APPENDIX F – AUTOMATION ENGINEERING REQUIREMENTS

1 PLC PROGRAMS

1.1 PLC PROGRAM LANGUAGE

1.1.1 The Schneider Electric Modicon PLCs support all five languages defined by IEC 61131-3. However, the specific language used for an application must be selected as per Table F1. Note that more than one programming language may be used within a single PLC program.

Table F1: Permitted PLC Programming Languages

Language	Permitted	Notes
Function Block Diagram	Yes	Preferred for most general applications
Ladder Diagram (Ladder Logic)	Yes	Permitted for specific logic applications with minimal analog control
Instruction List	Not Generally	May be considered for a very specific subroutine requiring high performance
Structured Text	Yes	Appropriate for certain math and logic applications
Sequential Function Chart	Not Generally	May be considered for complex sequencing applications when difficult to implement in a different language.

1.2 PLC CONFIGURATIONS AND PROGRAM LOGIC

1.2.1 All PLC configurations and program logic shall be fully accessible and editable by the City of Winnipeg. PLC systems that are password protected, and as a result made inaccessible for modification by the City for any reason, will not be accepted under any circumstance. This applies to PLC systems used in any application, including process and HVAC applications.

1.2.2 A standard library of function block classes are available and it is expected that new PLC programs be implemented with these function block classes. Where an existing function block class does not provide the required functionality, develop a new function block class and add it to the library for re-use.

1.2.3 Programs are to be implemented using an object-oriented approach, utilizing user-defined data types and encapsulation where possible.

1.2.4 Programs are to be implemented using positive logic, meaning that discrete variables are to be named based on the function they perform in the 1 State (True State).

1.2.5 Use state machine logic for state-based and sequencing applications.

1.2.6 Refer to the City of Winnipeg Tag-name Identification Standard, document code 612620-0014-40ER-0001, for standards regarding naming of tags and function block classes.

1.3 PROGRAM STRUCTURE

1.3.1 Segregate programs into multiple tasks and routines to improve readability and maintenance of the program.

1.3.2 The name (identifier) of all tasks and routines shall contain the identifiers of the equipment they are associated with. Exceptions to this rule include system tasks that cannot be renamed, and routines that are not directly associated with equipment such as input/output mapping routines. When using periodic tasks, the priority number and scan rate of the task shall be included in the name of the task.

1.3.3 The name for each X80 RIO adapter in the configuration shall include the physical rack identifier and the assigned drop number per the rotary switches on the front of the module.

1.3.4 The name for each X80 I/O module in the configuration shall include the rack identifier and slot number in which the module is installed.

1.4 PROGRAM DOCUMENTATION

1.4.1 Provide complete documentation within PLC programs to aid in full understanding of the logic. Note that the level of documentation expected is greater than what an experienced programmer would need, since the programs may be viewed and maintained by personnel who may not have substantial programming experience, or may not be fully familiar with “class based” function block programming.

1.4.2 Where documentation is provided for specific logic, avoid creating documentation that simply repeats the logic. Documentation should describe the functionality of the logic. For example, avoid saying “the A bit turns off the B bit after 10 seconds”. Instead, say “the discharge pressure sensor turns off the motor after it indicates low pressure for 10 seconds”.

1.4.3 All routines shall contain a documentation header containing the authoring company name, the date the routine was created, the current revision number of the routine, date of the latest revision, and the document number of the associated Functional Requirements Specification if applicable.

1.5 VARIABLE DATA TYPES

1.5.1 For each variable tag, use a data type that results in the least amount of memory usage while still providing the required number of significant figures.

1.5.2 For all digital (On/Off or True/False) variables, use the EBOOL data types.

1.5.3 For analog integer variables in the range of -32768 to +32767, use the INT data type (16 bits).

1.5.4 For analog integer variables in the range of -2147483648 to +2147483647 and that exceed the range of the INT data type, use the DINT data type (32 bits).

1.5.5 Use of UINT or UDINT is to be avoided to ensure that the data is not misconstrued as being signed data by an ancillary system (e.g. Microsoft Excel).

1.5.6 For non-integer analog data, use the REAL data type. Do not use the INT or DINT data types with an implied decimal for storing non-integer data.

1.6 CONTROL MODES

1.6.1 Process equipment may be controlled from a number of sources including the PLC system, panel instruments, and manual pilot devices. Operator controls shall be provided on the HMI system and/or in the field for selection of the active control source.

1.6.2 The following equipment operating modes have been defined.

1.6.2.1 PLC Only – The equipment is always controlled by the PLC, although may be switched between Manual and Auto modes via the HMI. Manual controls are provided on the HMI.

1.6.2.2 Local/Off/Remote – A Local/Off/Remote switch is provided at the equipment or at the motor controller (e.g. MCC, or VFD). When in Local mode, the equipment is controlled via the local pilot devices. When in Remote mode, the equipment is controlled from the PLC system.

1.6.2.3 Hand/Off/Remote – A Hand/Off/Remote switch is provided at the equipment or at the motor controller. When in Hand mode, the equipment runs continuously. When in Remote mode, the equipment is controlled from the PLC system.

