elementary control method has been defined for selecting the operation of redundant instruments. Each control strategy that uses redundant instruments uses this elementary control method.
- Elementary Monitoring Method: An elementary monitoring method is a pre-programmed module used for monitoring specific equipment such as a power monitor or VFD. Communication to this type of equipment is typically not hardwired and logic is required to poll the equipment for its data. The intent of defining an elementary Monitoring Method is to aid the programmer in modularizing the PLC code so that it follows a standard approach to monitor similar equipment over non-hardwired communication links.

4.0 SCADA and PLC Hardware Standards

4.1 SCADA COMPUTER HARDWARE

4.1.1 Servers

The following guidelines apply to new servers:

- New SCADA Servers will be selected for performance and reliability, consistent with the requirements of the SCADA applications.
- Critical applications will utilize redundant servers.
- RAID hard drives will be installed in all new servers. The class of RAID hard drive will be determined by the specific requirements for each server. At a minimum the hard drives need to be mirrored to provided redundant storage.
- Hard drives will be solid state.
- The hard drive capacity will be determined by the specific requirements for each new server.
- Each server will be equipped with a dual network interface card (NIC).
- Each server will be equipped with a DVD/CDROM.

4.1.2 Operator Workstations

Workstations are located in the control room and at critical process areas throughout the plant. The workstations are standard off-the-shelf computer hardware running the FactoryTalk SE client software. The following guidelines apply to new operator workstations:

- New operator workstations will be selected for performance and reliability, consistent with the requirements of the SCADA applications.
- Workstations in control rooms and other environmentally controlled areas will be provided with a flat panel monitor, keyboard and mouse for the operator interface.
- Redundant processors, dual NICs, etc. are not required.
- RAID hard drives are not required.
- Solid State Drives will be used for all new computers to increase reliability
- Each operator workstation will be equipped with a DVD/CDROM.
- Screen resolution shall be compatible with graphic screen layouts (1920 x 1080).

4.1.3 Process Area Operator Interface Terminal (OIT)

Panelview Plus 700, which is programmed with FactoryTalk ME software, shall be use as OITs located throughout the plant in control panels close to the process equipment. OITs shall be housed in enclosures designed for the ambient environment in which each OIT is located. The following industrial ratings apply to the enclosures:

- NEMA 4 enclosures will be used in damp or wet areas.
- NEMA 4x enclosures will be used in corrosive environments.

- NEMA 12 enclosures will be used in other areas.

4.1.4 Local Control Interface

Local control devices include but are not limited to: HOA switches; LR switches; OSC switches; Reset Buttons; Potentiometers; and other local interface devices. Local control devices will only be located in one location for control. This means that if an operator wants to control the equipment locally, they will have only one possible physical location to control the equipment in local mode. Indication devices such as pilot lights, speed indicators, etc. will be located next to the control equipment and in other locations, if desired.

For example, if a designer is including a local control panel for a WAS pump, then all local control devices for that WAS pump will be located on the control panel only and nowhere else. However, indication devices such as pilot lights, indicators, and digital readouts can be provided in multiple places, if desired.

4.2 PLC HARDWARE STANDARDS

4.2.1 PLC Overview

Standard programmable logic controller (PLC) processors used for new additions to the DWM control system are redundant Allen-Bradley ControlLogix L7x PLCs for critical process areas and Allen-Bradley CompactLogix L3x PLCs for non-critical process areas. PLC design specifications shall be reviewed by a Rockwell distributor prior to being released for bid to verify that the PLCs specified are still offered and supported by Rockwell.

4.2.2 PLC Equipment Standards

4.2.2.1 Processors

Standard PLCs used for DWM control systems are Allen-Bradley ControlLogix series for critical process areas and Allen-Bradley CompactLogix for non-critical process areas. ControlLogix and CompactLogix processor firmware must match the software version. The processors will have to have the firmware flashed with the correct version before a program can be downloaded.

4.2.2.2 Redundancy

ControlLogix processors shall be provided with redundant monitored hot standby equipment. Each PLC system shall have dual processor chassis, dual processors, dual communications modules and dual redundancy modules. Each chassis shall be equipped with a dedicated power supply.

4.2.2.3 PLC/HMI Communications

PLCs shall communicate with each other and to the FactoryTalk SCADA System via Ethernet communications equipment via Rockwell Automation standard Ethernet/IP through the Ethernet bridges installed in each processor chassis.

Communications to legacy PLC equipment shall be via Data Highway bridge modules.

4.2.2.4 Device Level Ring for RIO Communications

All PLCs with Remote Input/Output (RIO) shall communicate to RIO chassis via Ethernet using a Device Level Ring (DLR). Refer to section 6.1.1 for DLR details.

DLRs shall be used to communicate with Ethernet/IP enabled devices such as VFDs, Power Monitors, etc. Where possible when Ethernet Communication is used the designer shall attempt to specific equipment that uses the DLRs and Ethernet/IP.

4.2.3 Input & Output Circuits

Hardwired I/O to be used on all new field equipment to be interfaced to PLCs shall follow the following standards.

4.2.3.1 Discrete Inputs

In many cases the monitored device is equipped with a relay that is energized in response to a change in status. A set of the relay's dry contacts is wired to the PLC discrete input module, which detects changes in state. Discrete inputs are usually wired to the control system through a relay in the monitored device.

The standard voltage for discrete input circuits is 24 VDC. The PLC panel shall be equipped with redundant 24 VDC power supplies which provide power for the DI field circuits. The relay in the monitored device shall be completely isolated from the control power for the equipment, thus the designation "dry contact." Interposing relays shall be provided where required to provide dry contacts. 120 VAC DI circuits shall not be implemented.

All PLC discrete input cards will be accompanied with a manufactured wiring system that includes prewired cables and printed circuit boards with fused inputs and terminals for field wiring.

4.2.3.2 Discrete Outputs

All discrete output circuits shall be 24 VDC. All PLC discrete output cards will be accompanied with a pre-manufactured wiring system that includes prewired cables, connectors, printed circuit boards with individually fused outputs, pluggable relays with a form C contact and terminal blocks for field wiring.

4.2.3.3 Analog Inputs

Analog input signals shall be scaled between 4 and 20 mA DC.

- The signal for two wire devices shall originate in the PLC enclosure. The PLC enclosure shall have dedicated redundant 24-volt power supplies for loop power.
- The signal for four wire devices shall originate at the instrument or equipment. Instruments will typically be powered from a 120 VAC source.

PLC panels shall be designed, constructed and prewired so that each analog input channel and shield wire is wired to the field terminal blocks in both the two-wire and four-wire configurations. The PLC panels shall be designed and fabricated so that each analog input circuit is prewired in a configuration that supports both two-wire and four-wire configurations without changing internal panel wiring. Shields shall be grounded at one end of the cable only, which shall be at the PLC control panel.

4.2.3.4 Analog Outputs

Analog output (AO) signals shall be scaled between 4 and 20 mA DC.

4.2.3.5 Special Purpose Circuits

In addition to standard analog and discrete inputs and outputs, some projects may require special purpose circuits to convey signals to the PLC. Allen-Bradley and third parties manufacture a wide variety of modules that mount in the PLC chassis for this purpose. For example, temperature monitoring is commonly done via RTD (Resistance Temperature Device) sensors which utilize different electrical signals than 4-20 mA analog signals.

When new PLC I/O is implemented, the standard I/O circuits described above are the preferred method for interfacing signals with the PLC. However, other methods may be used if the standard signal types are not applicable.

4.2.3.6 Implementation Requirements

- Spare Inputs – PLC panels shall be designed with a minimum of 25% spare I/O of each type, or a minimum of two circuits of each type, whichever is greater.
- Field Terminal Blocks – All I/O circuits shall be factory wired from each PLC module to terminal blocks dedicated for field wire terminations.
- Spare Circuit Terminations – All spare I/O shall be factory wired to the field terminal blocks.
- Field instruments and VFDs shall not utilize Ethernet communications when the being used for control of equipment. Ethernet communication is acceptable for monitor only or supplemental information such as maintenance or performance data. It is acceptable to use both hardwired control and Ethernet communication if both monitoring and control are used; however, the signals that are used for control must be hardwired. Where possible Ethernet/IP protocol will be utilized for Ethernet communication with the PLC.
- Intrinsically safe devices shall be used where instruments and/or instrumentation circuits are in explosive environments.

The following table lists the modules that are acceptable for use on DWM projects:

Table 4-1 Approved PLC I/O Modules

I/O TYPE	CONTROLLOGIX	COMPACTLOGIX
Digital Inputs	1756-IB16I 1756-IB32	1769-OB16 1769-OB32
Digital Outputs[1]	1756-OB16E 1756-OB32	1769-OW8 1769-OW16
Analog Inputs	1756-IF16[2]	1769-IF4I
Analog Outputs	1756-OF8	1769-OF4

[1] Wired to interposing relays
[2] Eight field inputs wired for isolated differential mode

4.3 HAZARD AND ENVIRONMENTAL ANALYSIS

When adding or replacing SCADA equipment (i.e. servers, workstations, OITs, PLCs) an hazard and environmental analysis shall be completed the documents the heat, noise, HVAC requirements, power consumption etc. This analysis shall be used to determine if any additional work needs to be performed to reduce hazards or improve the environment where the equipment will be located.

4.4 PROCESS MONITORING GUIDELINES

Signals for process values such as flows, levels, analytical values, etc. shall be monitored by the SCADA System and stored for historical data trending and retrieval.

All process and equipment faults and abnormal situations shall be monitored by the SCADA System and alarmed remotely at SCADA.

SCADA workstations must provide not only process information but also status information for operations. All pumps, valves, gates, blowers, mixers, and like process equipment shall have signals to the control system which define the equipment's state of readiness, operation and control mode.

The following are general guidelines for selection of points to be monitored by the control system:

- Analog values for all major process variables such as flow, level, and pressure.
- The status of all major process equipment such as pumps, blowers, compressors, valves, etc. The lead process engineer will determine the major process equipment.
- The status of all process variables or equipment monitored or controlled by a PLC.
- The status of all mode selectors as local/remote and hand/off/auto switches.
- Limit switches on all computer controlled, two-state valves (both open and closed).
- Limit switches on all valves and gates used for flow routing.
- Motor speed for all variable speed devices that are to be monitored or controlled by the control system.
- All safety indicators (e.g., explosive gases, fire detection, etc.).
- Valves used strictly for maintenance such as isolation valves on pump suction and discharge may not be monitored.

4.5 INSTRUMENT TAG GUIDELINGS

All instruments shall be provided with an International Society of Automation ISA style instrument tag. The tag shall be shown on the P&IDs, Input/Output Lists, and instrumentation lists. The tag name shall be generated according to the following standards:

- The first part of the tag shall be the Instrument Function Code assigned using the ISA standard.
- The second part of the tag shall be a three-digit Loop Number with no duplications in each process area.
- A third part of the tag shall be an alpha sequence code used as needed where more than one type of the same instrument is installed in a single loop.

Input and Output points that interface to the PLC will have a software tag name that differs from the instrument tag name described above. Software Tag Naming Conventions are described section 7 below and software tag names will also be shown on the P&IDs and Input/Output Lists.

Table 4-2 Instrument Tag Examples

EQUIPMENT	TAGNAME
Raw Influent Pump #1 Flow Meter	FIT-1001
Raw Influent Pump #1 Suction Pressure	PIT-1001
Raw Influent Pump #1 Discharge Pressure	PIT-1002

5.0 Equipment and Instrumentation Standards

This section details the I/O that shall be provided for all equipment that requires a hardwired connection. Hardwired signals are those that require two conductors to be connected for each signal connected to the PLC equipment. This is as opposed to signals being exchanged over a network connection.

5.1 VALVE ACTUATOR STANDARDS

This section includes actuator standards and PLC interface standards for typical valves. All valve actuators will be equipped with switches to control the valves directly at the valve actuator or local control panel. The position indication of the valve must be available for critical valves during a power failure scenario. The selected valve actuator must be capable of displaying valve position regardless of power to the actuator. In some cases, a local control panel will be provided to enable O&M personnel to control one or more valves. These local control panels will be equipped with switches and indicators as required to meet the specific requirements for control. Each project shall evaluate the process area requirements and determine the need for a local control panel, which may be needed in the following situations:

- If valve actuators are not readily accessible to personnel.
- If several valves control a process or system in a coordinated manner, such as Dual Media Filter control valves.
- If valve actuators are pneumatically operated or electrically operated.

In most cases monitoring and control will be wired to PLC control panels, which are often different from local valve control panels.

The lead process Engineer will work with DWM staff to determine if electric or pneumatic actuators are acceptable for the process or application of the valve and whether the valve is located near a readily accessible pneumatic air source.

5.1.1 Open/Close Valves & Gates (Electric Actuators)

Open/close valves are either fully opened, fully closed, or in an intermediate position when "in travel" from one position to the other. In some cases, a valve fault indication is available to immediately let the operator know there is a problem with the valve. The tables below show the typical PLC I/O to be provided for valves and it indicates the control switches to be provided. The switches described in the table below will be mounted on the valve actuator if the valve is accessible by an operator; otherwise, the switches will be in a local control enclosure or panel conveniently located for operator use.

Table 5-1 Typical Open/Close Valve I/O

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Local-Remote selector switch in "Local"
Discrete Input	Local-Remote selector switch in "Remote"

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Valve Open position (limit switch contact closed in open and intermediate states)
Discrete Input	Valve Closed position (limit switch contact closed in closed and intermediate states)
Discrete Input	Valve Common Fault Alarm
Discrete Output – Momentary	Valve Open command
Discrete Output – Momentary	Valve Close command

5.1.2 Throttling Valves & Gates (Electric Actuators)

Throttling valves and gates are digitally opened and closed and position is monitored allowing the valve to be stopped in any position. The table below shows the typical PLC I/O to be provided for these types of valves and gates. The table also indicates that the control switches to be provided if a local control panel is installed. Local control panels shall have an Open-Stop-Close switch for local control and an indicator of position, and a Local/Remote switch for allowing remote control. For new applications, modulating valves as described in the following paragraph are the preferred type where control of valves in the intermediate positions is required.

Table 5-2 Typical Throttling Valve and Gate I/O

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Local-Remote selector switch in “Local”
Discrete Input	Local-Remote selector switch in “Remote”
Discrete Input	Valve Open position (limit switch contact closed in open and intermediate states)
Discrete Input	Valve Closed position (limit switch contact closed in closed and intermediate states)
Discrete Input	Valve Common Fault Alarm
Analog Input	Valve position feedback
Discrete Output – Momentary	Valve Open command
Discrete Output – Momentary	Valve Close command

5.1.3 Modulating Valves & Gates (Electric Actuators)

Modulating valves and gates are similar to throttling valves and gates in that they require positioning between fully opened and fully closed. Modulating valves and gates are different than throttling valves in that they can accept a 4 to 20 mA input signal to position the valve. The table below shows the typical PLC I/O for these types of valves and gates and the control switches if a local control panel is installed. Local control panels shall have either a 0-100% positioner adjustment mechanism or an Open-Stop-Close switch for local control along with an indicator of position, and a Local/Remote switch for allowing remote control.

Table 5-3 Typical Modulating Valve and Gate I/O

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Local-Remote selector switch in “Local”
Discrete Input	Local-Remote selector switch in “Remote”
Discrete Input	Valve Opened position (limit switch contact closed in opened and intermediate states)
Discrete Input	Valve Closed position (limit switch contact closed in closed and intermediate states)
Discrete Input	Valve Common Fault Alarm
Analog Output	Valve position control
Analog Input	Valve position feedback

5.2 MOTORS AND PUMPS

5.2.1 On/Off Motors and Pumps

Equipment and pumps are either on (running) or off (not running) at one, constant speed. The table below shows the typical I/O for on/off motors and pumps. Motor control panels shall have an HOA switch for local operation.

Table 5-4 Typical On/Off Motors and Pumps I/O

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Hand-Off-Auto selector switch in “Hand”
Discrete Input	Hand-Off-Auto selector switch in “Off”
Discrete Input	Hand-Off-Auto selector switch in “Auto”
Discrete Input	Running status
Discrete Input	Overload
Discrete Output - Momentary	Run command
Discrete Output - Momentary	Remote Reset

5.2.2 Motors and Pumps with Variable Frequency Drives (VFD)

Although the majority of motors and pumps operate at one constant speed, some equipment is provided with VFDs. This allows the operating speed of the equipment to be changed in response to process conditions. This requires additional I/O to be connected to the PLC to monitor and control the equipment. The table below shows the minimal I/O for motors and pumps with variable frequency drives. An additional serial interface may be considered on a project-by-project basis to monitor maintenance and performance data. HOA switches are provided in one location for field control. In many cases, VFDs are provided with a local operator interface terminal; all control from these terminals shall have an associated enable or disable switch mounted inside the panel (not accessible to operators) for maintenance personnel only. Under normal operating conditions the enable-disable switch will be in the disable position to disable the control features of the operator interface terminal. DWM operators will control all VFDs in Local Manual from hand switches, potentiometers, and indicators mounted on the VFD or local control panel.

