Specification

Digital Technology & Information I-SPE-STD-005 Process Control Standard

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(Refer Controlled Document in REX for Author, SME, Owner and Approver details)

Contents

1. Purpose

This document is part of a suite of Seqwater Engineering Standards which are in alignment with the Seqwater Quality Management System. Their purpose is to provide a consistent approach to the development, modification, and management of Seqwater infrastructure that is fit for purpose, economic over the life of the asset, and meets Seqwater's risk appetite and compliance requirements including Work Health and Safety obligations.

The purpose of this Specification is to provide the minimum requirements and recommendations for Control System Design: Process Control Functionality.

This document must be used in conjunction with the documents it references to assist in ensuring fit for purpose infrastructure. This Standard Specification is not intended to be relied on solely for design, supply, and installation works; advice from specialist engineers and/or manufacturers may be required on a case-by-case basis.

2. Scope

This Specification applies to all Seqwater employees, contractors, suppliers and consultants working for or on behalf of Seqwater unless otherwise stated. It applies to all new assets and to all existing assets undergoing refurbishment or modification. It must be used in conjunction with other relevant Seqwater Engineering Standards and project specific documents to define the technical requirements for infrastructure design and construction.

Where single or discrete components of an existing non-compliant system are to be replaced, refurbished or modified, this standard should not automatically be applied to the entire system retrospectively, however consideration should be given, in consultation with relevant stakeholders, to the extent of the application of the standard outside of the components requiring replacement, refurbishment or modification, to ensure safe, economic, and fit for purpose infrastructure.

Seqwater Engineering Standards include Standard Specifications, Drawings, Procedures, Templates, Forms and Preferred Equipment Lists. Together they detail Seqwater's minimum requirements and recommendations to provide infrastructure that will be fit for purpose, safe, and cost effective to operate and maintain. However, compliance with these requirements and recommendations does not remove, and cannot be relied on as meeting, the designer's overarching responsibility for ensuring infrastructure designed is fit for purpose and safe to construct, operate, maintain, and demolish. The designer must exercise appropriate due diligence to identify and manage hazards so far as is reasonably practicable.

Designers must also ensure compliance with relevant Australian Legislation, Standards, Codes and Guidelines (including those produced by Water Services Association of Australia). Where no Australian Standard exists for a particular application, work must conform to the most current version of an industry accepted international standard. Seqwater Engineering Standards use the International System of Units (SI), unless noted otherwise.

Deviation from meeting the minimum requirements in this Standard Specification requires written agreement from Seqwater as per the deviation process detailed in Procedure X-PRO-STD-008 Asset Standards Management and Application. That process includes completion of an X-TMP-STD-022 Asset Standards Deviation Request Form together with relevant supporting documentation, and submission by the Seqwater Project Representative to the

Seqwater Engineering Mailbox. Where noted in this Standard Specification that Seqwater approval, agreement, or acceptance shall/must be sought, such approval, agreement or acceptance must be gained through the Seqwater Asset Standard Deviation process, as outlined above.

Responsibility for ensuring compliance with Seqwater Engineering Standards lies with those engaged in the management and execution of design, construction, and modification of Seqwater infrastructure. This includes modifications to the functional design of the infrastructure including technical changes made which would extend an asset outside of its design operating envelope and/or approved operation and maintenance practices.

Any ambiguities or conflicts identified between specific requirements within this Standard and project documents, another Seqwater Engineering Standard or Australian Legislation, Standards, Codes or Guidelines, must be brought to the attention of the Seqwater Document Owner as listed in the document footer, via the Engineering Mailbox, for clarification. Where it is proposed to proceed without meeting the requirements of this standard, agreement must be obtained via the Deviation Process, as outlined above.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this Engineering Standard, the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability of standards to be applied to the works. These can be accessed on the Waternet Seqwater Engineering Standards & Framework page or from your Seqwater project manager, design manager, or engaging officer.

The standard control philosophy aims to prescribe the foundational behaviour and systems implemented in our control systems. These build upon the standard instrumentation and actuation standards at Seqwater and form a foundation for future automation and optimisation of Seqwater assets through operating safely and achieving the required setpoints.

Seqwater uses a set of states, modes, functions and systems to present and process signals within the control system. This standard aims to support operations by ensuring the standard interpretations are transparent, purposeful and discriminatory. In addition, it covers safety, automation and alarm standardisations present at Seqwater including high priority alarms and interlocks.

High priority alarms and interlocks are those that have been identified through risk assessment processes as critical to meeting Seqwater's obligations. These will typically protect against loss or damage to one or more of the following categories:

- Environment
- Product quality
- Safety
- Social license to operate

This standard specification outlines the key management requirements of such alarms and interlocks.

3. Control Philosophy

This standard uses the following Process Control Hierarchy model[1] to conceptualise and implement a standardised control philosophy. Each subsequent layer or level offers further functionality and integration with overall business processes however depend on the stable function of preceding layers.

- Instrumentation and Actuation: This layer represents physical devices and encapsulates measurement of, and direct interaction with, the process. This layer contains all hardware interlocks and features that physically exist in the field. This layer is described by equipment and instrument engineering standards at Seqwater.
- Regulatory Control: The most fundamental level of control, this layer communicates and processes all information from the instrumentation and actuation. From communicating hardwire interlocks tripped in the field, on-off controllers through to PID, with feed forward, sequence control and signal processing. Control at this level often occurs within seconds and is the domain of this standard.
- Constraint Control: At this level of control plant process variables are identified that improve the processing plants main KPI. The Process Control is designed to minimise or maximise these identified variables within the constraints of plant operation. This standard aims to support however does not consider the execution of constraint control.
- Optimisation: This level of control connects business and process. Typically, the KPI's of the plant are optimized by the control system through equation or model.

3.1. Process Envelope

Maintaining plant operation within the process design envelope is the primary function for the regulatory layer.