1.6.2.4 Hand/Off/Auto – A Hand/Off/Auto switch is provided, with the Auto mode providing automatic equipment control via a controller other than the PLC system.

1.6.3 Using the "Auto" designation for PLC system control is not recommended as this designation can conflict with the HMI Auto/Manual modes that may be provided on the HMI/PLC system.

1.6.4 Where Local/Off/Remote or Hand/Off/Remote switches are provided, connect one of the "Remote" position contacts to a PLC input and program the PLC such that its outputs associated with the equipment is only enabled when in Remote mode.

1.7 CYBER SECURITY

1.7.1 Security controls and safeguards shall be provided with all new PLC system and network installations to prevent internal and external threats from affecting plant assets through system vulnerabilities.

1.7.2 Security controls and safeguards are divided into the several categories including:

(a) Corrective – Controls that minimize the effect of an attack and the degree of resulting damage;

(b) Detective – Controls that determine if an attack has occurred, or is in the process of occurring, and initiate corrective controls;

(c) Deterrent – Controls that reduce the ease in which an external threat can affect assets; and

(d) Preventative – Controls that prevent external threats from affecting assets.

1.7.3 Controls and safeguards shall be provided to protect against the various types of attacks which include:

(a) Passive – Monitoring, capture, and analysis of communication, and decrypting weakly encrypted data;

(b) Active – Attempts to circumvent or break encryption, modify information, and introduce malicious code;

(c) Close-In – Attaining close proximity to system components to learn about the implementation and modify, gather, or deny access to information;

(d) Spoof – Modification of the source address of packets the attacker is sending so that they appear to be originating from someone or something else;

(e) Buffer Overflow – Sending more data to a system than is expected, causing complete failure or unexpected operation of the system; and

(f) Hijack – Taking over a session between two systems and disconnecting one of the systems from communication.

1.7.4 Network firewalls, gateways, and encryption shall be used at appropriate points within the networks to inspect and control network traffic as a means to mitigate attacks. Firewalls shall use techniques such as packet filtering, stateful inspection, deep-packet inspection, and rate limiting.

1.7.5 Firewalls used in the process control system network shall be purpose-built for process control systems, and shall be able to perform packet inspection on common industrial Ethernet protocols such as Ethernet/IP and Modbus/TCP. For example, the following mechanisms shall be provided for Modbus/TCP enforcement.

1.7.5.1 User-definable lists of allowed Modbus unit IDs, commands, registers, and coils.

1.7.5.2 Protocol "sanity check" blocks any traffic not conforming to the Modbus standard.

1.7.5.3 Automatic blocking and reporting of traffic that does not match the rules.

1.7.6 Firewalls shall also incorporate a logging mechanism to allow for routine inspection of event messages to determine if attacks have been attempted, have occurred, or are in progress. In addition to internal logging, the device shall be capable of logging to an external (syslog) monitoring system.

1.7.7 Encryption shall be used for all wireless communication and any inter-plant communication that uses the Internet. Wireless (Wi-Fi) networks shall not use Wired Equivalent Privacy (WEP) as it is easily breakable even when configured correctly. Wi-Fi networks shall use WPA or WPA2 encryption. At minimum, Virtual Private Networking (VPN) shall be used for inter-plant communication or anywhere the Internet is required for transmission of data associated with the process control system.

1.7.8 All Ethernet network switches shall be managed switches and have all unused ports disabled. Network switches shall be password protected.

1.7.9 All process control system devices that incorporate password protection shall be configured with a password other than the default password. The same password should not be used on multiple devices.

1.7.10 Field devices that incorporate physical DIP switches or jumpers to prevent write access to the device and do not require frequent configuration changes should be set read-only to prevent unauthorized or accidental change.

1.7.11 Demilitarized zones with upstream and downstream firewalls should be used for access to such systems as an Information Server and a read-only HMI terminal server. These systems shall still incorporate authentication mechanisms and credentials to prevent access by unauthorized users. Systems in demilitarized zones shall be configured read-only.

1.7.12 Restrict physical access to process control system equipment, including programmable controllers, network switches, and field devices. This may be achieved via a lock on the enclosure containing the devices, or placing the devices in a locked room.

1.7.13 Disable unused services on computer servers to improve security and performance.

1.7.14 Configure user and group security appropriately; do not grant unnecessary privileges.

1.7.15 Avoid use of personal or commercial grade hardware and software components (e.g. virus scanning and firewall software) that may be incompatible with process control system components. For example, some firewall software may block network packets that are required for redundant HMI server synchronization and may prevent failover of the HMI server. Be aware of such issues, and properly configure and test all components.

1.7.16 Computers associated with the process control system shall not be directly connected to the Administration or Security networks. Similarly, computers on the Administration or Security networks shall not be directly connected to the Process Control System Network. Where connections between networks are required, they shall occur through firewalls.

1.7.17 Components providing system security shall be implemented in a manner that failure of the component acts to disable system functionality rather than disable system security.