Table 5-5 Typical Motors and Pumps with Variable Frequency Drives I/O

TYPE OF PLC I/O SIGNAL	SIGNAL DESCRIPTION
Discrete Input	Hand-Off-Auto selector switch in “Hand”
Discrete Input	Hand-Off-Auto selector switch in “Off”
Discrete Input	Hand-Off-Auto selector switch in “Auto”
Discrete Input	Running status
Discrete Input	VFD alarm/fault
Discrete Input	Motor Overload
Analog Output	Equipment speed control
Analog Input	Equipment speed feedback
Discrete Output	Run command
Discrete Output - Momentary	Remote Reset

5.3 PACKAGED EQUIPMENT

5.3.1 Packaged Equipment Monitoring and Control

Some equipment installed at the plant will be “packaged” to consist of the actual process equipment in addition to the associated controls, starters, etc. The equipment manufacturer generally provides this packaged equipment. Similar to the discussions above, monitoring and control needs to be provided for this equipment. PLC I/O requirements will change depending upon the piece of equipment. In some cases, the manufacturer will embed a dedicated PLC within the packaged equipment. In other cases, the equipment will be monitored and controlled by a plant PLC that may not be dedicated to the packaged system. Minimally, inputs such as Local-Off-Remote/Hand-off-Auto position, equipment running status, valve position monitoring, and system alarms I/O are included. Outputs shall include equipment start/stop control as allowed by the equipment (i.e., not all packaged equipment will be remotely controlled).

Each designer shall evaluate the requirements for interfacing packaged equipment to the DWM SCADA System including implementation of new PLCs, interfacing to existing PLCs, and the SCADA HMI monitoring and control requirements. If the manufacturer provides an embedded PLC, it should be specified as one of the standard models used by DWM.

5.4 PANELS AND ENCLOSURES

When designing a panel, several requirements for materials, arrangement, and doors need to be considered as detailed in the sections below. For reference, Hoffman is considered to be the acceptable level of manufactured quality.

5.4.1 Panel Materials of Construction

Panels designed for dry indoor applications shall be gasketed NEMA 12 (indoor, dust tight), painted, carbon steel shell.

- Panels designed for installation outdoors will be NEMA 4.
- Panels designed for corrosive areas will be NEMA 4X.
- Holes in panels for face-mounted devices, conduits, etc. will be sealed such that the NEMA rating of the panels is not degraded.
- Panel exteriors will be painted ANSI-61 gray finish.
- Panel interiors will be painted white.
- Panel will include a lockable hasp.

5.4.2 Panel Arrangement

Panels shall be arranged so conduits enter the panels from the top or bottom only, not from the sides. A minimum six-inch high concrete maintenance pad shall be provided under every freestanding vertical panel.

On the panel interior, panels containing a field interface device, such as a PLC, shall have the PLC located in the upper portion of the panel. Incoming power connections, power distribution, power supplies, and other devices related to panel and instrument power shall be located below the field interface device. If no field interface device is contained in the panel, the devices related to panel and instrument power shall be located at the top of the panel. Field terminals shall be installed in the lower portion of the panel. Analog and digital signals shall be segregated to the maximum extent possible to avoid interference between the two types of signals.

5.4.3 Corrosion Mitigation

Panels shall be designed to minimize the deleterious effects of corrosive gases, regardless of whether the panel location is designated as corrosive. The following measures shall be taken:

- A minimum of two (2) corrosion inhibitor canisters shall be installed inside each control panel.
- Panels shall not be constructed with entries for air ventilation.
- If air conditioning is required, the type that prevent the introduction of outside air shall be provided.
- For panels located in corrosive areas, conduits entering the panels shall be sealed.

5.4.4 Provision for Fiber Optic Cabling

Where fiber optic cabling is routed in the vicinity of or passes through a control panel, the need to terminate the cable on a patch panel to provide access to the Fiber Optic Cable System shall be evaluated and provision made as required while doing the panel design. Fiber patch panels shall be mounted to a back panel or mounted to the panel side. ST style fiber connectors shall be used for all fiber connections unless unavailable for the application.

5.4.5 Lighting

Each freestanding control panel and each panel for outdoor or outdoor enclosure service shall be provided with a panel light. LED panel fixtures are the preferred types of panel light. A door switch shall control the light. The light will not be powered from a UPS.

5.4.6 Convenience Receptacle

Each panel, regardless of size or mounting, shall be provided with a duplex convenience receptacle. This receptacle shall be in addition to those needed for plug-in transformer type power supplies for communication or other permanently installed equipment. A separate, orange-colored, isolated ground receptacle shall be provided and connected to the UPS power feed for panels that are powered from both UPS and non-UPS circuits.

5.4.7 24 Volt DC Power Supplies

Power supplies for dc circuits in panels shall be redundant. Additionally, regulated power supplies shall be specified for installation.

5.4.8 Indicating Lights

Indicating lights shall be transformer type with LED lamps. Lights shall be push-to-test, oil tight, and complete with the appropriate color lens. Color schemes shall be as indicated in the table below.

Table 5-6 Indicating Light Color Scheme

INDICATION	COLOR
Running	Green
Stopped	Red
Valve Opened	Green
Valve Closed	Red
Control Power On	White
Alarm	Amber

5.4.9 Panel Locations

Panel locations shall meet National Electrical Code requirements, even when they do not have power distribution provisions.

5.4.10 Panel Installations

Floor mounted panels shall be mounted on concrete housekeeping pads in damp or wet areas and in equipment line-ups where the adjacent panels are mounted on housekeeping pads.

All panels shall be installed in accordance with DWM seismic requirements.

Holes shall not be cut in the bottom of free-standing enclosures unless the equipment is not installed in an area subject to standing water or flooding. Right angle steel material shall be welded to the bottom front and sides of the free-standing enclosure for the purpose of anchoring the panels. The surface area around the welded areas shall be repainted to match the exterior paint color and performance requirements.

5.4.11 Uninterruptable Power Supply

Each critical PLC or RIO panel will be equipped with an Uninterruptable Power Supply UPS. Where UPSs are required, service power will be to the input of the UPS. The output of the UPS will provide power to the critical components in the PLC or RIO panel. This arrangement will allow the UPS to provide the power to the panel with or without service power; if the UPS fails and service power is available the PLC panel will utilize the service power; otherwise, the panel will lose power for a potentially prolonged period.

The UPS will be sized to provide power the panel for 15 minutes under worst case future loads.

Each PLC or RIO panel with a UPS shall monitor the following points associated with the UPS:

- Utility Power Available Status
- UPS Operating on Line Power
- UPS Operation on Battery Power
- UPS Low Battery Alarm
- UPS Load Protected Status
- UPS Replace Batter Alarm
- 24VDC Power Supply “A” Online Status
- 24VDC Power Supply “B” Online Status

5.4.12 PLC & Instrument Power Distribution

Noncritical PLC control panels and associated instrumentation are powered from a nearby power source that is readily accessible. However, critical processes are supported by redundant PLC equipment and a redundant power arrangement as shown on the figure below Control System Power Distribution Diagram. Important features for power distribution are:

- The Process Area Control Power Distribution Panel (120/240V) fed via the 480-volt AC supplies power to the PLC Control Panel and to other equipment in the associated process area such as local control panels.
- Depending on the number and size of the electrical power loads, a separate PLC power panel may be required.

- An uninterruptible power supply (UPS) is installed to provide backup power to the PLC control panel and to devices served by the instrument power supplies.
- The PLC Control Panel is fed from a separate 120-volt AC circuit for panel lighting, convenience receptacles and optional air conditioning.
- Critical process area PLCs are redundant, each with its own power supply which are backed up by a UPS.
- Redundant 24-volt DC instrument power supplies are provided. These serve circuits within the panel and external instruments.

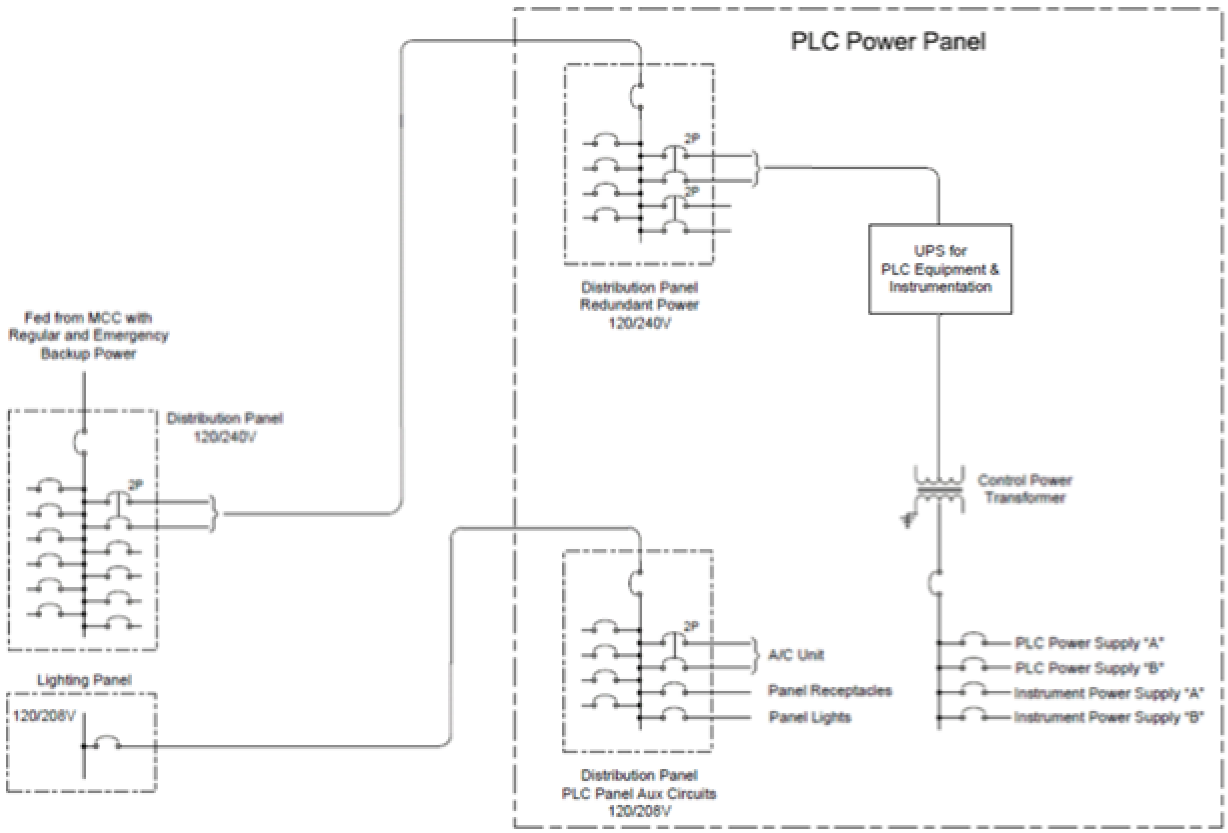


Figure 5-1 Control System Power Distribution Diagram

5.5 POWER MONITORING

Separate standards for power monitoring at DWM have been established for 12kV and 480V equipment.

5.5.1 12kV Power Monitoring

To be determined.

5.5.2 480V Power Monitoring

Where power monitoring is provided for 480V electrical equipment, monitors will be Allen-Bradley PowerMonitor 5000 devices. Power monitors will be provided with an Ethernet Industrial Protocol

(Ethernet/IP) interface card for data communications to the SCADA system via Ethernet/IP with CIP protocol.

6.0 Networks

6.1 PLC COMMUNICATIONS NETWORKS

Reliable communications between PLCs and between PLCs and SCADA servers is essential for the distributed operation and control of the SCADA System. This section identifies standards for PLC communications, which cover new and existing PLCs.

However, new PLCs will also need to communicate with legacy PLCs on a peer-to-peer basis because, in several situations, process values that are required for the control logic in a PLC are wired as inputs to one or more PLCs located in different locations in the plant. The same holds for several control outputs.

6.1.1 Ethernet Device Level Rings (Includes Remote I/O)

A Device Level Ring (DLR) network is a single-fault tolerant network intended for the interconnection of automation devices. DWM uses these networks for connecting devices that communicate over the Ethernet Industrial Protocol Ethernet/IP. DLRs can recover from a fault in 1 to 3 milliseconds. The diagram below shows how a DLR network can be connected.

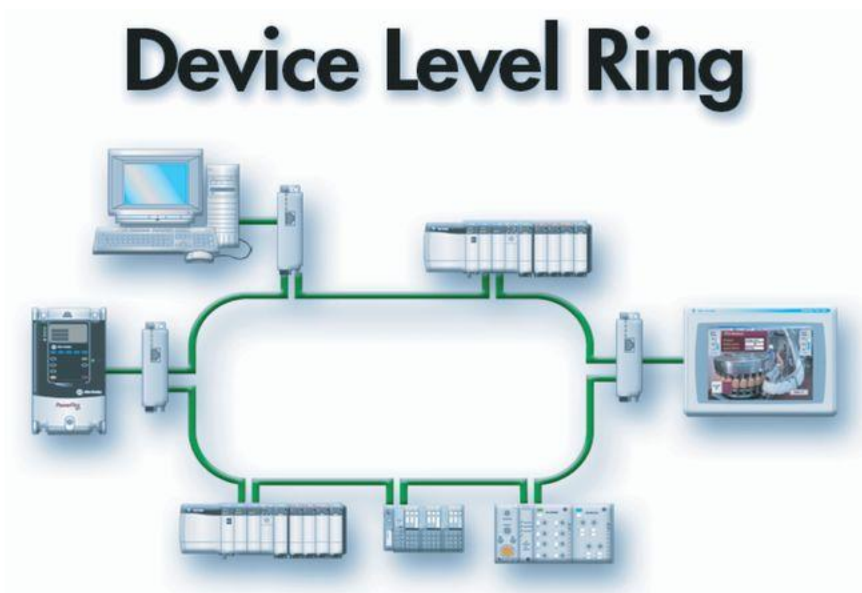


Figure 6-1 Device Level Ring

DWM uses DLR networks for connecting VFD drives to the SCADA network to provide a higher tolerance to network communication problems. DLR networks are also used for communicating to Remote I/O chassis for both redundant and non-redundant PLCs.

SCADA Standards Requirement – During the design phase of each project implementing new or upgraded PLCs, the following requirements must be addressed for PLC communications:

- Evaluate requirements for peer-to-peer communications.
- Evaluate requirements for communications between PLCs and the top-end SCADA System.

- Make provision in the design, if necessary, for communications to legacy PLC equipment over the Data Highway.

6.1.2 Ethernet SCADA/PLC Network

The SCADA Standard for PLC networks is Rockwell Automation Ethernet/IP, except where the requirements of a project need to support legacy systems. Fiber optic cable is used to convey Ethernet signals for all cables that leave the building envelope and for links over 300 ft. SCADA networks shall be physically separated from Administration networks. These networks are not allowed to be within the same fiber cabling.

The SCADA Standard for each type of PLC is as follows:

- **ControlLogix PLCs** – Provide redundant 100 Mbps Ethernet connectivity to the SCADA System Network.
- **CompactLogix PLCs** – Provide 10 or 100 Mbps Ethernet connectivity to the SCADA System Network. Redundant access to the network is desired, but not a requirement if it is not practical.

6.2 NETWORK ARCHITECTURE

Network equipment shall be provided to distribute, convert and convey information throughout the plant. The DWM SCADA network can be configured in three different topologies based on site conditions. Star, ring or hybrid topology are defined in the following sub-sections.

6.2.1 Star Topology

A star topology relies on a central device to exchange data between the other components. The center to the "star" is typically an Ethernet switch or radio with servers, workstations and PLCs on the spokes of the star. The server or switching equipment in the center hub is a single point of failure for the entire network.

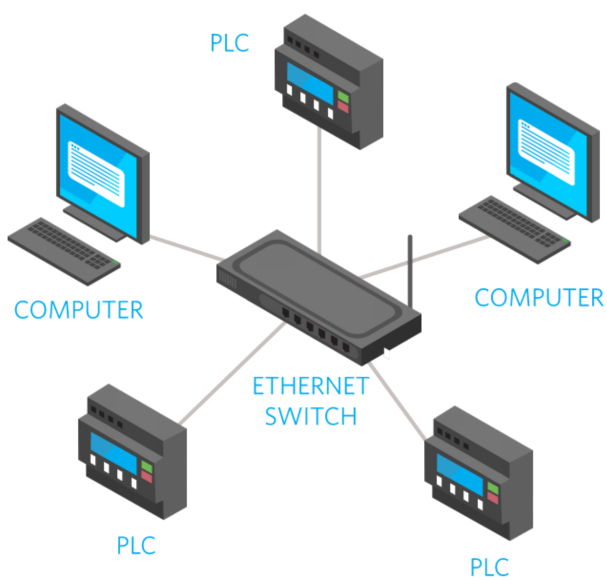


Figure 6-2 Example of a Star Network Topology

6.2.2 Ring Topology

Bidirectional or self-healing ring allows data to travel in both directions around the ring. Nodes typically have an Ethernet switch with Rapid Spanning Tree Protocol (RSTP) to prevent bridge loop and provide fault tolerance by automatically sensing failure of an active link and rerouting network traffic over the previously turned off segment. The self-healing ring topology has the advantage of maintaining communications between all other nodes on the network if one node or segment fails.