The schematic below (Figure 1) shows a representation of a simple two variable process envelope. A supplementary schematic from I-SPE-STD-006 Monitoring and Control System Alarm and Event Management is also shown below (Figure 2) for explanation of alarming in addition to interlocking and process permissives. The schematic in Figure 1 represents:

- **Operating Envelope:** In this operation the process would function within bounds that can be considered normal operation (In Figure 1, the operating envelope represents the 'Normal' layer). The designer of the process would have provided for all operating windows representing different known conditions that the process would be required to function (shown in Figure 2). Regulatory Control function is to retain the process within this operating envelope, even with the advents of upsets and feed disturbances. However deliberate optimisation and improved performance with movement throughout the operating envelope is the domain of constraint control and optimization.
- **Design Envelope:** The design envelope contains the operating envelope and a margin. In Figure 2 the two-layer labelled as "upset" with the outer hashed ring corresponds to the Design Envelope. Interlocks that shutdown equipment or processes into a safe state a present within the margin of the design envelope. These interlocks and any shutdown sequences are a part of the regulatory control. Interlocks in this layer can be termed the last automated line of defence to prevent an undesirable or unsafe state.

[1] Adapted from King, M., 2010, Process Control: A Practical Approach, John Wiley & Sons.

- **Beyond Design Envelope:** The process should never deviate to beyond the design envelope as this would be an undesirable or unsafe state. If plant controls fail, then the last line of defence is mitigation, before the plant emergency response is activated. Mitigations are designed to reduce the severity of an incident of the process deviating beyond the design envelope. An example of such a mitigation could be bunding to contain chemical spills.

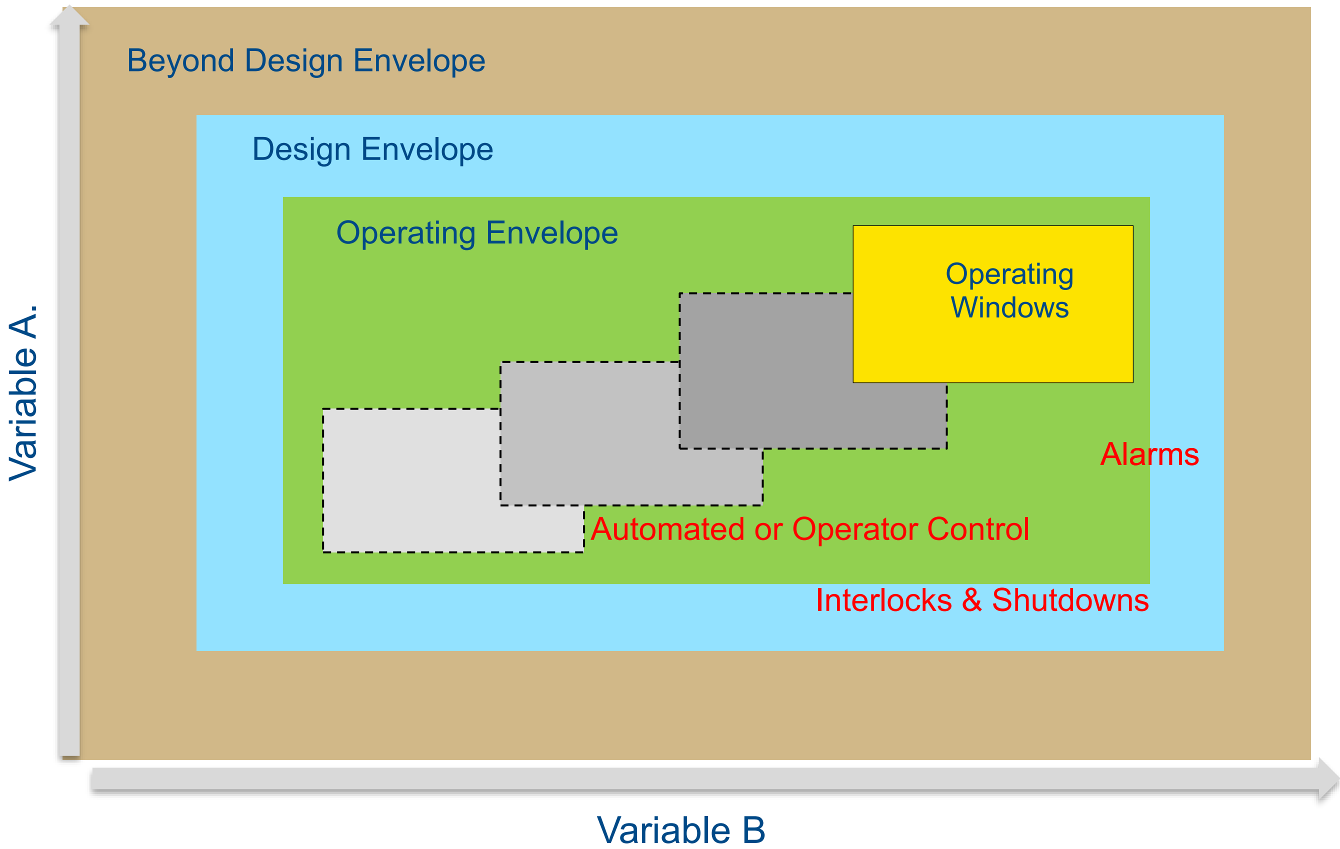


Figure 1 - Process Envelope Schematic, Interlocks and shutdown to prevent unsafe operation, alarms to alert operators and automated or operator control operating windows.

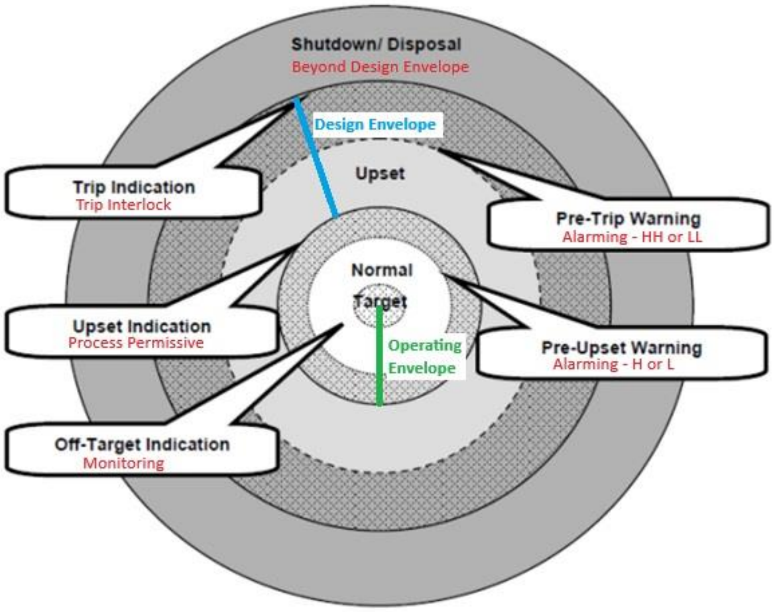


Figure 2 - Contextual representation of alarming and interlocking from I-SPE-STD-006 Monitoring and Control System Alarm and Event Management, with operating and design envelope noted

3.2. General Control and Automation Narrative

Plant automation maintains the operation of the plant within its operating envelope. It ensuring that operations can monitor the process and identify any emergent abnormal situations.