1.7.18 Use the following standards and guidelines when implementing system security:

(a) NIST Special Publication 800-82, Guide to Industrial Control Systems (ICS) Security;

(b) ISA/-62443 (formerly ANSI/ISA-99.00.01): Security for Industrial Automation and Control Systems;

(c) North American Electric Reliability Corporation (NERC), Critical Infrastructure Protection (CIP) Cybersecurity Standards;

(d) NIST Special Publication 800-53, Recommended Security Controls for Federal Information Systems;

(e) Department of Homeland Security, Catalog of Control Systems Security: Recommendations for Standards Developers;

(f) AMI-SEC Task Force, AMI System Security Requirements; and

(g) DOD Instruction 8500.2, Information Assurance (IA) Implementation.

1.8 DELIVERABLES

1.8.1 All deliverables are to be sealed by a qualified professional engineer.

2 AUTOMATION ENGINEERING DOCUMENTS

2.1 GENERAL

2.1.1 All drawings and other deliverables related to a design are the responsibility of the design engineer.

2.1.2 All automation deliverables are to be sealed by a qualified professional engineer.

2.1.3 All drawings shall be comprehensive in nature to allow for effective use in construction and maintenance.

2.1.4 The project includes additions, expansions, upgrades, or modifications to an existing site and facilities, up-date existing drawings.

2.1.4.1 Loop drawings, motor schematics, and wiring diagrams must always be updated.

2.1.4.2 PLC system I/O schematic drawings must always be updated.

2.1.4.3 Updates to or superseding existing P&ID drawings is mandatory. Partial P&ID diagrams showing a small portion of the process modifications are not acceptable.

2.1.4.4 Update of existing instrument plan drawings to reflect new work.

2.1.5 Clearly indicate all demolition requirements on the drawings and in the specifications. Where demolition requirements are significant, create dedicated demolition drawings. Generally abandoned equipment, wiring, etc. shall be removed unless specifically requested by the City that the equipment/wiring be retained, or removal is not practicable.

2.1.6 Acceptance testing requirements shall be defined for every project. Acceptance tests shall use industry approved methods. Acceptance testing forms shall be completed for every project and included with the operations and maintenance manuals/Information. The Design Team is responsible for reviewing the completed acceptance test forms to ensure that the installation complies with the specifications.

2.2 DRAWINGS

2.2.1 **General**

2.2.1.1 The automation drawings produced shall be comprehensive to cover the scope of the project, and shall be detailed to an “industrial” level of detail. “Commercial-grade” drawings that have excessive use of “typical” and general lack of detail are not acceptable.

2.2.1.2 The title block format shall be acceptable to the City and utilize a City issued drawing number and include a revision table.

2.2.2 **Loop Drawings**

2.2.2.1 Loop diagrams shall be developed for:

(i) each installed instrument and device during detailed design for the tender ready documents. Typical loop diagrams are not acceptable; and

(ii) typical loop diagrams for each type of instrument and device for preliminary designs.

2.2.2.2 This Work requires the generation of new Instrument Loop Diagrams and does not apply to the revision of existing instrument loop diagrams. This Work also applies to Instrument Loop Diagrams provided by packaged equipment vendors and contractors.

2.2.2.3 Existing facilities do not necessarily comply with these requirements. The expectations regarding application of these requirements to existing facilities must be decided on a case-by-case basis in consultation with the Project Manager, however general guidelines for application are presented as follows:

(i) All new facilities must comply completely.

(ii) All major upgrades to a facility, or a larger facility’s process area, must completely comply. Any existing instruments within the area being upgraded and incorporated in to a new PLC system should be re-identified.

(iii) All minor upgrades should utilize these requirements as far as practical for new instruments, however in some cases compromise with the existing practice may be required.

2.2.2.4 All components of the loop and the loop itself, including connections to multi-point devices, programmable logic controllers, power sources, etc should be identified (all instrument numbers should agree with the P&ID).

2.2.2.5 Divide the drawing into columns such that each column represents a physical location. Title each column with the physical location it represents.

2.2.2.6 The loop diagram should include word descriptions of loop functions. The title should be adequate and include the device identification tag. Descriptions of special functions and features that are not obvious, especially safety and shutdown circuits, should be given.

2.2.2.7 All interconnections with electrical cables, conductor pairs, pneumatic multi tubes, and individual pneumatic and hydraulic tubing should be shown (this includes junction boxes, terminals, bulkheads, ports, and computer input/output, such as I/O connections, grounding systems, grounding connections, and signal levels). All interconnections should be uniquely identified and clearly labeled per the City of Winnipeg Water and Waste Department Identification Standard.

2.2.2.8 The location of devices should be identified using descriptors such as field, field terminals, control cabinet, PLC section, rack and slots.

2.2.2.9 Electrical power, air and hydraulic supplies, including the designated voltage and pressure values, should be shown.

2.2.2.10 Provide all instrument and/or device settings on the loop drawing, such as dip switch settings, dial settings, etc.

2.2.2.11 For analog loops, such as 4-20 mA and 0-20 mA loops, where there are multiple load devices within the loop, indicate the impedance of each device in the loop.

2.2.2.12 Supplemental drawings and records should be referenced to show interrelations with other control loops, such as overrides, interlocks, cascades, and shutdowns.