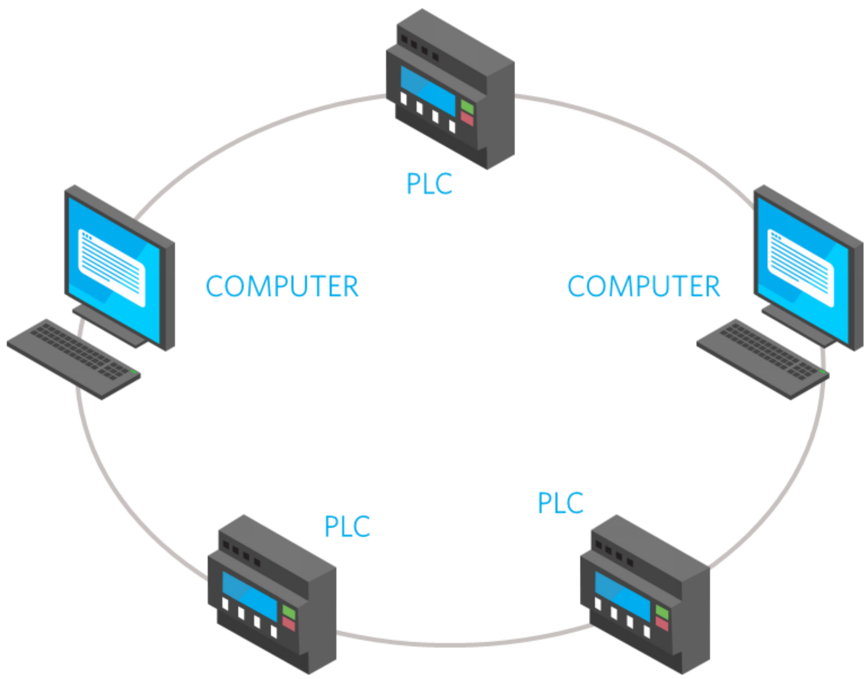


Figure 6-3 Example of a Ring Network Topology

6.2.3 Hybrid Topology

As the name implies, a hybrid topology implements a combination of two or more of the topologies described above. Hybrid topologies are generally implemented to strike a balance between reliability and cost while considering the process environment and communication distances and the physical locations of servers, workstations and PLCs.

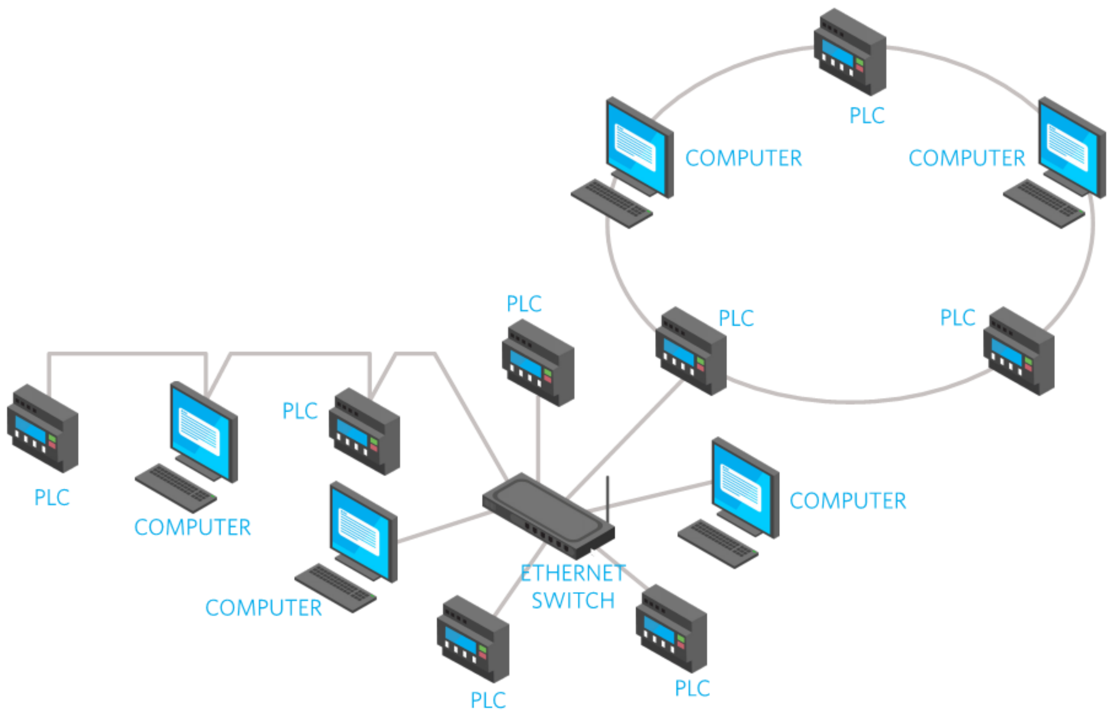


Figure 6-4 Example of a Hybrid Network Topology

6.2.4 Redundancy

Depending on the location and feasibility redundancy will be required. Plant sites will require a redundant network that has physical separation between fiber optic cables connecting the building at a plant site.

6.2.5 Distribution Ethernet Switches

Distribution Ethernet switches provide connectivity to HMI Servers, HMI Workstations, and other control room computer equipment associated with the SCADA network. Two distribution switches will be provided for redundancy at plant facilities. DWM has standardized on the Allen Bradley Stratix 5410 Industrial Distribution Ethernet Switches for Distribution level switches with SFP ports utilizing 1000Base-SX and 10/100/1000Base-T. Ethernet switch design specifications shall be reviewed by a Rockwell distributor prior to being released for bid to verify that the switches specified are still offered and supported by Rockwell.

6.2.6 Access Ethernet Switches

Access Ethernet switches will be provided for each area of the plant where PLC, VFDs, Power Monitors, and or other Ethernet monitoring devices are required to connect to the SCADA network. Each Access level switch will be connected to a Distribution switch and a connection between the access level switches will be made with SFP ports utilizing 1000Base-SX. DWM has standardized on Allen Bradley Stratix 5700 Industrial Managed Ethernet Switches for access level switches.

Ethernet switch design specifications shall be reviewed by a Rockwell distributor prior to being released for bid to verify that the switches specified are still offered and supported by Rockwell.

6.2.7 Miscellaneous Ethernet Switches

Miscellaneous Ethernet switches are used to extend SCADA network connectivity to non-critical communication devices that are not conveniently located next to an Access level switches. Miscellaneous switches are used in HMI Workstation panels allowing an operator to interface with the HMI at remote areas located around the plant. DWM has standardized on Allen Bradley Stratix 2500 Lightly Managed Switches miscellaneous level switches. Ethernet switch design specifications shall be reviewed by a Rockwell distributor prior to being released for bid to verify that the switches specified are still offered and supported by Rockwell.

6.3 NETWORK CABLING

6.3.1 Ethernet Cable

Cable for Ethernet wiring shall be Cat-6 cable, except where fiber optic cable is utilized. Cable shall be Cat-6 for networks speeds greater than 100 MB/s. Jacket color coding for cables shall be as follows:

- Standard Cat-6 - Yellow
- Crossover cables - Red

Straight through cables shall be wired using the T568-B standard for both connectors as shown in the table below (connector pin numbers are left to right with the clip down). Crossover cables shall be wired using the T568-A standard for one connector and the T568-B standard for the opposite end as shown in the table below.

Table 6-1 Ethernet Cable Connector Wiring

CONNECTOR PIN	568-A WIRING CONDUCTOR	568-B WIRING CONDUCTOR
1	White/Green	White/Orange
2	Green	Orange
3	White/Orange	White/Green
4	Blue	Blue
5	White/Blue	White/Blue
6	Orange	Green
7	White/Brown	White/Brown
8	Brown	Brown

6.3.2 Media Converters

Fiber optic to copper media converters shall convert twisted pair cable transmissions to fiber optic cable transmissions at 10/100/1000Mb speed. Converters shall provide auto-sensing detection of network speed and full duplex or half duplex signaling. ST style fiber connectors shall be used for all fiber connections unless unavailable for the application. Converter copper port shall be RJ-45. Converter fiber port shall be compatible with connectors provided with fiber cable jumpers and compatible with fiber cable type and light wavelength. The converter shall be powered from 120 volts ac or shall be provided with a plug-in transformer to provide the required voltage to the device. Converters shall be as manufactured by Transition Networks, D-Link, Black Box, or equal.

6.3.3 Fiber Optic Patch Panels

Patch panels shall be provided at each fiber optic cable termination point. All fibers will be connectorized and terminated at patch ports. The ports provide ready access for drops to fiber optic transceivers or switches in network equipment. Dust caps shall be installed on all unused ports to prevent fouling the end of fibers. ST style fiber connectors shall be used for all fiber connections unless unavailable for the application.

The patch panels shall meet the following requirements:

- The patch panel shall be provisioned to splice, terminate, and patch multiple fiber optic cables. Splice trays, strain relief cable attachment points, fiber organizers and bend radius hardware shall be furnished with each termination cabinet.
- Panel size shall be suited to the number of fibers to be terminated within the cabinet. Couplings shall be furnished and mounted for each fiber to be terminated.
- Patch panels will be wall-mounted or rack-mounted depending on their location.

6.3.4 Fiber Optic Cable

Backbone and Distribution fiber optic cables shall meet the following requirements:

- ST style fiber connectors shall be used for all fiber connections unless unavailable for the application.
- Backbone fiber optic cables shall be indoor/outdoor rated meeting the riser requirements for Type OFNR cables of the National Electrical Code (NEC) Section 770.
- Riser Applications – Applicable Flame Test UL 1666.
- Every fiber in the cable must be usable and meet required specifications.
- All optical fibers shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical, and environmental requirements of this specification.
- All optical fibers shall be 100 percent attenuation tested. The attenuation shall be measured at 850 nm and 1300 nm for multimode fibers.
- The attenuation of the cabled fiber shall be uniformly distributed throughout its length such that there are no discontinuities greater than 0.2 dB at 850 nm/1300 nm (multimode) in any one-kilometer length of fiber.

- The fiber shall meet the optical requirements of EIA/TIA-492AAAD, "Detail Specification for 850-nm Laser-Optimized, 50-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers Suitable for Manufacturing OM4 Cabled Optical Fiber" over 550 meters.
- Optical fibers shall be placed inside a loose buffer tube. The nominal outer diameter of the buffer tube shall be 3.0 mm.
- Each fiber shall be distinguishable from others by means of color coding in accordance with TIA/EIA-598-A, "Optical Fiber Cable Color Coding."
- The jacket shall be continuous, free from pinholes, splits, blisters, or other imperfections. The jacket shall have a consistent, uniform thickness; jackets extruded under high pressure are not acceptable. The jacket shall be smooth, as consistent with the best commercial practice. The jacket shall provide the cable with a tough, flexible, protective coating, able to withstand the stresses expected in normal installation and service.
- The outer cable jacket shall be marked with the manufacturer's name or UL file number, date of manufacture, fiber type, flame rating, UL symbol, and sequential length markings every two feet (e.g. "50/125 MICRON – TYPE OFNR – (UL) 00001 Feet"). The print color shall be white.
- The cable shall be all-dielectric.
- The cable shall be gel-free.

Jumper cables and patch cords shall be pre-connectorized in the factory with laser optimized connectors.

6.3.5 Cable Fiber Count

PLCs are integrated to the Plant Fiber Optic Cable System at one of two levels of the plant cable topology:

- <u>Backbone Loop Cables</u> - Two overlapping backbone loops to connect the Core Switches with each of the Distribution Switches.
- <u>Distribution Cables</u> - Several distribution cables to connect all other locations to backbone nodes.

Fiber optic cables shall be provided with the following minimum fiber counts:

- 48 fibers for Backbone Cable
- 24 fibers for Distribution Cable

These fiber counts shall be provided for cables integrating with the Plant Fiber Optic Cable System at the Backbone and Distribution levels. Alternate fiber counts may be provided for special purpose cables.

6.3.6 Fiber Optic Conduits and Innerduct

Conduits for Backbone Loop Cables shall have a minimum diameter of two (2) inches. A three-cell fabric innerduct shall be installed in each conduit. A pull string shall be provided in each cell.

Conduits for Distribution Cables shall have a minimum diameter of one (1) inch.

7.0 PLC Software Standards

7.1 PLC PROGRAM DESIGN

7.1.1 Programming Language

Several programming language types, as defined in the ISO 61131 automation programming standard, are available for programming. Ladder logic, functional block, and structured text are preferred languages for DWM.

The programming software shall be Studio 5000 for ControlLogix family processors. The version shall be coordinated with the version currently installed at DWM to ensure compatibility with existing versions PLC software and hardware.

7.1.2 Program Format & Structure

Programs shall be written to include the following:

- Input processing
- Alarm processing
- Sequential logic
- SCADA mapping
- PLC to PLC Communications
- PLC to SCADA Communications
- Output processing
- Periodic logic

7.1.3 Data Types

User-Defined Data Types are used as well as predefined data types. User-Defined Data Types is a custom data structure created by the user that can contain predefined data types or other user-defined data types.

7.1.4 Add-on Instructions (AOIs)

AOIs are user function blocks within the program containing:

- Input and output variables acting as an interface with the application
- A processing algorithm that operates input variables and completes the output variables such as a PID control loop.

AOIs shall be used for all elementary control methods, elementary monitoring method, and wherever possible to minimize replicating code for a function. The following AOIs have already been defined and shall be used as applicable.

- Motor
    - includes constant and two speed pumps

- Valve or Gate
    - includes open/closed and modulating
- Analog
    - includes raw to engineering value scaling, out-of-range alarm, and four state alarming: High-High, High, Low, and Low-Low

The following tables define the attributes of each AOI.

Table 7-1 Motor AOI Attributes

ATTRIBUTE NAME	DATA TYPE	DESCRIPTION
AlarmFail	Bool	Failed Alarm Input
AlarmOverload	Bool	Overload Alarm
AlarmReset	Bool	Operator Alarm Reset
AlarmStartFail	Bool	Failed To Start Alarm
AlarmSummation	Bool	Alarm Summation
AlarmTempHigh	Bool	Temperature High Alarm
Auto	Bool	In Computer Auto
Available	Bool	Available For Auto Control
Lockout	Bool	Computer Lockout
Remote	Bool	In Remote
Running	Bool	Running
Runtime	Real	Runtime Hours
SpeedCommandAuto	Real	Auto Speed Command
SpeedCommandManual	Real	Manual Speed Command
SpeedFeedback	Real	Speed Feedback
StartCommand	Bool	Manual Start Command
StopCommand	Bool	Manual Stop Command

Table 7-2 Valve or Gate AOI Attributes

ATTRIBUTE NAME	DATA TYPE	DESCRIPTION
AlarmBothLimits	Bool	Both Limits Active Alarm
AlarmCloseFail	Bool	Failed To Close Alarm
AlarmFail	Bool	Failed Alarm Input

ATTRIBUTE NAME	DATA TYPE	DESCRIPTION
AlarmOpenFail	Bool	Failed To Open Alarm
AlarmSummation	Bool	Alarm Summation
Auto	Bool	In Computer Auto
Available	Bool	Available For Auto Control
CloseCommand	Bool	Manual Close Command
Lockout	Bool	Computer Lockout
OpenCommand	Bool	Manual Open Command
Opened	Bool	Opened Status
PositionCommandAuto	Real	Auto Position Command
PositionCommandManual	Real	Manual Position Command
PositionFeedback	Real	Position Feedback
Remote	Bool	In Remote

Table 7-3 Analog AOI Attributes

ATTRIBUTE NAME	DATA TYPE	DESCRIPTION
AlarmDeadband	Real	Alarm Deadband Setpoint
AlarmHigh	Bool	Alarm High
AlarmHighHigh	Bool	Alarm High High
AlarmHighHighSP	Real	Alarm High High Setpoint
AlarmHighSP	Real	Alarm High Setpoint
AlarmLow	Bool	Alarm Low
AlarmLowLow	Bool	Alarm Low Low
AlarmLowLowSP	Real	Alarm Low Low Setpoint
AlarmLowSP	Real	Alarm Low Setpoint
AlarmSummation	Bool	Alarm Summation
ScaledRangeHigh	Real	Scaled Range High
ScaledRangeLow	Real	Scaled Range Low
ScaledValue	Real	Scaled Value
SimulateEnable	Bool	Simulate Value Enabled

ATTRIBUTE NAME	DATA TYPE	DESCRIPTION
SimulateValue	Real	Simulated Value

7.2 TAG NAMING CONVENTION

7.2.1 Purpose

The purpose of this section is to provide a standardized method of assigning PLC tag names to the PLC/SCADA tag database. It will be followed in all DWM projects. Some of the key goals in the PLC tag naming standard are:

- ***Consistency***. The format of the names and the assignment of characters for typical equipment and process functions should be the same throughout the PLC/SCADA tag database.
- ***Recognizability.*** The reader who has a basic familiarity with the process area and process functions should be able to understand what each PLC tag name represents without having to resort to other documents such as lookup tables.
- ***Readability***. The format and character assignment for PLC tag names should facilitate comprehension by the reader. The use of delimiters and a combination of upper and lower characters are used to improve readability.
- ***Conciseness***. PLC tag names are often used outside the tag database such as columns in reports, on HMI graphical displays, PLC program logic, etc. so it is helpful if they are not lengthy. Short designations are preferable over longer ones if it does not make them less recognizable.
- ***Expandability***. New PLC tags should be easy to add without conflicting with existing designations.