The control system design and philosophy must support the operator in the designed control modes. High levels of automation must be supported with high level overviews and displays suited for monitoring. While manual processes with high levels of operator interaction and resourcing will focus on granular and detailed displays.

Devices and equipment at Seqwater may have the ability to be monitored or operated remotely from a SCADA and operated locally depending on the requirements of the functional description. To support this there is a system of modes, functions, states and control that make up the control philosophy.

The table below provides a descriptive summary of the Seqwater standardisations and safety requirements and how they relate and interact to each other. Feature and standard prescription are provided in the relevant sections of this standard.

Table 1 Device features summary as they relate to each operating mode.

	Mode: Remote Automatic	Mode: Remote Manual	Mode: Local
Operator Responsibility	Monitor Plant for abnormal situations arising	Control from HMI to maintain plant in operational envelope.	Operate in the field within the design envelope.
Process Envelope Operability	Operation Envelope and into some margin of the design envelope.	Operation and up to the trip point in the design envelope	To the very limit of the design envelope and at times beyond the design envelope
Actuator & Drive Manipulation	Automatic cannot be directly changed. Controlled by PID, Permissives & Sequences.	Operator set and managed through the HMI	Operator set and managed in the field
Setpoints	Achieved through automation.	Managed and met by operator.	Managed and met by operator.
Permissive	STOP/START and OPEN/CLOSE equipment as per programming	Not Used	Not Used
Safety Features			
TRIP Interlocks	Triggers put devices in a safe state.	Triggers put devices in a safe state.	Not active.
Hardware Interlocks	Triggers as per equipment design.	Triggers as per equipment design.	Triggers as per equipment design.
Equipment Functions (Features of Seqwater library blocks)			
Disable	Moves Equipment to fail safe state and removes remote operation.	Moves Equipment to fail safe state and removes remote operation.	No impact to equipment operation.
Maintenance	As Designed-no default functionality.	As Designed-no default functionality.	As Designed-no default functionality.
Force	Instrument reading overwrite available only in maintenance for analogue instruments	Instrument reading overwrite available only in maintenance for analogue instruments	Instrument reading overwrite available only in maintenance for analogue instruments

Equipment States			
Fault (physical devices only)	Equipment cannot run	Equipment cannot run	Equipment cannot run
Available (physical devices)	Able to perform as required	Able to perform as required	Able to perform as required
Available (logical devices)	The logical device can be operated without any limitations	The logical device can be operated without any limitations	The logical device can be operated without any limitations

Control groups will be designed to achieve a specific process outcome. The objectives of a control group will be described in the Functional Description A while the design of the automation will occur in Functional Description B.

Within normal operating windows it is expected that control groups operate co-operatively without any operator intervention maintaining overall plant KPI's and setpoints.

Due to changes in process demand (e.g. high throughput, reduced feed quality) the plant will be pushed to the edge of its normal operating window. Constraints in individual control groups and equipment will emerge and, the process automation will function to retain within these constraints with operations only monitoring performance.

Due to maintenance requirements, planned or forced, equipment or instruments may be offline (e.g. out of service or Fault). This may present a constraint within the Control Group resulting in restricted plant capacity; however, operation should remain as automated as possible.

To ensure success when monitoring the plant, the state and operation of the process within the operating envelope is communicated to the operator through High Performance HMI techniques. This is guided by ISA101 HMI Design Standard and includes concepts such as a designed display hierarchy, deliberate use of colour and a priority of information over data through the use of graphical displays.

4. Seqwater Standardisations

Seqwater maintains the following standard definitions for its Control Systems. Device within this standard applies to a representation of a physical or logical component of plant represented on a P&ID. These standard definitions must be followed when displayed on any HMI for use by operators.

Physical devices exist in the field and are equipment reflected and represented in the PLC and SCADA.

Logical devices exist only in the PLC and SCADA.

4.1. Control Modes

Control Modes indicate how a device is being controlled and how its direct inputs are being changed. These definitions do not discriminate on proximity or geographic location. Seqwater has three control modes as follows.

When a device has inputs, the control modes must reflect the following descriptions. When required by design, additional modes may be required.

Local: The device is being controlled from the field. PLC and SCADA have no impact on the control and actuation of the device; it can still be monitored from SCADA.

Remote Manual: The device is being controlled from SCADA by the operator. Control and actuation of the device is by the interpretation of operator command.

Remote Automatic: The device is being controlled programmatically. Control and actuation of the device is automated through the programming associated with the device in the PLC.

4.2. Functional States

Functional States: describes the range of functions of a device. When applicable a device must have these states and display them explicitly to the operator when a device is selected. When required by design, additional functional states may be required.

Fault: The inability to perform due to an internal state.

This definition is aligned to ISO14224. Only physical devices can fault and only signals originating from the device can result in a fault.

Available: State of being able to perform as required

This definition is aligned to ISO14224. The available state in Seqwater control narratives and on HMI is qualified with Available to perform in all of its required control modes.

A device will be available if it is:

- Not in Fault - As the device has an internal error.
- Not Tripped - As the device has moved into a shutdown state.
- Not Interlocked – As there are interlocks preventing its operation
- Not in Error – As the PLC and logic is preventing its operation
- Not Disabled – As it has been determined by operations to not being able to perform as required.

The following do not impact the available status:

- Changes in control mode – As control modes are separate to device capability to perform.
- In Maintenance – As this function is not standardised.

4.3. Equipment Functions

Seqwater maintains the following standard functions for its devices in the Control System. These are to be applied from design through to implementation.

4.3.1. Disable

To exclude a device from remote control modes the disable function can be used. Toggling Disable will force the equipment to reach its failsafe state (OFF state in most cases), and equipment will become unavailable to operate from SCADA, until toggled again. The equipment will remain energised so that it can be readily brought back into operation by enabling it.