2.2.2.13 Although loop design often requires input from several different design areas, design responsibility and configuration control of the loop should be centered within a single function.

2.2.2.14 Descriptions should be given for controller action, control valve action, control valve failsafe action (electronic and/or pneumatic failure), and solenoid valve action.

2.2.2.15 Calibration information should be shown in consistent units that match the applicable instrumentation index.

2.2.2.16 Unique identification numbers consistent with other record documents should be shown for equipment such as racks, panels, and junction boxes.

2.2.2.17 Indicate the source of power (and common / neutral connections) for all loops.

2.2.2.18 Provide an appropriate symbol within each special terminal to indicate the type of terminal:

(i) Indicate fused terminals with a small fuse symbol inside the terminal. Provide the fuse rating below the terminal.

(ii) Indicate disconnect terminals with a small disconnect symbol inside the terminal.

(iii) Indicate potential earth terminals with a small ground symbol inside the terminal.

2.2.2.19 Show the instrument identifier within an instrument bubble symbol adjacent to and pointing at the instrument.

2.2.2.20 Show all field instrument and control panel device part numbers on loop drawings.

2.2.2.21 For intrinsically safe wiring, indicate the following:

(iv) The classification of the hazardous location (e.g. Class I, Zone 1, Group IIC),

(v) For intrinsically safe apparatuses (field devices) other than simple devices, the manufacturer, model, and entity parameters of the apparatus,

(vi) Manufacturer/model and/or permissible entity parameters of the associated apparatus (e.g. IS barrier),

(vii) Maximum entity values for the cabling.

2.2.2.22 Size of Drawing: Loop diagrams shall be prepared as ANSI B (11 x 17 inch) drawings. The smallest letter size shall not be less than 2.5 mm (3/32 inches).

2.2.2.23 The loop diagram will generally contain only one loop. Special situations may necessitate a combination of loops on one drawing. The drawing should be arranged to prevent congestion and should provide extra space for future revisions. Complex loops that require more than one sheet may be expanded to as many ANSI B sheets as necessary. Adequate continuation points should be provided for proper understanding of the total loop configuration.

2.2.3 Instrument Segment Drawings

2.2.3.1 The instrument Segment Drawings shall be prepared for PROFIBUS instruments.

2.2.3.2 All new PROFIBUS instruments shall be shown on the instrument segment drawings.

2.2.3.3 Indicate all instrument and networking equipment identifiers.

2.2.3.4 Indicate the cable identifier and cable type for each cable on the drawing.

2.2.3.5 Indicate the estimated length for all cables on the drawing.

2.2.3.6 Indicate allowable minimum and/or maximum cable lengths on the drawing where applicable.

2.2.3.7 Indicate the network speed(s) on the drawing.

2.2.3.8 Indicate the location and type of terminations on the drawing.

2.2.3.9 Indicate the network address number of each device on the drawing.

2.2.3.10 Provide a Segment Schedule on the drawing, showing the number of devices, total length, and maximum spur length for each segment.

2.2.3.11 Size of Drawing: Instrument segment drawings shall be prepared as ANSI B (11 x 17 inch) drawings. The smallest letter size shall not be less than 2.5 mm (3/32 inches).

2.2.4 Instrumentation Location Plan Drawings

2.2.4.1 All new instruments shall be shown on instrument location plan drawings.

2.2.4.2 Provide instrument elevation drawings for instruments that are to be installed at a specific elevation and where sufficient detail cannot be provided in plan view.

2.2.4.3 All instrument identifiers are to appear on the drawings.

2.2.4.4 All process/mechanical equipment, if applicable, shall be shown with a lighter line weight.

2.2.4.5 The instrument plan and elevation drawings are to be scaled typically at 1:50 on a standard A1 size drawing.

2.2.5 Instrument Installation Details

2.2.5.1 The instrument installation details shall be provided for all instruments that require a specific means of installation.

2.2.5.2 Show all installation details including instrument orientation, mounting bracketry, cables, conduits, strain reliefs, pull boxes, and junction boxes as applicable.

2.2.5.3 For magnetic flow meter installations, show grounding ring installation and connection details.

2.2.5.4 All structural and mechanical equipment, if applicable, shall be shown with a lighter line weight.

2.2.5.5 Instrument installation details are typically shown as a detail on a standard A1 size with a recommended drawings scale or 1:10 to a maximum of 1:20.

2.2.6 Control Panel Layouts

2.2.6.1 Provide control panel layout drawings for all control panels that are to be constructed by a contractor.

2.2.6.2 Provide a bill of materials, indicating the quantities, manufacturer name, model name, and a description for each component.

2.2.6.3 Show exterior panel dimensions.

2.2.6.4 Show the exterior (typically the front door only) elevation of the control panel with all components to scale.

2.2.6.5 Show the interior elevation panel layout of all components to scale. The only component not shown on the layout shall be the wires.

2.2.6.6 Where dedicated wireways are required, indicate the type or category of wiring that may be installed in each wireway.

2.2.6.7 For each terminal block, indicate which side is for field wiring side and which side is for internal wiring.

2.2.6.8 Provide construction notes indicating specific construction details.

2.2.6.9 The control panel layout drawings are to be produced on a standard A1 size with a recommended drawings scale or 1:5 to a maximum of 1:10.