Each point in the PLC databases will be associated with a tag name. The tag name will be common between the PLC and the SCADA server. The tag names will be limited to 40 characters in length. Attributes will not be included in the 40-character count since they are not part of the base tag but an attribute to the base tag. Concise tag names are preferred if clarity is not compromised.

7.2.2 Basic Format

The general format of all tag name assignments will be to start with characters representing general areas and systems, and progress to more specific categories. Delimiters are used for readability. PLC tag names will be mnemonic so that they are easy to understand.

The tag name in all cases will begin with a three- to five-character text string corresponding to the DWM site. For example, tag names at Pole Bridge facility will begin will “PB” and at Scott Candler will begin with “SC”. The following table provides a complete listing on all the DWM sites.

The tag name in all cases will include with a two- or three-character text string corresponding to the process area. This text string will be the second set of characters in every tag name. For example, tag names involving the Waste Activated Sludge process will include “WAS” and the ones involving Influent Pumping will include with “INFP”.

Under bars will be used as delimiters. Hyphens are not allowed.

All tags associated with a single pump, valve, instrument, etc. will utilize the same base characters with an attribute. For example, the attributes "Opened" and "Closed" will be added to the base characters for a valve corresponding to the open and closed states of the valve.

The general format is as follows:

Site _ Process Area _ Equipment Designator _ Delimiter . Attribute

- ***Site*** is a three to six character site designation that will be the first characters of every tag name.
- ***Process Area*** is a two- or three-character area designation that will be the second set of characters of every tag name.
- ***Equipment Designator*** defines the specific equipment for which the tag is assigned.
- ***Equipment Sequence Number*** unique alpha-numeric identifier.
- ***Attribute*** defines the specific process function of the tag.

7.2.3 Sites

DWM operates multiple treatment facilities, storage tanks, booster pumps, and lift stations. The following table lists the site designation for each site location that shall be used as the first part of the PLC tags.

Table 7-4 Sites

SITE DESIGNATION	SITE DESCRIPTION
JWPS	John A. Walker Raw Water Pumping Station
SCFP	Scott Candler Water Filtration Plant
SFTF	Snapfinger Advanced Wastewater Treatment Facility
PBTF	Polebridge Advanced Wastewater Treatment Facility
CDST	Columbia Drive Ground Storage Tank
DWST	Dunwoody Ground Storage Tank
LHST	Lithonia Ground Storage Tank
RPST	Redan-Panola Ground Storage Tank
TSST	Tucker Stand Pipe Ground Storage Tank
WCST	Wesley Chapel Ground Storage Tank
WMST	Whites Mill Ground Storage Tank
HDBP	Henderson Booster Pumps
MVBP	Midvale Booster Pumps

SITE DESIGNATION	SITE DESCRIPTION
NSBP	North Shallowford Booster Pumps
SDBP	Steel Drive Booster Pumps
TMBP	Tilly Mill Booster Pumps
RVBP	Ridgeview Booster Pumps
ADET	Avondale Elevated Tank
CMET	Clairmont Elevated Tank
DWET	Dunwoody Elevated Tank
MAET	McAfee Elevated Tank
TKET	Tucker Elevated Tank
WLLS	Ward Lake Lift Station
SWLS	Sweetwater Lift Station
SSLS	Scarbrough Square Lift Station
LCC3LS	LCC 3 Lift Station
LCC2LS	LCC 2 Lift Station
LCC1LS	LCC 1 Lift Station
RLLS	Rogers Lake Rd Lift Station
PBLS	Pennybrook Lift Station
NGSLS	New Gibralter Square Lift Station
PWLS	Pepperwood Lift Station
FSLS	Fourth Street Lift Station
SMPLS	Stone Mtn Park Lift Station
SM2LS	Stone Mill 2 Lift Station
SM1LS	Stone Mill 1 Lift Station
SM3LS	Stone Mill 3 Lift Station
HM3LS	Hammermill 3 Lift Station
HM2LS	Hammermill 2 Lift Station
HM1LS	Hammermill 1 Lift Station
RA3LS	Royal Atlanta 3 Lift Station
RA1LS	Royal Atlanta 1 Lift Station

SITE DESIGNATION	SITE DESCRIPTION
RA2LS	Royal Atlanta 2 Lift Station
CCKLS	Camp Creek Lift Station
LSLS	Leeshire Lift Station
MILS	Mountain Industrial Lift Station
LHVLS	Lehaven Lift Station
PPLS	Perimeter Park Lift Station
SRBLS	South River Bend 2 Lift Station
KWLS	King Way Lift Station
SRLS	Salem Road Lift Station
BFLS	Briarwood Field Lift Station
CCLS	Coffer Crossing Lift Station
OHSLS	Oak Hill Springs Lift Station
HMHLS	Harmony Hills Lift Station
RVLS	River Vista Lift Station
BLS	Burlington Lift Station
GRLS	Greenridge Lift Station
HHLS	Holly Hills Lift Station
HRLS	Hearn Road Lift Station
MLPLS	Medlock Place Lift Station
CLLS	Camelot Lift Station
LWLS	Lewis Way Lift Station
BWFLS	Beechwood Forest Lift Station
SFLS	Stratfield Lift Station
GPLS	Green Pastures Lift Station
SGLS	Summit Glen Lift Station
SRB1LS	South River Bend 1 Lift Station
CHLS	Chester Hills Lift Station
BWLS	Boulder Walk Lift Station
KMLS	Klondike Manor Lift Station

SITE DESIGNATION	SITE DESCRIPTION
SVLS	Serenity Village Lift Station
WRLS	Windy Ridge Lift Station
OLLS	Oak Leaf Lift Station
TELS	Thurgood Estates Lift Station
MSLS	Moss Stone Lift Station
RV4LS	River Vista 4 Lift Station
TGLS	Turnberry Gates Lift Station
SCLS	Stoney Creek Lift Station
BM1LS	Browns Mill 1 Lift Station
BM2LS	Browns Mill 2 Lift Station
NLRLS	Norris Lake Reserve Lift Station
LHLS	Lithonia Lift Station
HCLS	Honey Creek Lift Station
JCLS	Johnson Creek Lift Station
FRHLS	Flat Rock Hills Lift Station

7.2.4 Process Areas

The DWM facilities have been divided into subsystems organized by process area and location. The control system architecture follows a similar arrangement by process area. With respect to the PLC tag naming method, all PLC tags within a process area will be grouped together. A three- or four-character designation is assigned to each process area, which will be the first characters in each PLC tag name.

The table below lists these process area designations. Note that the list is incomplete and must be updated areas after process area designations have been determined.

Note: The following table reflects the Process Area Numbers currently used at Pole Bridge WWTF. There needs to be a project to standardize Process Areas across all the DWM facilities. Then the table below should be updated to reflect the new standards.

Table 7-5 Process Areas

PROCESS AREA	RELATED PROCESS
INFP	Influent Pumping
HDW	Headworks

AER	Aeration
SCLR	Secondary Clarification
FLC	Flocculation
FCLR	Final Clarification
CC	Chlorine Contact
CL2	Chlorination
RAS	RAS Pumping
WAS	WAS Pumping
SAB	Sludge Aeration Blowers
SLG	Sludge
SLDL	Solids Loading
ALUM	Alum
CSTC	Caustic
PLY	Polymer

Auxiliary Systems include miscellaneous equipment and small systems located throughout the treatment plant. Examples of Auxiliary Systems include elevators and plant alarms such as the Laboratory Fire Alarm.

7.2.5 Equipment Designator

The second set of characters in each PLC tag name is the Equipment Designator. Equipment designations are typically a concatenation of abbreviations representative of the actual equipment.

The Equipment Designator is not required to be of a specific number of characters. However, the characters used for specific types of equipment should be the same throughout the PLC tag database (for example, "Vlv" for valves and "Pmp" for pumps). Also, a goal is to make the designations concise because PLC tag names are referenced in other situations such as in report print-outs, PLC logic documentation and database listings.

The following guidelines are used to assign the Equipment Designator part of the SCADA tag names.

- No more than three characters will be used to represent a particular type of equipment unless more are needed for clarity. For example, "Pmp" and "Vlv" work well for pumps and valves, respectively. However, using the four characters "Clar" for "clarifier" makes it easier to understand than shortening it to three characters.
- When three or more characters are used in a designation, the first character will be upper case and the following characters will be lower case.
- Using the upper- and lower-case method, equipment and processes can be concatenated without using delimiters. This facilitates readability while keeping the overall length of the

tag name as short as possible. For example, “AerBas” is used for “Aeration Basin” and “InfVlv” is used for “Influent Valve”.

- Acronyms are represented with all upper-case characters. For example, “Waste Activated Sludge” is represented by “WAS” not “Was”.
- When acronyms are placed in concatenated strings, use an under-bar delimiter for readability. For example, the first WAS pump will be designated as “WAS_Pmp” not “WASPmp”.

Some of the most common abbreviations used in the creation of PLC tag names are included in the following table. New and different types of equipment will be assigned designations as required.

Table 7-6 Tag Name Abbreviations

ABBREVIATION	DESCRIPTION
Pmp	Pump
Vlv	Valve
Gate	Gate
FCV	Flow Control Valve
Inf	Influent
Eff	Effluent
Drn	Drain
Inl	Inlet
Disch	Discharge
Hdr	Header
BW	Backwash
DMF	Dual Media Filter
FR	Filter
Wtr	Water
Lvl	Level
Press	Pressure
Temp	Temperature
NTU	Turbidity
DOX	Dissolved Oxygen
TSS	Total Suspended Solids
BOD	Biochemical Oxygen Demand

ABBREVIATION	DESCRIPTION
AS	Activated Sludge
RAS	Return Activated Sludge
WAS	Waste Activated Sludge
Aer	Aeration
Bas	Basin
Sec	Secondary
Clar	Clarifier
Dig	Digester
Turb	Turbine
Mix	Mixer

7.2.6 Equipment Sequence Number

Equipment Sequence Number matches the P&ID unique alpha-numeric identifier that is part of the equipment identification description. See the P&ID standards in section 2 or sheet 1 of P&ID Legends & Abbreviations at the end of section 2.

7.2.7 Attributes

The last set of characters in each PLC tag name is the attribute, which is representative of the specific process function for each PLC tag name. Attributes were defined above as part of each AOI.

7.2.8 SCADA Tag Name Examples

Using the naming standards detailed in the preceding paragraphs, the following example SCADA tag names are shown in the table below.

Table 7-7 SCADA Tag Examples

SCADA TAG NAME	DESCRIPTION
PB_INFP_Pmp_1001.Running	Pole Bridge Influent Pump 1 Running
PB_HDW_InfGate_2001.Opened	Pole Bridge Headworks Influent Gate 1 Opened
PB_PLY_Lvl_3001.ScaledValue	Pole Bridge Polymer Tank 1 Engineering Value

7.3 ALARMS

Logic in the PLC determines if the equipment responds properly to an operator command, or if the equipment changed state without being commanded. Each controlled piece of equipment has two alarm status bits which are calculated by the PLC and are referenced by the SCADA FactoryTalk software. These are UnCommanded Change (UNC) and Control Timeout (CTO) alarms.

Note that when the equipment is in “Local” mode, neither the UNC alarm nor the CTO alarm will be calculated.

7.3.1 UnCommanded Change (UNC) Alarms

The PLC determines if the equipment changes state without being commanded. If the equipment changes state without being commanded, then the PLC will generate an UnCommanded Change Alarm. If the equipment is in “Remote Auto” mode, the PLC will normally place the equipment in “Remote Manual” mode to prevent any automatic logic from attempting to control the equipment. After an UnCommanded Change if the operator desires the equipment to be in “Remote Auto” mode, the operator will need to place the equipment back to “Remote Auto” mode from a SCADA computer – it will not automatically transition to this Control Mode. The UnCommanded Change alarm will be cleared when the operator either changes the Control Mode of the equipment or acknowledges the alarm. On the HMI display, the text ‘UNC’ will be displayed next to any equipment that is in UnCommanded Change alarm.

7.3.2 Control Time Out (CTO) Alarms

The PLC determines if the equipment does not change to the desired state after being commanded. Each piece of controllable equipment has a Control Time Out Setpoint, which is assigned a point in the FactoryTalk database, and in the PLC an associated Control Time Out Timer. After the operator issues a command to change the state of a piece of equipment, if the equipment does not change to the desired state before the Control Time Out Timer expires, then the PLC will generate a Control Time Out Alarm. If the equipment is in “Remote Auto” mode, the PLC will place the equipment in “Remote Manual” mode to prevent any automatic logic from attempting to control the equipment. After a Control Time Out alarm if the operator desires the equipment to be in “Remote Auto” mode, the operator will need to place the equipment back to “Remote Auto” mode from a SCADA computer – it will not automatically transition to this Control Mode. The Control Time Out alarm will be cleared when the operator either changes the Control Mode of the equipment or acknowledges the alarm. On the HMI display, the text ‘CTO’ will be displayed next to any equipment that is in Control Time Out alarm.

7.4 PLC TIME SYNCHRONIZATION

Time and date may be used in the PLCs for flow totals, controls, alarms, etc. Time and date are also used at the SCADA computers for alarms, reports, etc. Because date and time accuracy are important, all PLCs and all SCADA computers be must be synchronized daily. This will be done automatically using Rockwell Automation’s clock update tool software running on the primary HMI server at each DWM site.

7.5 PROGRAM DOCUMENTATION

PLC programs shall be well documented to aid in troubleshooting and understanding the logic. Documentation shall include the following:

- Overall program structure including subroutine overview
- An outline of the program flow with descriptions for each subroutine
- Rung annotations

- Controller tags
- Print-outs
- A laminated copy of the PLC logic will be provided for each PLC control panel

8.0 SCADA Software Standards

8.1 OVERVIEW

The standard SCADA software for DWM is Rockwell Automation FactoryTalk View SE which will be used for creating all additions and modifications to the DWM SCADA system.

FactoryTalk software runs on two classes of computers:

Servers that run the software applications that execute the primary SCADA functions including:

- Communicate with the PLCs to bring in data from the process areas and send commands to the PLCs.
- Run the real-time database that updates database points with the latest values.
- Maintains real-time updates for a wide variety of alarms.
- Serves the data to client workstations over the SCADA System Network.
- Runs a variety of background programs including reporting software, surveillance video windows, and a future Autodialer software.
- Arranged in a redundant configuration, automatically fails over to a backup server when the primary server fails.
- Supports real-time and historical collection of data. Note that a separate historian runs on a dedicated server computer.
- Support Terminal Services for operating on computers through Microsoft Remote Desktop or other remote desktop tools.

Thick Clients that perform the main Human-Machine Interface (HMI) functions that O&M personnel use to interact with the SCADA System at computer workstations located in the control room:

- View graphical displays that represent all process areas of the treatment plant.
- View real-time data in numeric and textual formats.
- View real-time and historical trends.
- View alarms on an individual basis and on Alarm Summary Displays.
- Perform supervisory control functions such as starting and stopping pumps and changing operating setpoints.

Thin Clients perform the same functions as Thick Clients; however, they run on Terminal Services located on the Servers via a remote connection. All remote workstations located throughout the plant, excluding the control room, utilize thin clients for interface to the HMI functions that O&M personal use to interact with the SCADA System.

8.1.1 High Level Data Handling

High level data handling includes totalizing analog values, alarm generation, historical archiving of data, and calculation of equipment runtimes.

The PLC programs will totalize the analog flow values and calculate equipment runtimes.

The SCADA server and the Historian will retrieve the data from the PLCs for operator display and for historical storage, trending, and reports.

The SCADA server will provide alarm functions. Discrete values tagged for alarming will be alarmed on the displays and the alarm summary when the value becomes true. The PLC will calculate alarms for analog values based on the setpoints configured in the system or entered from the HMI. Alarms will be configured for out of range, low-low, low, high, and high-high.

Key Performance Indicators (KPIs) will be added to dashboards that will be available to DWM operations managers. These KPIs will help management in the day to day operations of DWM facilities. DWM management will determine which KPIs will be displayed on these dashboards.