Disable function is applicable for process areas also (filters, chemical dosing etc.) as well as individual equipment.

When disabled, it is a requirement that alarms associated with the device are suppressed, however interlocks are still visible. Hardware Interlocks will still be active in the field and refer to alarm design and rationale to determine if they are to be suppressed while the device has a true disable status. Specific status indication whilst disabled (e.g., valve position) may be included in the design for safe operation so that the operator will make an informed decision prior to enabling.

Disable only affects the functionality of a device in Remote Auto or Remote Manual modes. Local operation is still possible even if the disabled function is active, as disabled is only functionally relevant to the remote modes.

The Disable function can be excluded for specific process critical equipment if determined in the design and with Principal approval.

4.3.2. Maintenance Function

The override allows the usual control philosophy of a devices modes, statuses and interlocks to be bypassed. To ensure safe operation of the device. This is accommodated through the maintenance input and status available.

The maintenance function, by default, is not configured for use. The only exception is instruments and analysers where the maintenance function allows access to the Force and Instrument Calibration functions. The maintenance function may be used to bridge code, such as interlocks or alarms, for specific equipment. The use of maintenance function should be confined to allow abnormal operation for known conditions for a defined period. All use of the maintenance function is subject to risk analysis and higher-level privileges above operator level, as outlined in I-SPE-STD-013.

Requirement of the maintenance function for individual equipment shall be specified in functional description (Part A or B).

4.3.3. Force

When it is necessary to complete maintenance, troubleshoot or calibrate instrumentation while the plant is operational it will be practical to either invalidate or overwrite the online reading. Where practical and possible it is preferred that the maintenance status be used to invalidate the reading for a set maximum amount of time for any alarms, interlocks or automated control. This means the actual measurement is reported and recorded through the measurement tag and is filtered downstream for any reporting and statistical requirements.

Where not possible or practical the forcing function provides for overwriting a variable via SCADA. The function can be applied for digital and analogue signals. Key requirements for forcing include:

- Indication on SCADA to the operator that a variable is being forced.
- Alarms are to remain active, but these shall use the forced value, not the actual process value.
- Logging of the force function on SCADA.
- A configurable time out with automatic reset.

For process critical equipment, the design should consider whether or not to allow for the force function. If it is included in the design, a maximum time period must be decided during the design phase and configured for the equipment. Appropriate privileges to put equipment into force from SCADA should be decided in the design phase, based on a risk assessment.

4.3.4. Instrument Calibration

Instrument calibration is a specific application of the force function. The intent is to allow water quality analysers to be taken out of service for calibration.

Alarms, trips, and interlocks remain active for the forced value during the calibration function. Both the process value (forced) and the real value shall be displayed and trended during the force function duration. The trend shall also display that the Analogue Input is being forced. The display and trend will be used to indicate to the operator what the output will return to when the force function is removed.

The use of the force function must be logged on SCADA. An operator should be able to see a summary of all currently forced analogue and digital inputs on SCADA.

There is a risk that during the force time a process upset occurs and a CCP alarm could be missed. Therefore, force must have a time out with automatic reset. The time out period has an upper limit, which cannot be altered by an operator. An operator can enter a time out value in SCADA, up to this limit.

When an Analogue Input is set to force the timer shall commence and the time remaining shall be displayed on SCADA. Once timed out, the force function shall automatically reset. Force function timers can be restarted while timing out. The force function can be individually turned off at any time.

5. Safety Requirements

To protect people and equipment the control system will prevent operation of equipment outside of the operating envelope. This will occur by operating devices into a pre-defined safe state through the use of the following functions and features. A cause-and-effect matrix I-TMP-STD-013 captures the following interactions within the control system.

5.1. Hardware Interlocks

These provide safety/protective functions (e.g., emergency stop, thermal overload); these interlocks need to be healthy for the equipment to operate in any control mode (Local, Remote Manual as well as in Remote Automatic control modes). Examples that could consolidate to a hardware interlock include:

i. Loss of control power
ii. Loss of mains power
iii. High temperature
iv. Oil in water in a pump
v. High torque in a valve
vi. E-Stop active
vii. Isolator open
viii. Power factor high / low

Additionally, safety trips (e.g., high level in chemical storage tank interlocks a delivery power socket) that are hardwired to protect against a hazard in all control modes is included in this definition.

5.2. Trip Interlocks

Trip Interlocks provide protection against undesirable operating conditions (e.g., low-level switch on a tank that a pump is drawing from). These protect the process from excursion towards design limits. These interlocks need to be healthy for Remote Auto and Remote Manual control modes at both an equipment and a process group level. At the process group, trip interlock is achieved with the *crash stop* interlocking function, as noted in 6.6.4. Shutdown interlocks are to be used to orderly shutdown a process. *Crash stop* interlock is reserved for high-risk scenarios from technical risk analysis typically associated with scenarios of personal safety or catastrophic loss of assets.

These interlocks will not be active in Local control mode. In SCADA Interlocks shall be shown as “ON” when the interlocking state is active and “OFF” when there is no interlocking i.e., when the conditions are healthy or normal. An override process can be used to manage interlocks to provide for abnormal operation requirements.

5.3. Trip-to-Manual Function

A trip to manual function is used to change a controller or device to manual mode with pre-defined fail safe setpoints[2]. This function should be considered for use under specific applications which are specified in the design documents (cause and effect and functional descriptions).

Where the design uses a trip to manual function, the following attributes shall be included:

- Clear display of the trip and change to manual mode for the operator’s action
- Override of the trip to manual function shall be provided for testing purposes
- Requirements / procedures to reset shall be specified for the application

5.4. Safety Interlocks & Trips

Safety related Interlocks and trips shall follow the functional safety lifecycle and design as in IEC 61508 and IEC 61511 (Figure 3). Functional safety is the risk reduction provided by the functions implemented to ensure the safe operation of the process. This is achieved by taking the plant to safe state if a process or equipment failure is detected. Any interlock requiring SIL rating shall be called as SIF. Consequence of failure of a SIF is outside business risk appetite as compared to a normal interlock or trip.

[2] Currently Seqwater blocks functionality trips to manual. Will be made selectable in the future. The blocks are not non-compliant or risky they are overly conservative as the risk mitigation is included as a default.