2.2.7 Control Panel Power Distribution Schematics

2.2.7.1 The control panel power distribution schematics shall be provided for all control panels.

2.2.7.2 Show the complete schematic for the power distribution, including component identifiers, terminals, terminal numbers, wires, and wire tags.

2.2.7.3 Show where the source of power terminates to the control panel, and include the name and details of the power source (e.g. “120 VAC from PNL-R731, CCT 12”).

2.2.7.4 Provide a fuse schedule on the drawing which lists the identifier, type, and rating of each fuse.

2.2.7.5 Provide a power consumption schedule for each major voltage level used within the control panel that summarizes the current consumption from each device, including PLC inputs and outputs. The total current consumption shall be provided at the bottom of the table.

2.2.7.6 Provide a terminal layout (arrangement) on the drawing for terminal blocks associated with power distribution.

2.2.7.7 The control panel power distribution schematics are to be produced on a standard A1 size drawing.

2.2.8 I/O Module Wiring Diagrams

2.2.8.1 The I/O module wiring diagrams shall be provided for all programmable automation controller I/O modules.

2.2.8.2 Show the I/O modules and their connections to the I/O (field) terminals. The field instruments and associated wiring to the I/O (field) terminals shall not be shown on I/O module wiring diagrams. The field wiring details must be shown on loop drawings or other automation / electrical diagrams.

2.2.8.3 Provide the I/O signal name and drawing reference beside each set of I/O (field) terminals associated with each I/O point.

2.2.8.4 Where fused I/O (field) terminals are used, provide a fuse schedule which lists the identifier, type, and rating of each fuse.

2.2.8.5 The I/O module wiring diagrams shall be produced on a standard A1 size drawing.

2.2.9 Network Diagrams

2.2.9.1 The network diagrams shall be provided for all new network equipment installations.

2.2.9.2 Use an Instrument Segment Drawing for all PROFIBUS instrumentation network drawings. See 2.2.3.

2.2.9.3 Existing network diagrams shall be updated where changes are made to an existing network.

2.2.9.4 Network diagrams shall show all networking equipment, including patch panels, network switches, routers, media converts, wireless devices, and cabling.

2.2.9.5 The port type (RJ45, FC, LC, ST, SC, etc.) shall be identified on the drawing using a specific symbol.

2.2.9.6 All port labels and/or port numbers for networking devices shall be indicated on the drawing in a manner that is consistent with the physical port labelling on the device.

2.2.9.7 All cable identifiers are to be shown on the drawing along with the cable types:

(i) For copper network cables, indicate the number of conductors, conductor size, and type of cable. Example: “4 PR, 24 AWG, CAT 6”.

(ii) For fibre cables, indicate the type of fibre (single-mode, multi-mode, hybrid, etc.) number of strands, core diameter, cladding diameter, and signal compatibility.

2.2.9.8 For long runs of fibre or CAT5e/CAT6 Ethernet cabling, indicate the estimate length of the cabling on the drawing.

2.2.9.9 For Ethernet Networks, indicate the IP addresses of the devices on the drawing. Note IP addresses are not to be made available to the public.

2.2.9.10 For Modbus/TCP, Modbus/RTU (serial), or other networks utilizing “Node” numbers, indicate all device node numbers on the drawing.

2.2.9.11 For outdoor wireless systems, show all antennae and lightning surge arrestors.

2.2.9.12 Provide a symbol legend on the drawing or on a standard legend sheet.

2.2.9.13 The network diagrams shall be produced on a standard A1 size drawing.

2.2.10 **Automation Conduit Riser Diagrams**

2.2.10.1 Where conduit sizing for the provision for future wiring is required, an automation conduit riser diagram shall be provided so that conduits are installed with the required spare capacity, and not sized by the installation contactor to the minimum size required by Code.

2.2.10.2 Show the conduit type and size for each conduit.

2.2.10.3 Show pull boxes, junction boxes, and panels as required.

2.2.10.4 Show area boundaries using boundary lines and show each pull box, junction box, and panel within the appropriate boundaries.

2.2.10.5 Provide a legend on the drawing or a standard legend sheet indicating the acronyms used. Examples:

ARC Aluminum Rigid Conduit

LFMC Liquid-tight Flexible Metallic Conduit

PB Pull Box

PVC Polyvinyl Chloride

2.2.10.6 The automation conduit riser diagrams are to be produced on a standard A1 size drawing.

2.2.11 **Process and Instrumentation Diagrams**

Note: Process and Instrumentation Diagrams are officially categorized under the Process discipline, but rely heavily on input from automation engineers.

2.2.11.1 See Appendix E.

2.3 OTHER DOCUMENTS

2.3.1 **Instrumentation List**

2.3.1.1 An instrumentation list is required for every project where new or city provided instruments are installed.

2.3.1.2 Provide an overall cover page, indicating client name (City of Winnipeg Water and Waste Department), project title, document title and document revision table. The cover page shall be seal by the Design Engineer.