8.1.2 Communications Failure

Communications failure may occur between the operator workstations and the SCADA servers, the servers and the PLCs, or a PLC to another PLC. Redundancy is built into the system to minimize the impact of a failure. The server computers are redundant with the primary server online. In the event of a communication failure, the secondary server will assume the primary operations. Selected PLCs are redundant, with the primary PLC on line, and the secondary PLC in synchronization with the primary. In the event of a failure of the primary PLC or PLC communications, the secondary PLC will assume the primary operations. The networks and switches are redundant. In the event of a failure of communications a secondary network path will assume the communications.

In the event of a catastrophic failure of the server or communications system, the isolated PLCs will continue to perform control functions based on the latest data available at the time of failure.

8.1.3 Power Failure

The SCADA servers, Historian server and operator workstations will be powered from UPS circuits. Upon power failure, the UPS will allow processors and workstations to remain in use until emergency or normal power is online.

8.2 SECURITY

The System Integrator shall be knowledgeable regarding the security policies and practices for the DWM SCADA System and develop new and upgraded automation systems in accordance with them. Note that the intent of the SCADA Standards is not to develop security standards for the SCADA System.

DWM SCADA security is based on National Institute of Standards and Technology (NIST) 800-82 Revision 2 – Guide to Industrial Control Systems (ICS) Security and International Electrotechnical Commission (IEC) 62443

SCADA security has become a prime consideration for utilities. As the systems have migrated from using isolated non-commercial networks to Ethernet IP networks using commercial off the shelf (COTS) technology, physical and cyber security of SCADA have become a necessity to prevent malicious and accidental attacks.

SCADA security is needed to discourage and prevent unauthorized access to SCADA servers, network equipment, PLCs, Remote Terminal Units (RTUs), radios, and cellular modems. The following is a list of issues that could occur with unauthorized access to a SCADA.

- Risk to public health and confidence
- Personal injury
- Equipment damage
- Process upsets leading to compromised process functionality, compromised process safety, or environmental releases
- Violation of legal and regulatory requirements
- Loss of integrity or reliability of process data
- Loss of system availability
- Publication of information to unauthorized destinations
- Misuse of confidential information
- Threat to national security

8.2.1 Security Objectives

Information security focuses on confidentiality, integrity, and availability as the primary objectives. Traditional Information Technology (IT) prioritizes these objectives in the order listed with confidentiality being the highest priority. For SCADA these objectives are typically reversed with availability being the highest priority, integrity the next highest, and confidentiality the lowest priority. Control systems should be available first and foremost to control the process. The integrity of the control system is the second most important to allow the process to be controlled properly. Confidentiality is not as important since the data often needs to be further analyzed within context to have value. Prioritizing the objectives in this way increases the system responsiveness, which can be seconds or milliseconds in control systems, whereas in traditional business systems response time can be much longer.

8.2.2 Foundational Requirements

The following list identifies the basic foundational requirements (FR) for SCADA security. These definitions are taken directly from IEC 62443.

- Access Control (AC): control access to selected devices, information or both to protect against unauthorized interrogation of the device or information.
- Use Control (UC): control use of selected devices, information or both to protect against unauthorized operation of the device or use of information.
- Data Integrity (DI): ensure the integrity of data on selected communication channels to protect against unauthorized changes.
- Data Confidentiality (DC): ensure the confidentiality of data on selected communication channels to protect against eavesdropping.

- Restrict Data Flow (RDF): restrict the flow of data on communication channels to protect against the publication of information to unauthorized sources.
- Timely Response to Event (TRE): respond to security violations by notifying the proper authority, reporting needed forensic evidence of the violation, and automatically taking timely corrective action in mission-critical or safety-critical situations.
- Resource Availability (RA): ensures the availability of all network resources to protect against denial of service attacks.

8.2.3 Defense In Depth

SCADA security needs to be implemented with multiple countermeasures that are layered or redundant. This is called defense in depth approach to security. This approach will help slow down a potential attack and will buy time to allow the attack to be recognized or stopped by the countermeasures. Defense in depth includes the following five areas.

- Physical Security
- Network Security
- Computer Hardening
- Application Security
- Device Hardening

8.2.3.1 Physical Security

Examples of physical security include perimeter fencing, gates, guards, door locks, and key cards. These physically help keep people out of areas that contain equipment associated with a control system.

SCADA server enclosure/rack shall be lockable as a first measure of physical defense. PLC panels should be locked to avoid unintended physical access to network assets that are located within the panels.

8.2.3.2 SCADA Network Security

Examples of network security are demilitarized zones (DMZ), firewalls, switches, routers, and intrusion detection and prevention systems. IEC 62443 also talks about isolating and securing the plant SCADA network in a similar way.

8.2.3.2.1 DMZ

According to NIST Special Publication 800-2 Guide to Industrial Control Systems (ICS) Security the following diagram is the best network architecture to secure SCADA systems.

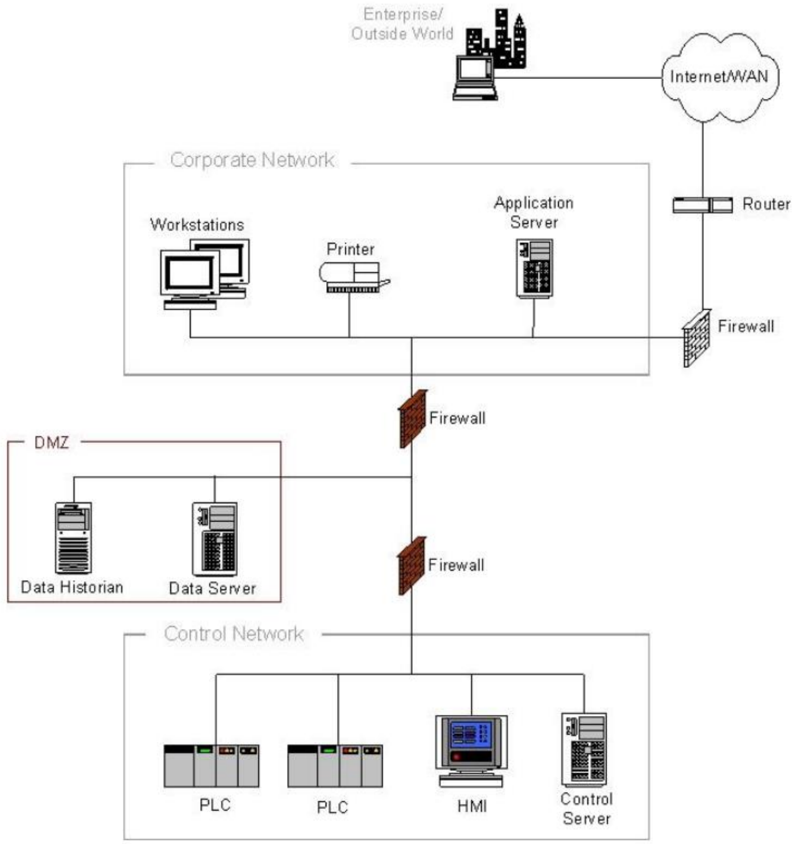


Figure 8-1 Paired Firewalls between Administration Network and Control Network

Source: Guide to Industrial Control Systems (ICS) Security page 5-12 http://dx.doi.org/10.6028/NIST.SP.800-82r2

The figure above shows a three-zone network architecture that includes a Control (SCADA) Network, Corporate (Administrative) Network, and Demilitarized Zone (DMZ). DMZ is a buffer that enforces data security policies between a trusted network (SCADA Network) and an untrusted network (Administrative Network). Servers with information that is used on both the SCADA network and administrative network are referred to as Shared Servers. These servers should be place in the DMZ. By placing these servers in the DMZ and correctly configuring the firewall there will be no direct communication path from the administrative network to the SCADA network. The firewall on the SCADA network side blocks arbitrary packets from proceeding to the administrative network. The firewall on the administrative network side can prevent unwanted traffic from a compromised server from entering the SCADA network and prevents SCADA network traffic from impacting the shared servers. Below is list of the types of servers that should be placed in DMZ include:

- Tier 1 or Primary Data Historian
- Patch Management
- Antivirus
- View Only HMI
- Remote Access
- Real Time Decision Support System (RT-DSS)

Using the network architecture in figure above creates a Defense in Depth architecture. Which includes using multiple overlapping security devices so that a failure in one device will minimize the effect to the entire network.

When using a DMZ with two firewalls in the network architecture, it is possible to configure the system so that no traffic will go directly between the administrative network and SCADA network. With a few special exceptions, all traffic from either side can terminate in the DMZ. Communications protocols that are used in a SCADA like EtherNet/IP, Modbus/TCP, and HTTP are inherently insecure. EtherNet/IP or Modbus/TCP are used to communicate between PLCs and data historian. HTTP is used to communicate between data historian and enterprise clients on the administrative network. These protocols can be used safely because neither cross between the two networks. If the Tier 1 or Primary Data Historian is on the administrative side of the network, insecure protocols must be allowed through the firewalls and every control device reporting to the historian is exposed to the administrative network.

There will be cases where data will need to be shared directly between the Administrative Network and SCADA Network. One example of this is Network Time Protocol (NTP). Time synchronization plays a critical role in Control Systems not only for the Historian but also in the HMI alarm and event logging and PLCs using time-based control. This being the case NTP is one of the few protocols that should directly traverse from the Administrative Network to the SCADA Network.

Rockwell Automation along with Cisco has developed a design and implementation guide for DMZ: https://literature.rockwellautomation.com/idc/groups/literature/documents/td/enet-td009_-en-p.pdf In this guide they call the DMZ and IDMZ (Industrial Demilitarized Zone) which same as the DMZ in the NIST document. This guide also recommends the three-zone network architecture with a DMZ. This document lists the following design principles for a DMZ on page 1-4: (some of the terms are changed to match the terms from the NIST document)

- All Control System network traffic from either side of the DMZ terminates in the DMZ; no Control System traffic directly traverses the DMZ
- EtherNet/IP Control System traffic does not enter the DMZ; it remains within the Control System Network
- Primary services are not permanently stored in the DMZ
- All data is transient; the DMZ does not permanently store data
- Functional sub-zones within the DMZ are configured to segment access to Control System data and network services (for example, IT, Operations and Trusted Partner zones)
- A properly designed DMZ will support the capability of being unplugged if compromised, while still allowing the Control Network to operate without disruption

The following figure illustrates the design principles above:

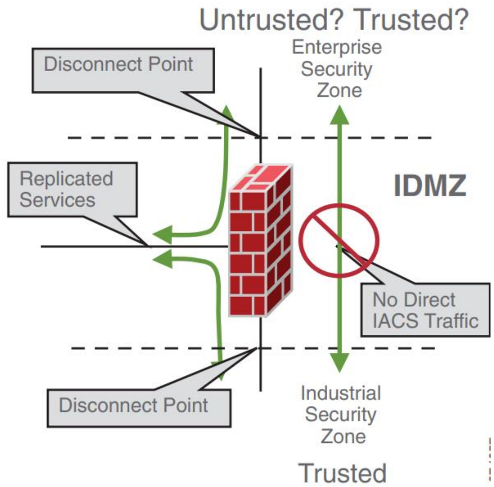


Figure 8-2 DMZ Design Principles

Source: Securely Traversing IACS Data across the Industrial Demilitarized Zone Design and Implementation Guide page 1-4 https://literature.rockwellautomation.com/idc/groups/literature/documents/td/enet-td009_-en-p.pdf

8.2.3.2.2 Firewall

Firewalls are installed on either side of the DMZ to add more layers of security. Firewalls restrict the flow of data from outside to inside the control system network and may consist of a dedicated hardware device or software on a server, router or Ethernet switch. Firewalls help prevent unwanted access to the control system network by inspecting the data flowing through the network. Anytime there is a connection to a network outside of the immediate control of the DWM a firewall should be used.

8.2.3.2.2.1 Firewall Configuration

These recommendations come from NIST Guide to Industrial Control Systems (ICS) Security page 5-16 http://dx.doi.org/10.6028/NIST.SP.800-82r2.

- The base rule set should be denying all, permit none.
- Ports and services between the control network environment and the corporate network should be enabled and permissions granted on a specific case-by-case basis. There should be a documented business justification with risk analysis and a responsible person for each permitted incoming or outgoing data flow.
- All “permit” rules should be both IP address and TCP/UDP port specific, and stateful if appropriate.
- All rules should restrict traffic to a specific IP address or range of addresses.
- Traffic should be prevented from transiting directly from the control network to the corporate network. All traffic should terminate in the DMZ.
- Any protocol allowed between the control network and DMZ should explicitly NOT be allowed between the DMZ and corporate networks (and vice-versa).
- All outbound traffic from the control network to the corporate network should be source and destination-restricted by service and port.

- Outbound packets from the control network or DMZ should be allowed only if those packets have a correct source IP address that is assigned to the control network or DMZ devices.
- Control network devices should not be allowed to access the Internet.
- Control networks should not be directly connected to the Internet, even if protected via a firewall.
- All firewall management traffic should be carried on either a separate, secured management network (e.g., out of band) or over an encrypted network with multi-factor authentication. Traffic should also be restricted by IP address to specific management stations.
- All firewall policies should be tested periodically.

All firewalls should be backed up immediately prior to commissioning.

8.2.3.3 Computer Hardening

Examples of computer hardening include antivirus software, application whitelisting, removal of unused applications, protocols, and services, and disabling unnecessary Ethernet and USB ports. Software vulnerabilities are the easiest way for someone to gain unauthorized access to a control system and are typically dealt with using software patches.

8.2.3.3.1 Software Patches

Keeping software up to date with patches will help prevent viruses, however automatically patching software can also have unintended consequences that may disable or crash part of the control system. The following is a list of software patching guidelines for control systems.

- Disable automatic software updates on computers.
- Create an inventory of software applications and versions.
- Monitor vendor services for operating system patch qualification and compatibility with vendor software.
- Request software patches and upgrades directly from the vendor.
- Install patches on a test system that is isolated from the operational control system. If test system is not available, install patch on a backup server and test before installing on the primary server.
- Inform users when a patch and upgrades will be installed to allow them to monitor for system issues after the installation.

Software patches shall be implemented in the SCADA system by first contacting the SCADA software manufacturer to verify that the patch has been validated with their software. If it has, then install the patch on the backup SCADA server. Once the backup server has been rebooted, then verify the backup server is still functioning properly with the new software patch. If the backup server is stable, switch the primary and backup servers and install the patch on the other server.

8.2.3.3.2 Anti-Virus Software

Anti-virus software or application whitelisting software shall be used on all SCADA servers and workstations. If anti-virus software is used, then it should be kept up to date. Weekly scans should be run during a low activity time of the day. The SCADA software manufacturer should be consulted before selecting the anti-virus software that will be installed on the SCADA machines. They should have recommendations for the anti-virus software that works well with their product.

8.2.3.3.3 Application Whitelisting

Application whitelisting prevents unauthorized software applications from running on a computer. If a software application is not whitelisted, then it will not run on the computer.

Application whitelisting software or anti-virus software shall be used on all servers and workstations. The SCADA software manufacturer should be consulted before selecting the application whitelisting software that will be installed on the SCADA machines. They should have recommendations for the application whitelisting software that works well with their product.

8.2.3.3.4 Other Computer Hardening

Unused Ethernet ports and USB ports shall be disabled on all computers. Software programs and applications that are not needed for the SCADA system be removed or not installed on SCADA computers.

8.2.3.4 Application Security

Application Security refers to applying good security practices, such as locking down access to critical process functions by requiring the use of username and passwords. An example of this would be requiring a username and password to login to a SCADA workstation to start or stop a pump or change a process set point.

- At a minimum that four security groups shall be created within the SCADA application software. These groups include guest, operator, supervisor, and administrator. The first level is the Guest security account which is the default account. This account has view only privileges.
- The first level is the Operator security account at the SCADA HMI workstations. When logged in the Operator account, the user can navigate between displays and trends and perform most process control functions. This level is appropriate for operations and maintenance staff and is the default level at startup. Access to the computer’s operating system is not possible under this security account.
- The second level is the Supervisor account which allows the user to perform additional control and setpoint changes not allowed under the Operator account. It also allows access to the operating system and miscellaneous functions such as starting up and shutting down the SCADA software on each computer. This level is appropriate for supervisors and some of the senior operations staff.
- The third level is the Administrator account and allows the user complete rights to the system including the right to perform programming functions for the SCADA system and to the computer operating system. This level is appropriate for system administrators and those who have programming responsibilities.

When an individual leaves DWM all of the SCADA security accounts shall be removed for all DWM facilities.

8.2.3.5 Device Hardening

Device hardening refers to changing the default security settings on devices to make them more secure than the out of the box configuration. For example, enabling security and changing the password on devices such as PLCs, routers, switches, firewalls, servers and workstations. Other ways include disabling unused Ethernet port or USB ports on devices.

Routers, managed switches, firewalls, servers and workstations shall have security enabled and the default settings be changed.

8.2.4 Security Zones

Security zones are logical groupings of items that share common security requirements. These items may be physical or virtual. These zones could be completely separate or zones within a larger zone that provides layered security. An example of security zones is depicted in the figure below.