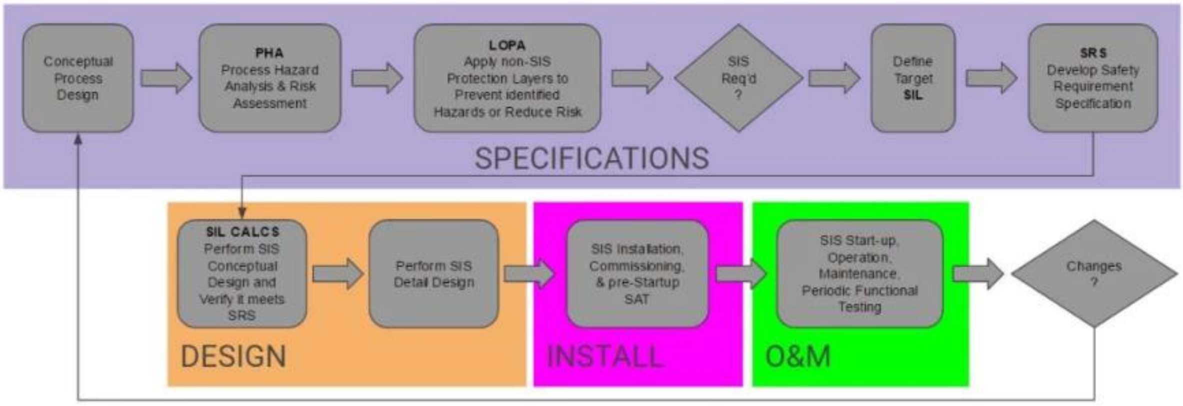


Figure 3 Functional safety lifecycle

The functional safety lifecycle shall be followed to identify and quantify the SIF and it's SIL rating as per IEC 61508.

In Seqwater, the following units (but not limited to) shall be considered for functional safety applications:

- Ammonia Storage
- Fluoride dosing
- Dam Gate / Control Valves
- Functions having environmental impacts, not within the financial risk appetite of Seqwater

Seqwater shall approve the application of functional safety in all instances.

5.5. Control Systems Fault

The control systems shall be designed to fail safely. The occurrence of any abnormal condition(s) within the control systems that affects *reliable, orderly, and safe operation* shall result in the automatic controlled shutdown of the affected area of the plant or the entire plant irrespective of the stage of the plant control sequence. The specific conditions that result in shutdown shall be determined through the design process considering the criteria of *reliable, orderly, and safe operation*.

During the design process if a control loop is identified as SIL rated loop then the design shall consider use of Safety PLC systems in consultation with the Principal. However, most of the control loops in various units in Seqwater are non SIL rated loops, hence a non-safety system is predominantly used as per *I-SPE-LST-001 Prescribed Equipment List*. The design shall adhere to fail safe requirements through the configuration of the control system devices, or the logic developed shall be fail safe. Any control signal loss due to communication failure shall be designed to be fail safe.

In the case of an abnormal event(s), the system shall be designed to be fail safe with all outputs returning to de-energised safe state.

A safe condition of control systems is one that involves no hazard to personnel and no unnecessary operation of plant or equipment.

6. Control and Automation Requirements

Within the operating envelope there are multiple stable operating windows depending on the demand on the plant and the current constraints it is operating under. As such there are many valid and stable operating modes within the plant each with their own demands from the operator and achievable throughputs and treated water quality.

This section prescribes and describes Seqwater requirements and preferences available when designing and implementing a control narrative.

The process hierarchy, which is documented in Functional Description Part A, is used to inform the control system hierarchy, which is documented in Functional Description Part B. Processes are structured as process groups which consist of equipment and / or blocks that must operate together to achieve a process objective or outcome. The control system hierarchy assembles code blocks from Seqwater's library into logical groupings. The following philosophies shall be applied:

- A group controller functions to communicate a group of devices to the operator and change the control scheme or setpoints of lower hierarchy equipment. When layered group controllers form a control hierarchy within the plant that needs to be communicated to the operator through SCADA screen hierarchy and design.
- Supervisory Controllers form the level of the hierarchy above instrumentation and actuation. If interlocking is not possible at the device layer it should be implemented here with interlocking at the group controller level avoided.
- How the control and automation is communicated to the operator needs to be considered. As such where possible permissives should be considered for sequencing followed by supported sequencing tools within Seqwater.

Override control schemes should be avoided. However, may be required during abnormal situations, such as during start up or to protect against constraints. All override control schemes shall require Seqwater approval.

6.1. Permissive

Permissives provide logic and communication to operators on the conditions that are required to be met for a device to continue (Process Permissive) or start (Start Permissive) operating under automatic remote control. These logical components in addition to "operate in auto" inputs as part of standard library blocks give simple sequence, on / off control and an additional layer of protection for other automated control types.

6.2. Setpoints and Parameters

The control systems are designed to operate using a combination of SCADA configurable Setpoints and PLC parameters.

PLC parameters are not accessible from SCADA. They are hard coded inside the PLC program. All PLC parameters shall be specified in the functional description part B.

SCADA configuration setpoints are process setpoints, control setpoints or Critical Control Point (CCP) parameters.

Differing levels of authority shall exist for managing change to SCADA configurable Setpoints.

For SCADA Security Privilege Levels & SCADA User Roles refer to I-SPE-STD-013.

All SCADA setpoints shall be specified in the functional description part B.

6.3. Control Loops

The following guidelines should be followed when using control loops for plant automation.

Feed forward –The desired outcome of the process is not considered during operation. A manipulated variable response to process variables is programmed. An actuator is manipulated based on process variables measured in the plant. This is used where the desired setpoint of a process variable is not measured online and cannot form part of the control scheme.

Feed Back – In Feedback (Closed Loop) control the desired outcome of the process is monitored during operation. The MV is continuously adjusted to ensure the PV converges to the SP. This is the preferred control loop where instrumentation allows as it accounts for the most disturbances.

Hierarchy– Closed loop control should be the highest parent controller. Controller targets should always be selected to reflect KPI's appropriate at that level of the control hierarchy. Control loop hierarchy should be constructed to allow for partial failure or partial downtime.