2.3.1.3 The instrument list shall include the following fields:

(i) Record Number

(ii) Revision Information

(iii) Instrumentation Loop Number

(iv) Instrumentation Tag

(v) Description of the instrument type

(vi) Description of the instrument service

(vii) Power Supply

(viii) Calibration Range

(ix) Communication (4-20 mA, HART, PB DP, etc.)

(x) Mounting Method

(xi) Supplied By

(xii) Specification Data Sheet

(xiii) Location Plan Drawing number

(xiv) P&ID Drawing number

(xv) Schematic/Loop Drawing number

(xvi) Notes

(xvii) The instrument list shall be prepared in Microsoft Excel or Microsoft Word, other formats may be accepted by the City with approval.

2.3.2 **Loop Number List**

2.3.2.1 The Loop Numbering List lists all of the loop numbers used at each facility to prevent inadvertent duplication of loop numbers and equipment identifiers.

2.3.2.2 Loop Numbering List is required for all projects where new equipment is installed.

2.3.2.3 The Loop Numbering List shall be divided by process area.

2.3.2.4 The Loop Number List shall include the following fields:

(i) Loop Number

(ii) Loop/Equipment Description

(iii) Reference Drawings (e.g. loop drawings, P&ID drawings)

(iv) Notes

(v) Revisions Information

2.3.3 **I/O List**

2.3.3.1 An I/O list is required for every project where changes to PLC system I/O are made.

2.3.3.2 Where possible, update an existing facility I/O list rather than creating a new I/O list. Alternatively, update the existing facility I/O list upon completion of the project.

2.3.3.3 Provide an overall cover page, indicating client name, project title, document code, and document revisions. The cover page shall be sealed by the Design Engineer.

2.3.3.4 I/O lists shall include the following fields:

(i) I/O Module Address (e.g. rack number and/or slot number);

(ii) Module Point (I/O point number or channel number on module);

(iii) Tag (instrument or signal tag name);

(iv) Description;

(v) For discrete I/O:

(vi) “0 State” Description (description of signal when FALSE)

(vii) “1 State” Description (description of signal when TRUE)

(viii) Indicate which state is used for alarms (if applicable)

(ix) For analog I/O:

(x) Type (4-20mA, 0-5 VDC, 0-10 VDC, etc.)

(xi) EU Range (engineering unit range) including raw min and max if scaling occurs in SCADA rather than in the PLC. Indicate engineering unit of measure

(xii) P&ID drawing (reference to applicable P&ID drawing)

(xiii) Loop/wiring drawing (reference to applicable loop/wiring drawing)

2.3.3.5 The list shall be grouped by I/O signal type:

(i) Discrete Input

(ii) Discrete Output

(iii) Analog Input

(iv) Analog Output

(v) HART Input

(vi) HART Output

2.3.3.6 An I/O list will typically be prepared in Microsoft Excel or Microsoft Word, but other formats may be accepted by the City with approval.

2.3.4 **Interface Maps**

2.3.4.1 Interface maps are required for projects where a new customizable controller is installed and makes data available to other controllers via a communication link. For example, a new standalone PLC is installed for an fuel oil system system, which is monitored by the facility PLC system using Modbus TCP.

2.3.4.2 For non-packaged systems, preparation of interface maps falls under the responsibility of the Systems Integrator. The Design Engineer may provide templates to the Systems Integrator for completion.

2.3.4.3 For packaged systems including equipment and a programmable controller or HMI, preparation of interface maps falls under the responsibility of the vendor.

2.3.4.4 Interface maps shall include an overall cover page, indicating client name, project title, document code, and document revisions.

2.3.4.5 Interface maps shall include the following fields:

(i) PLC Register or PLC Tag name;

(ii) Protocol Address (e.g. Modbus address);

(iii) Description;

(iv) Analog Range – Raw;

(v) Analog Range – Engineering Units;

(vi) Read/Write;

(vii) In the case of packaged control systems alarm limits should also be indicated,

(viii) Digital I/O, should identify, register number and bit number and 1 and 0 states (alarm, etc.); and

(ix) Notes.

2.3.4.6 An interface map will typically be prepared in Microsoft Excel or Microsoft Word, but other formats may be accepted by the City with approval.

2.3.5 Automation Cable Schedule

2.3.5.1 An automation cable schedule is required for every project.

2.3.5.2 Provide an overall cover page, indicating client name, project title, document code, and document revisions. The cover page shall be sealed by the Design Engineer.

2.3.5.3 All control cables shall be uniquely identified on the cable schedule. Cables shall not be entered as typical.

2.3.5.4 Where individual wires are routed in conduit, the wires shall be identified as an item in the cable schedule. This is not applicable to power wiring for minor circuits, such as lighting, receptacles, etc.

2.3.5.5 Cable schedules shall include the following fields:

(i) Cable Identifier,

(ii) Cable Type,

(iii) From (Source),

(iv) To (Destination),

(v) Spacing (typically not applicable to automation cabling),

(vi) Length (estimate),

(vii) Routing (brief description),

(viii) Notes, and

(ix) Revision of last change.

2.3.5.6 The length for each cable shall be estimated at design time to within ~10% accuracy for purposes of pre-bid cost estimating.