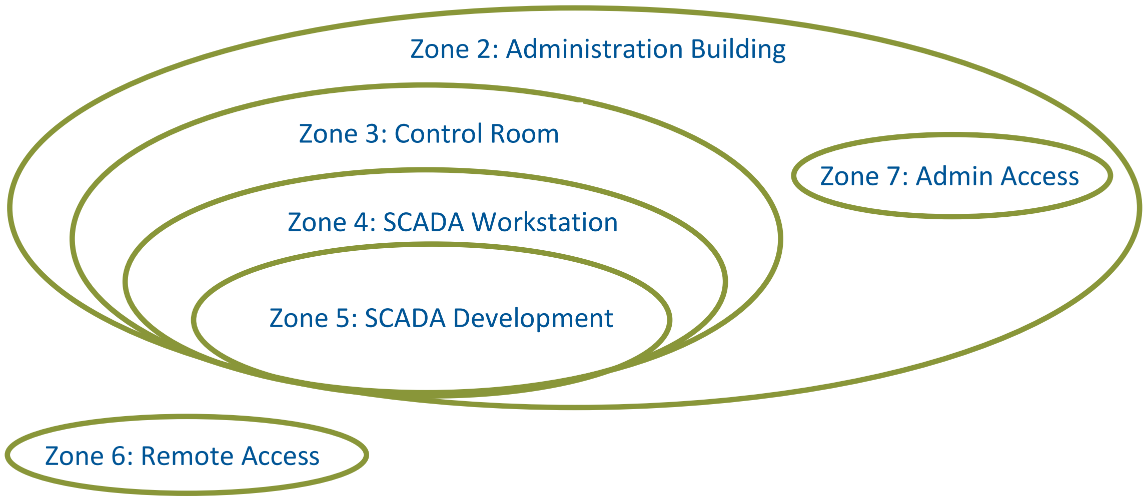


Figure 8-3 Security Zones

The first zone is the entire plant site (physical zone) where someone needs a security badge to be allowed to enter the gate. The second zone is the administration building (physical zone) where someone needs a badge with administration security access to enter the building. The third zone is the control room (physical zone) inside of the administration building. This could require the same administration security access or a higher level of security access to enter this room. The fourth zone is access to the SCADA workstation (virtual zone) inside of the control room. This requires a username and password to be able to change operational set points in the control system. The fifth is access to the SCADA development software (virtual zone) on the workstation. This requires a user with the highest security access. The sixth zone is remote access (virtual zone) to the SCADA network from outside of the plant utilizing the DMZ described in the DMZ section above. The seventh zone is admin access (virtual zone) outside of the plant SCADA network but inside of the administration building.

The above example above should be considered for each DWM facility. The physical security for zones 1, 2, and 3 are not part of the immediate SCADA system but should be considered as a means of adding layers to create a defense-in-depth approach to enhance the SCADA security and the overall plant security. At a minimum, security zones 4, 5 and 7 should be implemented when the new SCADA system is implemented. Zone 6 should be implemented once remote access is available for the plant.

8.2.5 Conduits

Conduits represent the data flow within or in and out of a security zone. Conduits can be considered a security zone that groups communications into logical groups. Conduits can be trusted and untrusted. If a conduit is within the same security zone or the security level between security zones have the same level the conduit is typically trusted. An example of an untrusted conduit from the security zones figure would be from the admin access zone (zone 7) to SCADA workstation zone (zone 4). The figure below depicts this conduit.

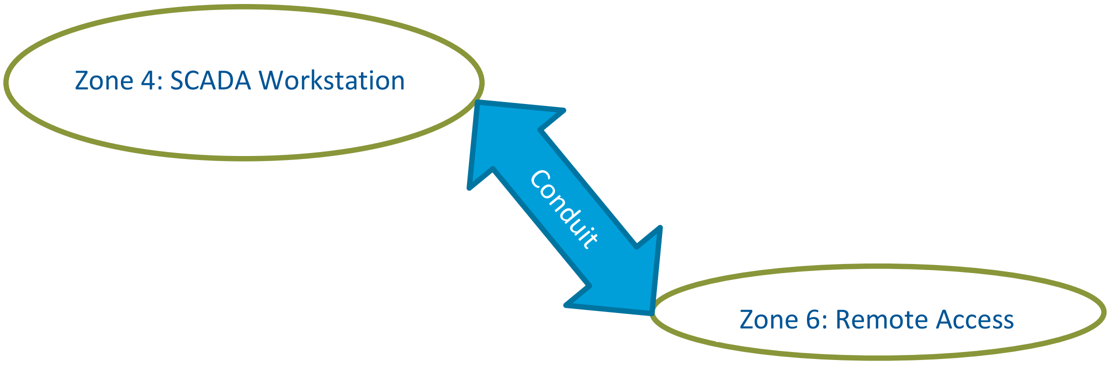


Figure 8-4 Conduit Example

8.2.6 Security Levels

Security levels need to be thought of as levels that apply to security zones instead an individual device, such as an OIT or SCADA workstation. To achieve a desired level of security for a zone, security capabilities of the individual devices and countermeasures should function together. Most devices and countermeasures have different inherent security capabilities. Using security levels that apply to zones will provide a frame of reference when deciding which devices and countermeasures to use.

To use this security level method effectively the levels should be defined for what each level represents and how to measure the level of security for the zone. These levels should be applied across all the DWM Facilities.

If the security zones example in section 8.2.4 is used, then security levels (SL) could be defined as stated in the following table.

Table 8-1 Security Levels Example

SECURITY LEVEL	NAME	DESCRIPTION
SL 1	Plant Site Access	User allowed to enter the plant gate via a key card.
SL 2	Operations Building Access	User has SL 1 privileges and allowed to enter the operations building via a key card.
SL 3	Control Room Access	User has SL 2 privileges and allowed to enter the control room via a key card. Inside the control room the user can view and monitor the SCADA system.
SL 4	Workstation Access	User has SL 3 privileges and has a login to a SCADA workstation that allows the users to modify control set points.
SL 5	SCADA Development	User has SL 4 privileges and has a login to allow the user to modify the SCADA configuration and programming.
SL 6	Remote Access	User has SL 5 privileges and has a login to allow access to the control system from outside of the plant.
SL 7	Admin Access	User has SL 2 privileges and has a login to one of the Administrative Network workstations.

For simplification purposes the table defines a security level for each security zone. The security levels could overlap into multiple security zones if it makes logical sense.

Security levels example in table shall be considered for each DWM facility. SL 1, SL 2, and SL 3 are physical security levels that are not part of the immediate SCADA system but should be considered. At a minimum SL 4, SL 5 and SL 7 should be implemented when the new SCADA system is implemented. SL 6 should be implemented once remote access is available for the plant.

8.2.7 Plant Network

To apply the recommend security zones and levels an example of a plant Control System Block Diagram is shown in the following figure. The figure below shows which devices are in security zones 2, 3, 4, 5, or 7.

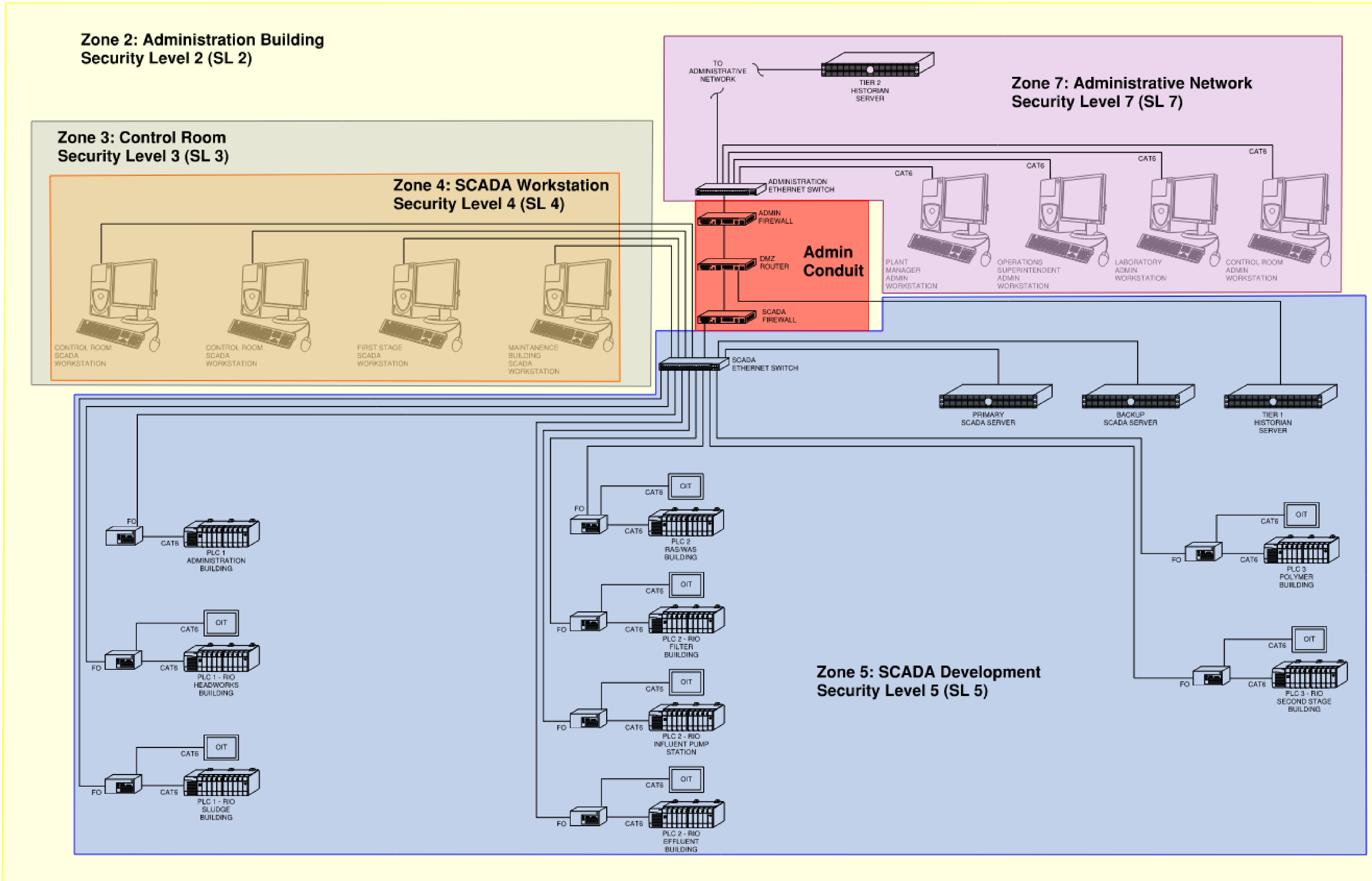


Figure 8-5 Example of Plant Network Security Zones

8.3 SCADA WORKSTATION DISPLAY STANDARDS

8.3.1 Types of Displays

There are three main types of displays:

- ***Process Graphic Displays.*** Process graphic displays show a dynamic schematic of the process.
- ***Tabular Displays.*** Tabular displays show static or dynamic data in a tabular format. Examples include alarm summaries, alarm timer setpoint entry displays and filter setpoint entry displays.
    - A minimum of one situational awareness screen shall be created per DWM facility that provides an overview of the facility. Information on this screen shall be determined by the designer and DWM facility management and SCADA Team. This information should be similar to the information on the daily report, which is described in the Reports section below.
- ***Trend Displays.*** Trend displays show the displays data in a graph type of format and may depict values in real-time or from historical data.

As desired, it is possible to combine different types of contents on a single display. For example, a tabular alarm summary could be located at the bottom of a process graphic or a trend could be embedded within a process graphic. The main operator interface to the process is via the process graphic displays.

8.3.2 Display Hierarchy

Although some of the displays are more comprehensive, such as the Wet Weather graphic, in general the displays are arranged by process areas within the plant and pump stations. The process graphic hierarchy is pyramidal in nature from the perspective of the overall process. Starting at the top-level screen, the operator may navigate to progressively more detailed and process specific screens. With each transition into a deeper level within the hierarchy, the display screen becomes more focused on a specific process, portion of the process or piece of equipment.

8.3.3 Display Design

The following will describe the design parameters used for SCADA development. All HMI graphics will use a display resolution of 1920 x 1080.

8.3.3.1 Navigation / Menu Bar

A drop-down menu-based navigation bar is fixed at the top of all screens and provides standard approach navigation to each major screen in the system. In addition to navigation bar some screens have more detail including but not limited to buttons for detail equipment overview, and buttons for following pipes to other process areas. The operator can navigate to any screen from the navigation bar or from the related navigation link on the process graphic itself.

The navigation bar will also include links to alarming, trending, and login information. It will show the time and provide critical general information and the title of the screen being reviewed.

Figure 8-6 SCADA Title Bar

8.3.3.2 Main Display Area

The main process displays contain the graphical depiction of the treatment train for control and data acquisition of the system. This main display area displays data read from the SCADA system including analog values, pump and valve statuses, etc. The standards used for the presentation of this data are described in the following sections of this document.

Right-clicking on the background will bring up a menu of relevant prebuilt trend screen associated with the graphic.

8.3.4 Graphics

Animated or moving graphics will not be used. Animated graphics generally do not provide meaningful information to an operator. Do not use spinning pumps, spinning mixers, bubbles, etc. All graphics will use color changes to indicate status. Wherever possible the operator interface will be via the computer mouse with keyboard use kept to a minimum.

8.3.4.1 General Arrangement

Graphical displays shall be laid out with symbols and objects arranged neatly and in alignment with each other. Objects shall be spaced to reduce clutter. Generally, the objects shall be arranged in accordance with the process flow from left to right and from top to bottom.

8.3.4.2 Symbols and Objects

Symbols and objects representative of each type of equipment, such as for pumps and valves, shall be identical, including background properties. Where multiple units of the same type of equipment are implemented, tag groups or other methods shall be used to facilitate graphical development and maintenance.

Global objects are custom defined objects that provide specific controls or animations associated with specific types of equipment in the PLC. Typically these objects are associated with AOIs defined in the PLC. The following global objects will be predefined and shall be used on new HMI screens. The objects are subject to change as development continues to progress.

Note: The following figures reflect the HMI graphics currently used at Pole Bridge WWTF. There needs to be a project to standardize HMI graphics across all of the DWM facilities. Then the figures below should be updated to reflect the new standards.

- Zero Decimals Dynamic Text

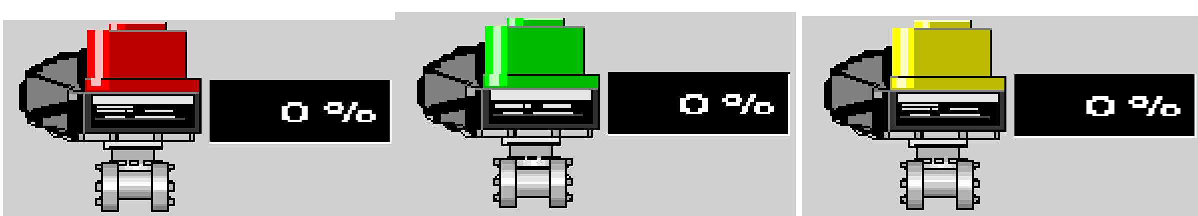
- One Decimal Dynamic Text

- Two Decimals Dynamic Text

Figure 8-7 HMI Dynamic Text Graphics

Figure 8-8 HMI Alarm Graphics (Blinking)

- Throttling Valve (Red = Closed, Green = Opened, Blinking Yellow = Alarm)



- Open/Close Valve (Red = Closed, Green = Opened, Blinking Yellow = Alarm)

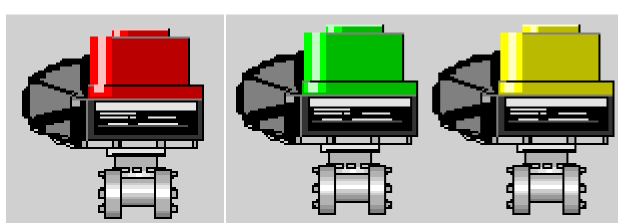
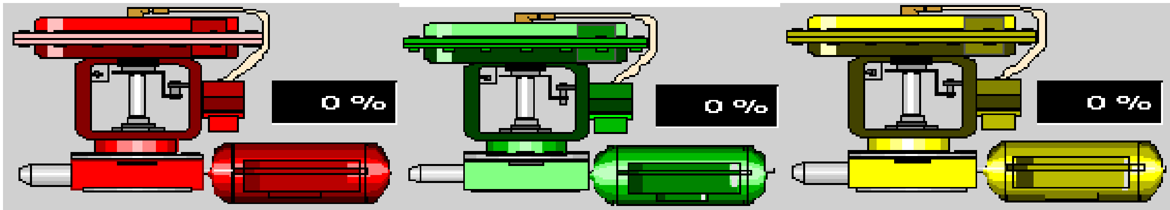


Figure 8-9 HMI Valve Graphics

- Throttling Gate (Red = Closed, Green = Opened, Blinking Yellow = Alarm)



- Open/Close Gate (Red = Closed, Green = Opened, Blinking Yellow = Alarm)