Design Considerations– The following shall be considered at the time of design:

- Scan rate required to be < 200ms unless agreed otherwise by the Principal.
- The normal control mode of the control loop and how a prolonged time in an abnormal control mode will be communicated (alarm, page design, KPI deviation trend).
- The complexity and usability of the control hierarchy and how the operator is expected to interact with it under normal operating conditions and abnormal operating conditions.
- Recommended tuning parameters and expected controller response (fast moving, slow moving, integrating process, dead time).
- Recommended scaling and linearization needed to improve the performance range of control loops.
- The operating window in which the controller is designed and how it will be communicated to the operator.

6.4. Duty/Assist/Standby Control

Definitions of equipment duty / assist / standby are as below:

Table 2 - Duty Assist Standby Sequence

Duty	Duty control is used when the process requirement is able to be provided by only one device operating at any given time.
Assist	Assist is used when the process requirement is not able to be provided by the Duty device alone and requires the operation of an assist device to share the load of the process. In some cases, there may be a need for multiple Assist devices to meet the process requirements.
Standby	The Standby device is ready to become the Duty or Assist if either of these running devices becomes unavailable. The standby device can be shared by multiple duty/Assist devices

Duty/assist/standby control(s) are only available in the remote automatic control mode. If the duty selected device is unavailable, then the standby equipment is to become duty. If no equipment is available to run in duty, then the process unit will fault.

6.5. Duty Rotation

The duty shall be operator selectable between fixed duty, time-based duty, or auto duty.

In fixed duty, the equipment selected for duty will operate if available. In time-based duty, the online equipment automatically rotates to the standby equipment, if available, after an elapsed time. In Auto duty, the duty rotation happens each time the process unit goes offline. This shall be achieved via a single SCADA selection box.

The rules as per the sections below shall apply for duty rotation of equipment.

6.5.1. Duty Tank Rotation

Duty selection between fixed / auto tank rotation:

The operator can select a fixed tank duty order that defines which tank to dose from and return to. If fixed duty is selected and the duty tank reaches a low level, then change to the next available tank in duty order.

Automatic tank rotation shall be a part of design. Rotating duty tank on a time basis should be considered. As fit for purpose for the tank(s), the influence of chemical delivery size and frequency, water age, solids deposition and other factors shall be considered in the design.

The tank rotation time shall be adjustable via SCADA HMI and the time remaining until the next tank rotation is also displayed in SCADA.

6.5.2. Duty Pump Rotation

Duty selection for fixed / auto rotation of the pair of pumps: If fixed duty is selected, i.e., 1/2 or 2/1, then the duty pump is operated, if it is available. If the duty pump becomes unavailable, then the standby pump, if available, is operated.

If the standby pump is operating and the duty pump becomes available again, then the duty changeover will happen from standby pump to duty pump in the fixed duty rotation. However, in auto duty rotation, the standby pump will keep operating until the standby pump goes offline.

If time-based rotation is selected, then the online pump automatically rotates to the standby pump, if available after an elapsed time (minutes).

The pump rotation time shall be adjustable via SCADA HMI and the time remaining until the next pump rotation is also displayed in SCADA.

This same philosophy should be extended to process groups with multiple duty pumps and a common standby. The goal in these multiple pump process groups will be to even the run hours of each unit. The design of multiple pump process groups duty rotation shall be described in the functional description parts A and B.

6.5.3. Duty Dosing Line Rotation

Duty selection for fixed / auto rotation for each pair of dosing lines: If fixed duty, (i.e., A/B or B/A), cyclic duty or dual duty is selected, then the duty dosing line is operated, if it is available.

If the duty line becomes unavailable, then the standby line, if available, is operated.

If auto dosing line rotation is selected, then the standby dosing line, if available, automatically rotates to become the duty line after an elapsed time (minutes).

The dosing line rotation time shall be adjustable via SCADA HMI and the time remaining until the next dosing line rotation is also displayed in SCADA.

6.6. Group Controller

The minimum functionality of a group controller is to provide for operation of equipment and / or blocks within a process group[3]. The group controller (via supervisory controller, refer to I-SPE-STD-020 Programmable Logic Controller (PLC) Blocks Specification (SPE-00526) is otherwise configurable to meet the requirements contained in a design. As this block has scope for variances in configuration, Seqwater shall be required to approve the proposed configuration for all group controllers. Documentation of the functionality requirements shall be included in Functional Descriptions Part A and B and must be provided as support for the adopted configuration.

The following functionality has been successfully used within Seqwater and may be included in a design:

6.6.1. Mode or function changes

For operator efficiency, the group controller can be configured to take the following actions for all or some of the equipment and / or blocks within a process group:

- Disable
- Auto mode
- Reset

The design of the group controller shall consider the risks associated with including or excluding the functionality as noted above.

An example might be the requirement for an operator to place each equipment into disable one by one in a process group rather than a single group disable balanced against the potential for inadvertent use.

6.6.2. Monitoring

Monitoring can be configured and would be case specific and outlined in the design. However, common functionality includes:

- Display and alarm that a process group equipment is in fault.
- Process group equipment are available.
- Equipment is running.

This type of monitoring should not be applied as a norm to all equipment but be considered in the design process for key equipment conditions.

[3] I-SPE-STD-020 Programmable Logic Controller (PLC) Blocks Specification (SPE-00526) uses the terminology 'service' to describe the function whereby an equipment / block receives an output that allows it to operate with interlocking / permissives. In practice the output can be to change the mode of the equipment to AUTO to allow it to operate. Note that the supervisory controller can be used for monitoring only but in this context, it would not be defined as a group controller.

6.6.3. Shutdown

Shutdown is used to stop the process. A group controller shutdown could be configured to trigger with an operator initiation and / or a configured condition(s) being achieved. A shutdown may be configured to start a sequence or steps through to a process stop.

A group control shutdown should be considered as a means to stop a process group as part of normal operation, i.e., within the operating window. The function is configurable so can be used to stop a process when equipment is in any remote mode, but auto mode is the standard implementation. It can be used for a normal shutdown at the bounds of the operating window, with an appropriate margin.

The types of interlocks available as per each control mode and equipment functions are summarised below:

Table 3 Interlocks & Permissives compared to Control Modes and Equipment Functions

Interlocks	Control Modes and Equipment Functions				
	Disabled Function	**Maintenance Function**	**Local Control Mode**	**Remote Manual Control Mode**	**Remote Automatic Control Mode**
Hardware Interlock	✓	✓	✓	✓	✓
Trip Interlocks		configurable		✓	✓
Start Permissive					✓
Process Permissive					✓
Group Control Shutdown				configurable	✓

6.6.4. Interlocking

If Interlocking at the group control level has been approved by principal approval it may be included in the design. These have been used in Seqwater for inputs external to the group control which is required to stop all equipment that is part of the group control.