2.3.5.7 A cable schedule will typically be prepared in Microsoft Excel or Microsoft Word, but other formats may be accepted by the City with approval.

2.3.6 Lamacoid Schedule

2.3.6.1 A lamacoid schedule is a requirement for every project. Note that the creation of a lamacoid schedule at design time greatly assists the contractor, helps provide a higher quality of identification lamacoids for maintenance personnel, and can be created for a minimum effort above that required to thoroughly review a contractor-produced lamacoid schedule.

2.3.6.2 Provide an overall cover page, indicating client name, project title, document code, and document revisions.

2.3.6.3 All automation lamacoids shall be uniquely identified on the lamacoid schedule, except lamacoids for cables may reference the cable schedule.

2.3.6.4 Lamacoid schedules shall at minimum include the following fields:

(i) Item

(ii) Line 1 (text to appear on row 1)

(iii) Line 2 (text to appear on row 2)

(iv) Line 3 (text to appear on row 3)

(v) Text size

(vi) Notes

(vii) Revision of last change.

2.3.6.5 A lamacoid schedule will typically be prepared in Microsoft Excel, but other formats may be accepted by the City with approval.

2.3.7 Process Control Narrative

2.3.7.1 Provide a Process Control Narrative for all projects where new process equipment is installed. While this document is primarily written by process engineers, the automation engineers should review and provide input.

2.3.7.2 Provide an overall cover page, indicating client name, project title, document code, and document revisions.

2.3.7.3 Provide a listing of reference drawings (typically P&IDs).

2.3.7.4 Provide equipment and instrument listing, complete with identifiers (tag numbers) and descriptions.

2.3.7.5 Provide a detailed textual description of all the control modes of the process.

2.3.7.6 Indicate general arrangement details, such as equipment physical locale and configuration where required to clarify the process control.

2.3.7.7 For each operating mode describe the normal operation of each piece of equipment.

2.3.7.8 Describe the operation of equipment under abnormal circumstances (e.g. instrument failure, mechanical failure, etc.), where possible.

2.3.7.9 Indicate special requirements of the automation system to accommodate maintenance activities, as required.

2.3.7.10 Indicate operating setpoints for each operating mode.

2.3.7.11 Indicate process interlocks and major equipment protection interlocks. Standard interlocks (i.e. motor overload) can be detailed in the Functional Requirements Specification (2.3.8).

2.3.7.12 Indicate required major alarms. The complete set of alarms will be in the Functional Requirements Specification.

2.3.7.13 A process control narrative will typically be prepared in Microsoft Word, but other formats may be accepted by the City with approval.

2.3.8 Functional Requirements Specifications

2.3.8.1 Provide a Functional Requirements Specification (FRS) for all projects where programming of a PLC or similar system is required.

2.3.8.2 Specific functional requirements for each piece of equipment in the design that is controlled by the programmable controller.

2.3.8.3 Provide textual descriptions, cause-effect matrices, or high-level function block logic diagrams of the required equipment functionality as required.

(i) Use pseudo-code and function block logic diagrams only when necessary, i.e. when it is not possible to convey functionality using alternate means.

(ii) Textual descriptions should be used to provide a general understanding where required, but should not be used alone to describe detailed logic.

2.3.8.4 Functional requirements specifications are typically prepared in Microsoft Word, and may reference external documents such as cause-effect matrices that were generated using Microsoft Excel.

2.3.8.5 Functional Requirements Specifications are split into multiple documents as follows:

(i) A Standard Function Block Class FRS – contains the standard set of function block classes that are used within the process control system associated with the City's Water Treatment Program. Standard function block classes provide high-level functionality for equipment monitoring and control and can be saved into a repository for re-use.

(ii) One or more Process Area FRSs – specific functional requirements specifications for the equipment controlled by the PLC system. The specific FRSs are broken down by process area so that they are manageable in size. If the work associated with the project is all within one process area then only one Process Area FRS would be provided. If the work spans multiple process areas then one FRS would be provided for each process area.

2.4 CONSTRUCTION AND COMMISSIONING DOCUMENTS

2.4.1 GENERAL

2.4.1.1 Provide a header section at the top with the following fields, to be filled in by the contractor for Facility, Project Name, Plant Area, Tender number, and Document number

2.4.1.2 Provide a sign-off section at the bottom. Test forms and checklists are to be signed and dated by the tester and a witness, where the witness is a person designated by the Contract Administrator.

2.4.1.3 Forms and checklists will typically be prepared in Microsoft Word, but other formats may be accepted by the City with approval.

2.4.1.4 Test forms and checklists shall be prepared by the Design Engineer and filled in by the installation contractor.

2.4.2 INSTRUMENT TEST FORMS

2.4.2.1 Instrument test forms shall be provided with projects where new instruments will be installed.

2.4.2.2 Provide sections for filling in the following:

(i) Sensor / element and transmitter details indicating at minimum the units, design range, and configured range;

(ii) Inspection of instrument and installation;

(iii) For discrete instruments the setpoint trip point, the actual trip point, the setpoint time delay, the actual time delay, and the verification of the signal for each discrete state;

(iv) For analog instruments, verification of the signal under various process or test conditions; and

(v) For PROFIBUS instruments, the communication is functioning without error, the transmitter alarms are configured (as required), and the transmitter configuration is complete and saved.