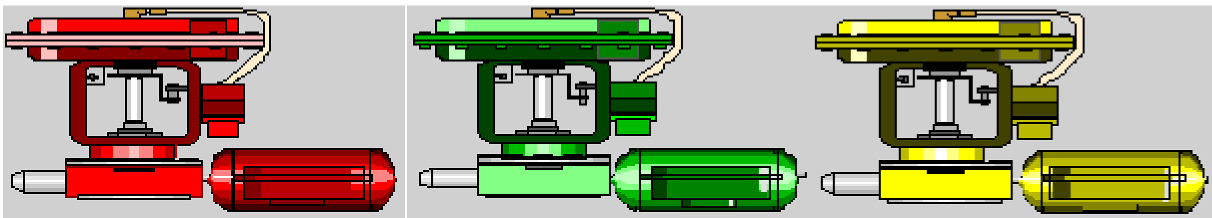
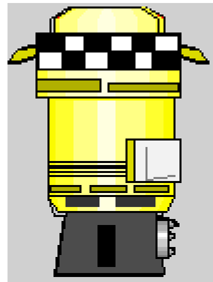
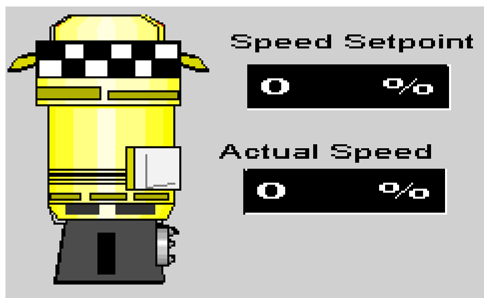


Figure 8-10 HMI Gate Graphics

- Constant Speed Pump (Red = Stopped, Green = Running, Blinking Yellow = Alarm)



- Variable Speed Pump (Red = Stopped, Green = Running, Blinking Yellow = Alarm)



- Metering Pump (Red = Stopped, Green = Running, Blinking Yellow = Alarm)

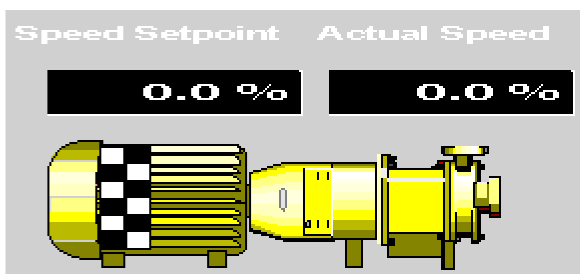
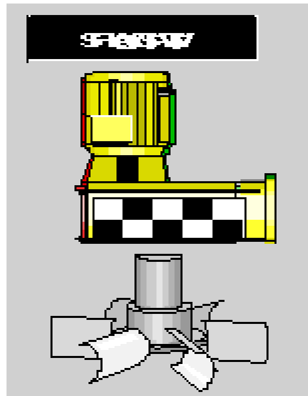


Figure 8-11 HMI Pump Graphics

- Two Speed Mixer (Red = Stopped, Green = Running, Blinking Yellow = Alarm)



- Single Speed Mixer (Red = Stopped, Green = Running, Blinking Yellow = Alarm)

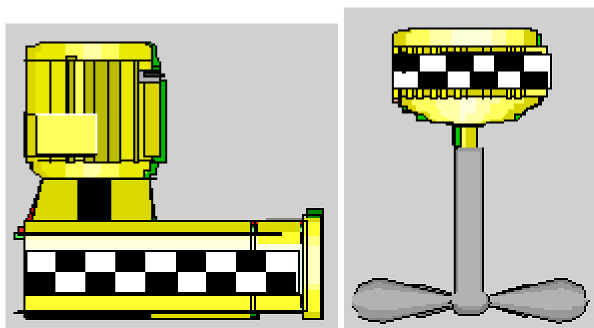


Figure 8-12 HMI Mixers and Aerators Graphics

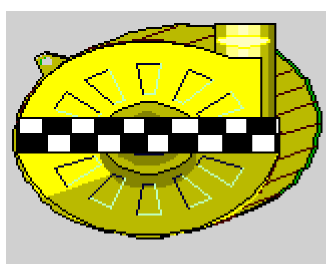


Figure 8-13 HMI Blower and Conveyor Graphics (Red = Stopped, Green = Running, Blinking Yellow = Alarm)

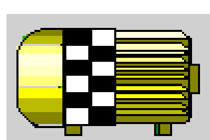


Figure 8-14 HMI Other Motorized Equipment Graphics (Red = Stopped, Green = Running, Blinking Yellow = Alarm)

8.3.4.3 Control Displays

Process and equipment control will be performed on pop-up windows and dialog boxes that are accessed by selecting the equipment symbol on the graphic displays using the left mouse button. The control pop-ups enable supervisory control by operators including:

- Starting and stopping equipment
- Opening and closing valves
- Entering setpoints
- Changing lead/lag sequencing
- Changing control modes such as Remote Manual and Remote Auto.

8.3.4.4 Data Links

Data links are used extensively to display numeric and textual data monitored by field instruments, values calculated by the PLCs or by the SCADA software, status of equipment, etc. Data links can also be special purpose data such as date, time, and network status. Engineering units shall be displayed along with numeric values. Alarm conditions, equipment status and control modes are commonly depicted as text in data links.

8.3.4.5 Color Conventions

HMI Standard symbols will be used wherever applicable. Equipment status or position will be distinguished by changing the displayed symbol color as follows:

Table 8-2 Gates and Valves Symbol Colors

COLOR	EQUIPMENT STATE
Solid White	Unknown
Solid Green	Open
Solid Red	Closed
Blinking Red/Yellow	Alarm

Table 8-3 Pumps or Other Two State Equipment Symbol Colors

COLOR	EQUIPMENT STATE
Green	Running
Red	Stopped
Blinking Red/Yellow	Alarm

Text for equipment monitoring that depicts dynamic status, such as Mode, Status, Position, Speed, Alarm etc., shall be shown in colored text adjacent to the symbol. Colors shall be as follows:

Table 8-4 Equipment Monitoring Text Colors

COLOR	TEXT
Solid Black	Description
Blinking Red/Yellow	Alarm
Solid Blue	All other status and modes

For example, the service mode for equipment is indicated via blue text adjacent to the equipment object symbol.

In addition, text for equipment monitoring that depicts dynamic status shall also be shown in a data link box within the equipment control pop-ups. The data link box shall be outlined in solid white with a dark gray background fill. Colors for characters within the box shall be as follows:

Table 8-5 Gates and Valves Data Link Box Character Colors

COLOR	CHARACTER TYPE
Solid White	All Modes
(Same as symbol color)	All Status
Solid Red	All Alarms

Table 8-6 Pumps and Other Two State Equipment Data Link Box Character Colors

COLOR	CHARACTER TYPE
Solid White	All Modes
Solid White	Unknown Status
Solid Red	Stopped Status
Solid Green	Running Status
Solid Magenta	Lockout Stop Status
Solid Blue	Out of Service Status
Blinking Red/Yellow	All Alarms

Numeric values for analog information that depicts dynamic status, such as level, turbidity, etc., shall be shown in a data link box. The data link box for monitoring values shall be outlined in solid white with a dark gray background fill, and the data link box for setpoint values shall be outlined in solid blue with a white background fill. Colors for characters within the box shall be white for monitoring values and black for setpoint values.

The instrument is out of service if it is in alarm or if it has been taken out of service via supervisory control, such as for maintenance purposes.

For graphics with a light gray overall picture background, the numeric and text boxes for data links have a black background to facilitate reading the data.

Special purpose systems may assign a dedicated color for data links. For example, the Recycled Water System uses magenta for data links corresponding to the industry standard color for the piping.

8.3.4.6 Background Programming

Programs running in the background of the SCADA software provide a critically important role in customizing the control application as implemented in each project they support the operational interface and control functionality in a variety of ways. In support of the operator interface, the background programs dynamically update the properties of objects that are depicted on process graphics and carry out programmed responses to push buttons and other mouse-activated actions, along with the capability to support a wide variety of user-defined objects.

Via a scheduler, predefined algorithms and third-party software applications can be invoked on a periodic basis or triggered via events.

Background programs shall be modular with comments to provide explanatory information. Programs and program scripts can be configured to run globally or be tied to a single graphic. Common variables, lookup tables, etc. shall be used for each type of device represented. For example, visibility properties of text or objects as determined by tag values may utilize a single global lookup table.

8.3.4.7 Fonts

All font styles shall be “Arial” and shall have a minimum size of 11 points. Fonts will be used in title case. An example of title case is “Scum Pump 1 Control Popup.” All standard symbols, object, and dynamos have been designed with specific font standards and shall not be changed. Any new dynamos shall follow previously developed dynamo font sizes and conventions.

8.4 DISCRETE CONTROL

8.4.1 Motor Control

All motorized equipment (motorized equipment where the motor runs continuously while the equipment is in operation) is controlled by two data points, regardless of the actual number of PLC Discrete Output points that are used to interface to the equipment. The data point will be addressed to bit fields in the PLC. Logic in the PLC performs the equipment interface. The supervisory control pop-up windows emulate momentary start and stop pushbuttons as follows:

Table 8-7 Start Pushbutton Commands

COMMAND (MOMENTARY)	VALUE
Start	1
No Action	0

Table 8-8 Stop Pushbutton Commands

COMMAND (MOMENTARY)	VALUE
Stop	1
No Action	0

When the PLC detects that the Start Bit is set, it initiates the control action (subject to satisfaction of permissives) and resets the Start Bit. And similarly, when the PLC detects that the Stop Bit is set it initiates the control action and resets the Stop Bit. Supervisory command bits are not retained in the PLC beyond the first pass through the logic.

After a preprogrammed short duration, the HMI software will set the command bit to zero, regardless of the result of the command.

8.4.2 Discrete Two-Position Valve Control

All two-position valves will be controlled via two or more HMI data points, regardless of the actual number of PLC Discrete Output points that are used to interface to the equipment. The supervisory control pop-up windows emulate momentary open and close pushbuttons as follows:

Table 8-9 Open Pushbutton Commands

COMMAND (MOMENTARY)	VALUE
Open	1
No Action	0

Table 8-10 Close Pushbutton Commands

COMMAND (MOMENTARY)	VALUE
Close	1
No Action	0

For some valves there may need to be additional points used to STOP, JOG OPEN and JOG CLOSE the valve.

Like the motor control above, when the PLC detects the bit set, it will initiate the control action and reset the bit at the end of the program scan.

After a preprogrammed short duration, the HMI software will set the command bit to zero, regardless of the result of the command.

8.5 ALARMING GUIDELINES

8.5.1 Introduction

Alarming is an essential component of the SCADA System. It performs a vital service in providing operators with real-time updates on alarm conditions on the SCADA graphics and, for critical alarms, through strobe flashers located throughout the treatment plant. Alarms are also logged so that post-event analysis can be done.

8.5.2 Alarm Monitoring Guidelines

The following are general guidelines for selection of alarms to be monitored by the control system:

- The PLCs will generate alarm signals for all process equipment and process variables, extreme signal levels (value out of range), excessive rates of change, controlled device failure to respond, and system diagnostic signals. The alarm levels for analog input variables in the PLC shall be settable from SCADA and shall not be set in the PLC analog input module.
- All emergency or alarm conditions shall be reported to SCADA for operator acknowledgement and response.
- The first level of alarms is designated as “Critical” alarms. For the sake of definition, the most critical alarms are conditions requiring immediate action such as effluent quality, safety conditions, hazardous chemical leaks, fire, torque and temperature overloading of motor driven equipment, and critical levels. Critical alarms will always generate the specific alarm annunciation at SCADA. Additionally, “Critical” alarms will result in the initiation of the alarm flashing indicators of the plant wide Critical Alarm Alert (CAA) alarm. Also, in situations where corrective action can be implemented by a PLC, there will be an automatic local response such as stopping a pump on a low suction level condition.
- The second level of alarms is designated as “General” alarms. These are conditions of potential problems unless corrective action is asserted on an "as soon as possible" basis. Such an alarm would be an impending excessive pressure or temperature overload condition of an operating device. “General” alarms are also specifically annunciated by SCADA but can be distinguished from “Critical” by alarm name, listing, color, and audible alarm tone. However, the implication is for corrective action to be taken to alleviate a potentially serious problem before equipment is damaged or a permit violation occurs.
- The third level of alarms is designated as “Events.” These are signals that do not require immediate operator intervention but are logged as events in the alarm history database.
- Alarm categories must be defined for each monitored point.
- Each alarm shall be evaluated for inclusion in a future Alarm Dial-out System.

8.5.3 Alarm Categories

SCADA System alarms are classified into three general categories, which are in turn broken into sub-categories.

- ***Two-State Discrete Alarms –*** Many alarms are determined by the on/off, de-energized/energized, etc. condition of a two-state device. In most cases the alarm condition corresponds to the energized state such as when relay contacts close in response to an alarm such as an adjustable frequency drive fault. However, in some cases the alarm condition occurs when a circuit is de-energized such as when a power supply fails.
- ***Analog Alarms –*** An analog alarm occurs when a continuously varying signal reaches an unwanted specified value as determined by a setpoint. Setpoints can be hardcoded in PLC logic or downloaded from the SCADA System for PLC generated alarms. Analog alarms in HMI are most commonly based on values entered into predetermined fields in the tag database. Another type of analog alarm is a Rate-of-Change Alarm, which occurs when an analog value changes at an excessive rate, such as a tank level due to a rupture.
- ***Sequential Logic Alarm –*** A sequential logic alarm occurs when an expected action does not occur within a given time period, such as a step in the backwash sequence that fails to occur.

8.5.4 Alarm Detection

SCADA System alarms are detected by the PLC logic. Simple algorithms implemented in PLC logic detect alarm conditions, which are then often used within the programmed logic. They are also communicated to the SCADA software for display and logging.

8.5.5 Alarm Display and Annunciation

Alarms are displayed and annunciated in several ways as described in this section.

8.5.5.1 SCADA Graphics

Alarms are displayed on SCADA graphics in one or more of the following ways:

- ***Alarm Summary Graphic –*** All alarms are displayed in a tabular listing on a full-page Alarm Summary Display. These include active alarms and conditions that have returned to normal from an alarm state if they have not been unacknowledged by an operator. Alarms are listed in chronological order with the most recent displayed at the top. Blinking text is shown for unacknowledged alarms and solid text is shown for acknowledged alarms. Alarm conditions must return to normal and be acknowledged before they are cleared from the Alarm Summary Display.
- ***Text Links –*** Selected alarms are shown on process graphics displays in blinking red text if unacknowledged and in solid red text after acknowledgment. Examples of the text are "Alarm," "Fail," and "Fault."
- ***Object Links –*** Selected alarms are indicated by dynamic coloring of objects representing equipment on process graphics. For example, a pump symbol will be displayed in blinking red while it is in alarm and not acknowledged and in solid red after acknowledgement.
- ***Alarm History Display –*** Alarms are logged in an alarm history file for each day. Users can query these files via a pop-up calendar and display all the alarms for the day that is selected. Users with Supervisor or Administrative security rights can export these alarms to a text file.

All alarms are displayed on SCADA graphics, whether they are displayed using the other methods described below.

8.5.5.2 Alarm Area Designations

The SCADA software has a feature to assign each alarm to an Alarm Area, which DWM utilizes as follows. The DWM treatment plant and pump stations have been divided into process areas with an Alarm Area assigned to each one. Each alarm is assigned to one of these Alarm Areas.

Alarm Summary Displays can be built to filter the alarms based on Alarm Areas and other criteria, so that only the alarms of interest are displayed.

Also, a process graphic screen can be assigned, so that when the alarm is selected on the Alarm Summary Display and a software push button is pressed via the mouse, the designated picture is opened.

8.5.5.3 Alarm Priorities and Summary Display Colors

Each SCADA database tag for which alarming is configured includes an Alarm Priority field. This field allows the alarm to be assigned to Low, Medium, High, or Urgent priority. Critical Alarms as described in this section are assigned to the Urgent Priority category.

The Alarm Summary Display colorizes the text of the alarms based on the Alarm Priority and the current alarm status of each point. The following table lists the DWM color scheme.

Table 8-11 Alarm Color Scheme

PRIORITY	COLOR
Urgent	Red
High	Orange
Medium	Yellow
Low	Green

8.5.5.4 Critical Alarm Alert System

The highest priority alarms are classified as Critical Alarms. It is essential that operators be made aware of the occurrence of these alarms, but it cannot be assumed that operators are always viewing SCADA computers. Therefore, an annunciation system has been implemented that energizes strobe light flashers strategically located throughout the plant when a Critical Alarm is detected. This is called the Critical Alarm Alert (CAA) System.

8.5.5.5 Panel Indicating Lamps

Indicating lamps are provided on several of the control panels to indicate a variety of alarms. In most cases the circuits are hardwired to devices independent of the process area PLCs. However, in some cases, a PLC may output a signal to energize an indicating lamp in response to an alarm detected in the PLC logic.