6.7. Sequence Control

A sequence will consist of a group of one or more inter-related equipment which together carry out a particular process. Automatic sequence logic shall be provided in the control systems to control and monitor each sequence. The auto sequence logic will:

a. Control and monitor the ordered start-up or shutdown of each item in the sequence in accordance with a predefined program and designated process and time requirements

b. Whilst the sequence is running, continue to monitor each item and provide start/stop control and/or open/close control(s) for individual equipment in accordance with predefined process and time requirements.

c. The status of various steps in the sequence shall be displayed on SCADA system

7. Standard Process Control Patterns

States or Status can apply to all levels of the hierarchy. A state will reflect the status of the equipment or process group. Some states include, available, online, offline, starting, running, stopping, stopped and Fault. There may be procedures that are active in transferring from one state to another. This section outlines key states used in Seqwater and the definition of these states. Each design may have additional states / status which must be outlined in the functional description documentation. Three states are found in almost all devices and outline which control modes are available to an operator.

7.1. Filters

Seqwater utilizes conventional water treatment extensively and filters are one of the main process units. Filters will operate in a sequence consisting of multiple states. The filter design shall include an offline state. The offline state shall also be the safe state for the filter. An offline state shall involve all valves to and from the filter as closed, which can be referred to as 'boxed up'. There shall be assurance that the valves are closed (e.g., limit switches). These states are mandatory for filters at Seqwater.

Online

Equipment is in Online state if it has successfully completed all the sequence steps to be Online. A filter may need to complete Fill, Reject and Online sequences in order to reach to Online state. In Online state Group Enabled shall be in "On" state.

Offline

Equipment is in Offline state if it has successfully completed all the sequence steps to be Offline or all items of equipment have been manually operated to the Offline state, e.g., all valves associated with a filter are fully closed. In Offline state Group Enabled shall be in "OFF" state.

To leave an offline state, particularly after a trip, the operator should be required to clear the latched interlock. Seqwater shall be required to approve the latching or otherwise of interlocks in a filter design.

The time taken to box up the filter, particular in the case of a trip shall be assessed in the design and Seqwater shall be required to approve.

The conditions that lead to interlocking the filter shall be considered in the design and approval by Seqwater shall be required.

7.2. On / off pump control with water tank storage

A common control in water systems is an on / off pump(s) function based on level in a water tank storage. This process configuration can take multiple variances (pumps are submerged in, drawing from, or discharging to, the water storage) but the concepts of operating and design envelopes are common.

Where pump equipment protection from dry pumping is required, for example pumping out of a tank with a very low level, the process shall interlock under all modes. This is, by definition, an equipment level interlock and would be hardwired.

Where tank overflow is a concern, for example pumping to a tank with a very high level, the process shall interlock under both remote modes (MANUAL and AUTO). Local mode may still allow for pumping without protection of a tank overflow interlock. The design shall consider the risk of operation without an overflow interlock in local mode and appropriate risk controls shall be identified and approved by Seqwater. If the risk is deemed unacceptable by Seqwater, local mode shall not be included in the design.

7.3. Chemical Dosing

Chemical dosing systems (including coagulants and disinfectants) are used extensively at Seqwater's water treatment plants. Measurements from the process which can be used in dosing include:

- The main process flow which is dosed by the chemical dosing system;
- a water quality parameter; and
- whether the plant is on or off.

During the design, the criticality of the chemical shall be assessed. Consequently, the importance to interlock or rely on automated functions only shall be considered for fault conditions of process measurements. All assessments of criticality and use of interlocking shall be approved by Seqwater.

For chemicals deemed critical to the process, at a minimum, a fault in the main process flow measurement shall result in an interlock of the chemical dosing system.

8. Signal Conditioning

The online measurements and readings from instrumentation, analysers, sensors and switches must be prepared for the control system through appropriate filtering, conditioning and scaling. The plant design and control narrative must consider the consequences of both known and unknown failures, and their likelihoods. The following prescribes and describes requirements and preferences for the processing of digital and analogue signals.

8.1. Analogue Signals

If not standard with selected hardware and firmware where required, noise filtering will be accepted and even at times required within the PLC to improve the automated response of control loops within the plant. The raw measurement will be made available for comparison against the filtered value for troubleshooting and auditing purposes.

The Functional Description A will describe the operating envelope for instrumentation. The Functional Description B will determine if linearisation of the signal is required across the specified range for stable control e.g. for pH measurements. Linearisation details shall be made available to expertise when troubleshooting or investigating instrument detail. Technical details on linearisation is not required to be shown during normal operation.

8.2. Digital Signals

A digital signal may require debounce within the control system if not already provided by hardware. This can be applied during Functional Description B or during commissioning to operate as required. Debounce refers to the removal of noise that would result in a Boolean state changing in the electrical and instrumentation domain. It does not refer to timers, or delays used in the process domain used to ensure that a trigger or alarm is activated due to minor deviations outside of a desired operating window. Debounce information shall be made available to expertise when troubleshooting. Technical details on debounce functionality is not required to be shown during normal operation.

8.3. Patterns for Duplicate and Redundant Signals

Depending on the risks in the process or automation targets for the process asset, errors in instrumentation or deviations in the measurement must be known when they occur. Duplicate or redundant analogue measurements or signals will be required with independent modes of failure. These multiple values may be directly measured, calculated or even inferred, however requirements on reliability and expected operating range must be considered in the design.

An error between redundant analogue can be calculated as a %, absolute or both. When this discrepancy exceeds manufacturers limits or what is expected within normal operating windows it will be considered an abnormal situation.

8.4. Precision and Scale

Numeric displays of process variables on the SCADA HMI shall use a maximum precision (number of displayed digits) and allowable scale (number of displayed digits to the right of a decimal point) respective of the process variable. This applies to any numeric display of a process variable on any SCADA page in use by the runtime. Precision and scale of other numeric displays of process variables in pop-up windows, setpoint entry boxes, trend windows, property configurations, metadata displays and displays outside of the runtime are not specified by this standard and may differ depending on design requirements. Specification of significant figures for calculations and reporting for quality purposes is described elsewhere.