2.4.3 I/O MODULE TEST FORMS

2.4.3.1 I/O module test forms shall be provided for new PLC installations for verification that each I/O point and associated HMI object(s) are configured correctly.

2.4.3.2 Provide a section for filling in the associated PLC identifier, PLC description, rack number, slot number, and module type.

2.4.3.3 Provide separate forms for each type of module (discrete input, discrete output, analog input, analog output, thermocouple input, RTD input, etc.).

2.4.3.4 Provide columns within the forms for the I/O point number, I/O point tag name, I/O point description, 0 State (False state) description, 1 State (True state) description, and checkboxes for indicating that each state has been verified:

(i) at the PLC Input/output module,

(ii) on the HMI graphic display, and

(iii) on the HMI alarm system.

2.4.4 PLC SYSTEM COMMISSIONING CHECKLIST

2.4.4.1 PLC system commissioning checklists shall be provided for new PLC installations for verification that each PLC system is installed and operating correctly.

2.4.4.2 Provide a section for filling in the PLC identifier, PLC description, processor and network adapter module numbers, and rack number.

2.4.4.3 Provide a section indicating that the following has been inspected:

(i) PLC cabinet is completely clean and there are no loose papers inside;

(ii) Ventilation openings are not covered;

(iii) Drawings are marked up as-built;

(iv) Communications between PLC and HMI system is acceptable;

(v) Communications between PLC and remote racks is acceptable, as applicable;

(vi) For redundant PLC applications, failover functionality from primary rack to secondary (standby) rack, then back to primary, is operational; and

(vii) Memory card(s) are installed and program has been transferred to the memory card(s), as applicable.

2.4.4.4 Provide a section for filling in the following run-time information:

(i) Percentage processor (CPU) utilization;

(ii) Percentage memory utilization; and

(iii) Program scan time.

2.4.5 ACTUATOR (VALVE OR DAMPER) COMMISSIONING CHECKLIST

2.4.5.1 Actuator commissioning checklists shall be provided for all new actuator installations for verification that the actuator is correctly installed and configured.

2.4.5.2 Provide a section for filling in the valve actuator details:

(i) Identifier (tag);

(ii) Description;

(iii) Manufacturer;

(iv) Model;

(v) Serial Number;

(vi) Design Range; and

(vii) PROFIBUS network address

2.4.5.3 Provide a section indicating that the following has been inspected:

(i) Actuator type and materials matches the P&ID and actuator data sheet;

(ii) Installation of actuator is correct;

(iii) Equipment tag is correct;

(iv) Configuration matches valve actuator settings sheet;

(v) Open/close/position command from process control system is functioning;

(vi) Status monitoring by process control system is functioning;

(vii) Drawings are marked up as-built; and

(viii) HMI graphic symbol, tag, and units are correct.

2.5 DESIGN CALCULATIONS AND STUDIES

2.5.1 GENERAL

2.5.1.1 All design decisions leading to important design activities, must be supported by an appropriate calculation, which may be required for verification and justification. The Design Engineer shall prepare design calculations as required. It shall be the responsibility of the Design Team to collect, verify, and file all such calculations.

2.5.1.2 The software tools or vendor PLC packages used for the required calculations must be approved by the Lead Engineer for each specific project.

2.5.1.3 Calculations done by subcontractors, contractors or vendors will be permitted if the calculation requires specialized knowledge or experience that a typical automation design engineer would not possess. In these cases, it is the responsibility of the design engineer to ensure that the calculations follow all City standards and guidelines.

2.5.1.4 The calculations and studies shall only be deferred to the contractor after review and agreement with the City.

2.5.1.5 The following are potential calculations that may be required by the design engineer depending on the size and complexity of the design:

(i) New control panels, power supply panels, networking panels:

- Wireway sizing / fill calculations, where there are a significant number of wires in the wireways and the percent fill is non-trivial,
- Heat load calculations, and
- Power supply loading calculations.

(ii) Wireway sizing/fill calculations for new junction boxes where there are a significant number of wires in the wireways and the percent fill is non-trivial.

(iii) Intrinsically safe installations:

- Indication of manufacturer, model number, and entity parameters of the intrinsically safe apparatus as they apply to the specific set(s) of terminals to be connected.
- Indication of manufacturer, model number, and entity parameters of the associated apparatus as they apply to the specific set(s) of terminals to be connected.
- Calculation of maximum allowable interconnecting cable entity parameters.

(iv) Size (volume) and loading (weight) calculations for the installation of cable trays including cable tray sizing (volume) and loading (weight) calculations.

(v) Fill calculations for conduit installations.

(vi) Safety Integrity Calculations.

(vii) Profibus installations:

- Bus voltage drop calculations.
- Bus current (loading) calculations.
- Max bus cable length (trunk and spur) calculations based on network speed and topology.

2.5.1.6 All design calculations relating to process control system performance and utilization should be included in the Operation and Maintenance Manuals for the associated areas.