8.5.5.6 Dial-Out alarms (Future)

Referred to as an auto dialer, DWM plans to implement a system that will contact designated personnel when high priority alarms occur. The system will consist of a third-party software application running on and integrated with the SCADA software, which will dial out through the public telephone system when specified alarms occur. Audible messages inform the contacted person the details of each alarm.

8.5.6 Alarm Logs

Alarms are logged by the SCADA System in daily alarm log files in text format. These files are easily retrieved for viewing and analysis by users.

Designated alarms are collected and stored in the SCADA Historian. They are treated like any two-state discrete data.

8.6 HISTORIAN

Data historical storage and retrieval will be provided with the FactoryTalk Historian SE software. Real-time data will be retrieved directly from the PLCs at a predetermined time base. Totalizer and runtime values shall be computed in the PLC.

Data to be retrieved from the PLC includes the following:

- Analog values for all process variables such as flow, level, and pressure.
- Totalized values for all process flow variables.
- Runtime values for all pumps, blowers, compressors etc.
- The status of all major process equipment such as pumps, blowers, compressors, valves, etc.
- Position on all computer-controlled valves (open, closed, percent open).

8.6.1 Operator Interface Data Retrieval

To be determined – Need to Discuss with DWM

8.7 REPORTS

At a minimum a daily report shall be created, the information on the daily report will be determined by designers and DWM staff during the design phase of the project. Examples for the information to be included are listed below:

- Influent and Effluent Flows
- Chemical Usage
- Alarm Count
- Out of Service Equipment
- Compliance Data
- Average Analyzer Values
- Max Analyzer Values
- Filter Backwashes
- Average Tank or Wet Well Levels

8.8 SYSTEM HELP FEATURES

"Help" features are provided on system graphics to display information useful to operators that does not appear on the base graphic. These include:

- Tool Tips consisting of text that appears when the cursor passes over the object
- Pop-up windows providing supplemental information to explain the instrumentation and control features in more detail. Typical information includes definitions of terms, brief descriptions of aspects of the process control, and explanations of alarms, setpoints, and calculations.

For each project involving new or modified graphics, the System Integrator shall evaluate each graphic to identify helpful information to provide operators, review suggested help features with DWM, and include pop-up pictures and tool tips in the SCADA System implementation.

8.9 SCADA INTERFACE WITH PLC – DRIVERS

RSLinx Enterprise driver will be used for communication to all control equipment.

8.10 CONTROL PANEL NUMBERING CONVENTION

All new control panel enclosures and remote I/O enclosures will be labeled according to the following convention.

Process Area - Panel Type - Sequential Number

Where,

<u>*Process Area*</u> *is the process area abbreviation associate with the control equipment*

<u>*Panel Type*</u> *is PLC or RIO*

<u>*Sequential Number*</u> *is an optional number used to distinguish between multiple panel types.*

The following are some example control panel numbers.

- RAS/WAS-PLC for Activated Sludge PLC Control Panel
- RAS/WAS-RIO1 for Activated Sludge Remote I/O 1 Control Panel

9.0 Project Documentation

Project documentation can be categorized into many types and they are generated from several sources. The table below provides a listing of each document type and the entity that generate it.

Table 9-1 Project Documentation Types

DOCUMENT TYPE	DESCRIPTION	PROVIDED BY
Process Flow Schematics	Process Flow Schematics are diagrams used to provide an understanding of an overall process. They may show the entire plant or individual process areas within the plant. They depict major process systems, equipment, and lines showing the direction of flow.	Lead Process, Civil, and/or Mechanical Engineer
P&ID	Process and Instrumentation Diagrams (P&ID) are used to show the general arrangement of equipment relative to the process. Instrumentation and control devices are shown wired to Programmable Logic Controllers and other monitoring and control devices.	Lead Instrumentation & Control Engineer
Control Strategy	Control Strategies define how a process unit is monitored and controlled. They include a high-level description of the process and major equipment, control modes governing the process, control sequences, detailed descriptions of operational interfaces, operating parameters, status and alarms conditions, and all other details to control the process. Typically control strategies will include detailed explanations of automatic controls in various modes of control.	Lead Instrumentation & Control Engineer
Control System Block Diagram	Control System Block Diagrams are used to convey conceptual network architecture and general Supervisory Control and Data Acquisition equipment. Equipment shown typically includes Programmable Logic Controllers, Human Machine Interface Servers/Workstations, network switches, and communication media.	Lead Instrumentation & Control Engineer
Loop Drawings	Loop Drawings are typically used by maintenance personnel for troubleshooting control loops. Typically, a loop drawing shows the detail wiring of related control and monitoring equipment. Details include all terminal blocks, wiring numbers, wire colors, conduits, pull boxes, instrument tag names, descriptions, and other detailed information about the wiring of the equipment.	Initially Provide by the Contractor Updated by Lead Instrumentation & Control Engineer

DOCUMENT TYPE	DESCRIPTION	PROVIDED BY
Control Panel Elementary Diagrams	Elementary diagrams are used by maintenance personnel and engineers to understand how equipment is controlled from a hardwired prospective. Hardwired controls show how the equipment is interfaced to instrumentation and monitoring equipment in PLC panels motor control centers, local control panels and field devices at equipment such as pumps and valves. In addition to the equipment that is controlled, they also show auxiliary devices such as hand switches, relays, and indicating lights. They sometimes include wire numbering, terminal block numbers, instrumentation symbols, and other electrical information related to hardwired monitoring and control. Elementary diagrams are often laid out in the "ladder" format.	Contractor
Interconnection Diagrams	Interconnection diagrams are used to show wiring between Programmable Logic Controllers PLC, control equipment and communications devices. Information typically includes PLC input points, terminal block number, wire labels, tag numbers, cable identifiers, panel designations, and descriptions of the interface points.	Contractor
Control Panel Wiring Diagrams	Control Panel Wiring Diagrams document the details inside of a control panel. This typically includes field terminal block number, wire numbering between field terminals to control devices or PLCs, power distribution in the panel, and physical layout of the equipment in the panel.	Contractor
Control Panel Parts List	Control Panel Parts List (or Bill of Materials) is a complete listing of all make and model number associated with equipment provided in the control panel. This is typically used by maintenance personnel when ordering replacement if the equipment fails.	Contractor
Panel Catalog/Product Manuals	Panel Catalog/Product Manuals are sometimes referred to as cut sheets and are included in operations and maintenance manuals. For simple equipment this could be a one sheet items showing the catalog information and part number for equipment. For more complex equipment this will be a manual associated with the operation and maintenance of the equipment.	Contractor
Instrument Manuals	Instrument Manuals are typically included in the operation and maintenance manual and are used to describe all the features, operations, configuration, and maintenance of a particular instrument.	Contractor
Instrument List	Instrument Lists are design documents typically provided to describe to the contractor the instrument, calibration range, and other features that are to be provided with the instrument.	Lead Instrumentation & Control Engineer

DOCUMENT TYPE	DESCRIPTION	PROVIDED BY
PLC Input/Output List	PLC I/O Lists are design documents to describe the input / outputs to be hardwired to the PLC.	Lead Instrumentation & Control Engineer
PLC Program O&M/Printout	PLC Program O&M / Printout is a print out of all the software logic and configuration of a programmable logic controller.	System Integrator / Programmer
SCADA/HMI/ Historian O&M	The SCADA/HMI/Historian Operation and Maintenance Manual includes hardware such as the top-end SCADA System computers, monitors, and network equipment along with the application software such as the core SCADA System software, the Historian and the reporting package.	System Integrator / Programmer
Network Configuration Documentation	The Network Configuration Documentation is a record of the custom configuration of the DWM SCADA System Network and includes network addresses, security parameters, and the network topology.	Network Programmer
PLC Program Backup File	The PLC Program Backup Files are stored on the maintenance laptop computer, CDROMs and network servers, and are used to restore the program if it is corrupted on a working PLC.	System Integrator / Programmer
SCADA/HMI/ Historian Backup	The SCADA/HMI/Historian Backup Files are stored on the maintenance laptop computer, CDROMs and network servers, and are used to restore the program if it is corrupted on the SCADA servers.	System Integrator / Programmer
Network Configuration Backup	The Network Configuration Backup files are stored on the maintenance laptop computer, CDROMs and network servers, and are used to restore the configuration of a network device such as an Ethernet switch if its configuration is corrupted or a new switch is installed to replace an old unit.	Network Programmer

10.0 Project Implementation

10.1 DESIGN PHASE

10.1.1 Design Deliverables

For projects containing instrumentation and controls components, the following documents are to be developed during the design phase:

- Preliminary Process and Instrumentation Diagrams (P&IDs)
- Final P&IDs
- Control Narratives (preliminary Control Strategies)
- Final Control Strategies
- Control System Block Diagram depicting the control system architecture and including the significant elements of the control system such as PLCs, instrumentation, SCADA computers and peripherals, and networking equipment
- Control Panel Drawings
- Elementary Control Diagrams
- PLC Input/Output List
- Specifications for instrumentation and field control equipment
- Instrumentation List

10.1.2 Standard I/O List Format

A standard I/O list shall be provided for each design. Explanations of the fields shown on the I/O list are provided below. Fields are ordered as they appear from left to right on the I/O list.

- **SCADA Tag** – Database identification for the I/O point
- **Panel ID** – Identification for the I/O cabinet or controller where the I/O signal terminates
- **Type** – Type of I/O signal, including AI (analog input), AO (analog output), DI (discrete input), DO (discrete output), PI (pulse input for totalization only)
- **Description** – Description of the function of the I/O signal
- **Field Device** – Tag number of the instrument or equipment device associated with the I/O point
- **Analog Data, Calibrated Range** – Scaled value in engineering units
- **Analog Data, Power** – This is either 2-wire (loop powered) or 4-wire (120 volts ac powered from the I/O cabinet)
- **Discrete Data, Closed State** – Indicates the state of the signal when the I/O point is energized (e.g., closed, opened, running, etc.)
- **P&ID** – P&ID number that the I/O point is located on

10.1.3 Control Narratives

Control narratives provide definition of the method of control for each process unit and major sequence in the system. The control narratives should describe normal operations as well as any automated emergency situations. Normal day-to-day operations should not require an operator to leave the control room to operate the equipment. The control narratives should account for all Standard Operating Procedures (SOPs); with a determination for each SOP as to if it should be automated. The Control Narratives need to support single shift operation of the facility. The determination of which SOPs are to be automated should be done in conjunction with operations. Thus, an SOP should be automated if:

- it is done on a regular basis;
- the timing of when it is done cannot be coordinated for manned shifts;
- it is required in an emergency in which it could not be accomplished otherwise if an operator is not on-site;
- or where significant effort can be saved by automating it.

The Control Narratives should include a summary table of all SOPs for the process, the frequency that they are used (each shift, daily, annually, etc.), and the level of automation to be done (local control only, Remote Manual, Fully Automated). Control Narratives should be organized by SOP such as filling an Aeration Basin or Draining an Aeration Basin.

Each Control Narrative for a process area should include the following components:

- A description of the Control Narrative and the equipment used in the procedure. This should include description of the primary objectives for the procedure, such as maintain a tank level, or provide setpoint chemical injection control.
- List of associated P&IDs.
- Description of Service Modes, as defined in the SCADA Standards. This should include an Equipment Operational Status table for complex equipment. For example, a filter might be "In-Service" when certain valves are opened and closed, and a tank is at a specific level.
- A description of control of the procedure in Remote Auto, Remote Manual, and Local Manual modes.
- A description of permissives (i.e. conditions that must be met) for the procedure to be initiated in the Remote Auto or Remote Manual control modes.
- A description of hardwired and PLC controlled software Interlocks for the Remote Auto or Remote Manual control modes.
- Identification of control set points for the control modes and conditions that will trigger adjustments under Remote Auto.
- A detailed description of the control sequences under Remote Auto and Remote Manual.
- A list of conditions that will generate an alarm specific to the control strategy.

10.1.4 Control Strategies

Control strategies provide detailed definition of the method of control for each loop and process control function in the system. Together with the P&ID drawings, the control strategies shall be used as the basis of programming for the PLC and HMI system. The control strategy will describe the equipment being controlled, modes of operation of the equipment, I/O in the PLC and automatic control of the equipment. All PLC calculations required, and any HMI requirements for control shall be fully described in the strategy.

10.2 CONSTRUCTION PHASE

10.2.1 Contractor/System Integrator Inter-relation

This section describes the general inter-relationships between the Construction Contractor and the System Integrator. Specific requirements that need to be specified are also included. The following figure shows the general coordination points on a typical project. Only the tasks are shown that have direct dependencies. This approach may be modified to fit the specific project. Shaded items on the timelines represent the primary responsible party for the task.

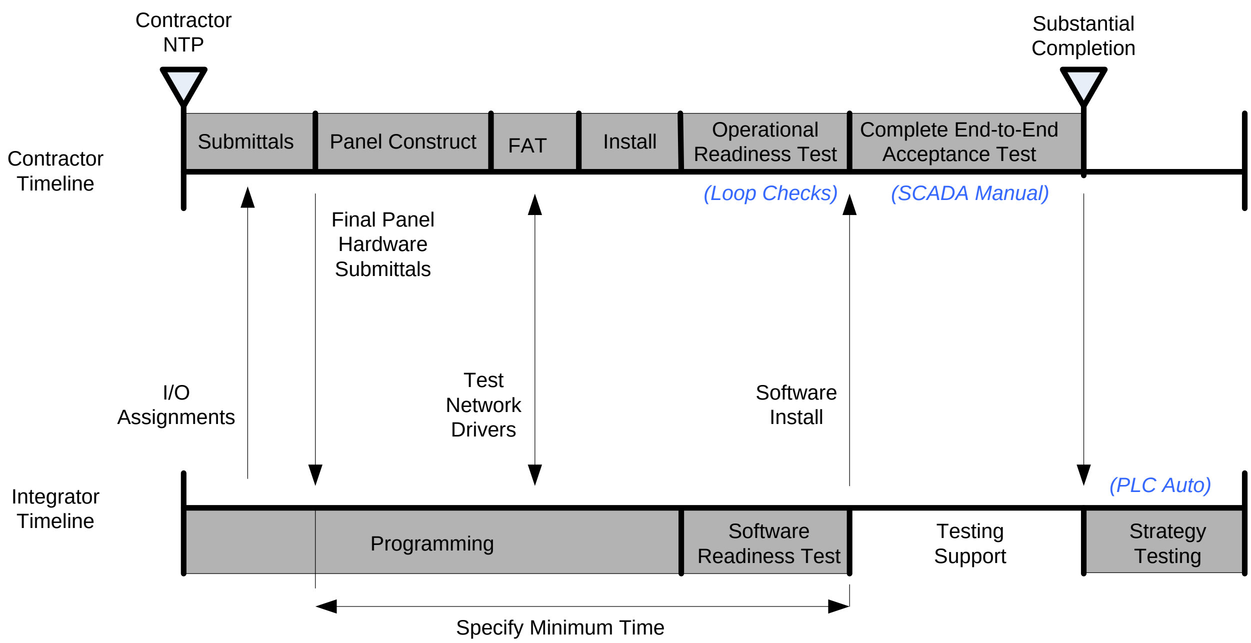


Figure 10-1 Contractor/Programmer Coordination Diagram

10.2.2 Panel Hardware Submittals

Final Panel Hardware Submittals must be received to be able to program the system. If there are any serial interfaces to instruments or other PLCs, details of these must also be provided to complete the programming. This may include make/model as well as detailed memory maps.

The System Integrator needs to coordinate the minimum time required to program the system after receiving this information. This is to be coordinated with the Contractor. This minimum time required must be specified so that the Contractor provides the necessary time.

One piece of any serial or networked instruments should be shipped to the System Integrator for software interface testing. For larger devices, time at the Factory Acceptance Test (FAT) for the System Integrator to perform testing should be included.

10.2.3 Panel Factory Acceptance Testing

Panel FAT shall include verification of final I/O as defined in the final hardware submittals. Any deviations need to be dealt with prior to shipment of panel to the field. Testing for all control panels shall be performed and/or witnessed by the System Integrator.

10.2.4 Operational Readiness Test (ORT)

The Contractor will verify correct termination of wire and cabling, and proper operation of instruments, such as calibration ranges. This testing includes loop testing from the field device to the PLC register.

10.2.5 Complete End-to-End Testing

The Complete End-to-End Testing tests each entire loop from the final field instruments to the PLC including custom HMI screens developed by the System Integrator for the purpose of loop testing. Remote Manual operation will be verified, but not Remote Auto Operation. The Contractor leads this test with some support from the System Integrator.

10.2.6 Contractor Substantial Completion

The Contractor substantial completion would typically occur prior to Control Strategy Testing. This should be evaluated on a project-by-project basis.

10.2.7 Control Strategy Testing

The System Integrator will perform the Control Strategy Testing. This will test all Remote Auto functionality.

The Contractor is not required for this testing but will need to be on-call to fix any issues that may occur with the equipment provide and/or installed by the Contractor. Significant operations support will be required.