Numeric displays shall not be padded - leading zeros shall not be displayed except for decimal values. For decimal values, or values in which non-zero digits exist only to the right of the decimal point, one zero will be displayed to the left of the decimal point (regardless of precision), and all leading zeroes between the decimal point and the first non-zero digit will be displayed. For example, 0.0012 will be displayed as is (scale permitting).

The appropriate engineering expertise should specify units, precision and scale for the display of information. Table 11 Precision and Scale Variable List in Appendix B provides a recommendation.

9. Alarms Design & Configurations

Alarm design is completed by process engineering as a part of considering the process envelope design and have specific contextual requirements based on the plant design. Alarm prioritisation & rationalisation requires the consideration of the plant design and as such the control system will provide states required to allow for alarm implementation as per *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management (SPE-00357)* and *I-SPE-STD-013 Control Systems Design and Construction (SPE-00361)*.

The design and configuration of alarms shall follow the processes as outlined in *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management (SPE-00357)* using *I-TMP-STD-008 Master Alarms Template TEM-00254*. Key alarm configuration information contained in the standard includes:

- Alarm priorities
- Alarm owners and acknowledgement authority
- Response time
- Dial out requirements

- Parameter, set points, deadband, alarm delay

The following sub-sections contain specific details relating to water quality alarms.

9.1. Determination of High Priority Alarms & Interlocking Requirements

Alarms are prioritised based on risk assessment as per the procedure outlined in *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management (SPE-00357)*. Interlocking is designed using technical risk-based assessments such as those outlined in *X-PRO-STD-013 Engineering Technical Hazard Study (PRO-02140)*.

Furthermore, specific risk tools such as bowtie and Layers of Projection Analysis (LOPA) can be used for analysis to determine alarming and interlocking.

Additionally, interlocking requirements may be justified based on production, product quality, environmental and social license analysis. One approach used, particularly for loss of production, is to undertake economic analysis to assess interlocking systems value. Input data for economic analysis would include factors such as:

- frequency which an interlocking system might be used
- probability of failure on demand of the interlock
- lost production due to shut down
- cost of design and install of the interlocking system
- any contractual or regulatory fees or penalties

9.2. Pre-determined High Priority Alarms & Interlocks

Seqwater has determined from other analysis high priority alarms and interlocks. These shall be implemented as outlined as follows.

9.2.1. Water Quality

Critical Control Points (CCP), Quality Control Points (QCP) and Operational pre-requisite programs (oPRPs) are assessed and determined via the *Water Treatment Plant and Supply System, Process Validation Standard* (SPE-00320), applied as a Site-Specific HACCP plan, consistent with Seqwater's regulatory requirements. Common CCPs, QCPs or oPRPs correspond to a measured value within the range of an analogue water quality instrument. Other CCPs, QCPs or oPRPs can correspond to the availability, measure value, calculated value or signal output of key instrumentation or equipment. The structure and function of CCPs, QCPs or oPRPs, as aligned to the alarming priorities from *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management* (SPE-00357) are shown in the table below.

Table 4 Critical Control Points Priorities and Functions

Alarm	Priority	Guide Notes	Function
Priority 1	Critical	CCP, QCP Critical	Aligns with the “trip indication” or boundary of the design envelope (A) and (B). It is common for a process to interlock under these conditions to default to a safe state. The decision to interlock is case dependent and shall be determined through analysis.
Priority 2	Action	CCP, QCP or oPRPs Action	Best aligns with the “upset indication” bound in process envelope design. Time is provided for the operator to act prior to interlocking the process.
Priority 3	Warning		

9.2.2. Control Loop Constraint

Where a control loop acts on a process variable that has a nominated value that sets the process envelope (operating or design), the set point shall be constrained with limits. The set point limits shall be noted in the functional description documentation. Controller output limits may also be used and shall be noted in the functional description documentation.

The use of manual mode to operate without controller limits shall be considered in the design and proposed for Seqwater approval. It may be necessary for abnormal operation to function without controller limits. As guidance, setpoint limits in both automatic and cascade modes, shall only be removed via a managed override process, as per section 9.4.

9.2.3. Safety Related Alarms

Alarms classified in LOPA as defined in section 5.4, by the functional safety lifecycle, as safety related alarms shall always have the highest (1) alarm priority. Theses alarms shall also have a defined testing frequency and a test procedure. These alarms shall be differentiated on graphics from other high priority alarms.

9.3. Water Quality Alarms

A CCP action, a priority 2 alarm, can escalate to a priority 1 alarm if not acknowledged within the set acknowledge times as per section 6.3 of *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management* (SPE-00357). The CCP action shall remain active until acknowledged regardless if the CCP critical is active. That is, CCP critical is not itself an escalation of the CCP action.

Alarms shall be tested and documented including completed test sheets consistent with the requirements in *I-SPE-STD-011 Control Systems Testing* (SPE-00360) and associated test sheets (*I-TMP-STD-007 Control Systems Test Sheets* (TEM-00212)).

Alarming display shall be as per the requirements in *I-SPE-STD-013 Control Systems Design and Construction* (SPE--00361).

Alarm set points are set at a privilege level. The parameters that should be available for configuration by a Seqwater employee with access privileges of an Operations Supervisor or above are as follows:

- Enable / Suppress
- Calibration time

- Escalation time periods
- Dial out ability including delay times

All requests to change any of the above configurable parameters will be accompanied with a confirmation dialog box.

9.4. Alarm Masking and Interlock Override

Alarms can be disabled / inhibited at the appropriate privilege as per section 9.3. These shall be noted in *disabled alarm window* as per *I-SPE-STD-013 Control Systems Design and Construction (*SPE-00361*)*.

Masking of CCP alarms shall be approached on an individual alarm basis. Examples of where CCP alarms may be masked included:

- Plant stopped
- Plant starting
- Plant stopping
- Instrument calibration

Details of masking shall be captured in the alarms register for the site and shall require Seqwater approval.

In instrument calibration the process value is either held or forced to an entered value. If during the calibration time, a process upset occurs, a CCP alarm can be missed. Therefore, calibration must have a time out with automatic reset and the time must only be set by higher privileges. The default time out for instrument calibration with an associated CCP alarms shall be 30 minutes. This may be varied based on risk assessment, with higher privileges to adjust the time based on specific instrument maintenance requirements.

Interlock integrity shall be considered in the design. Hardwired interlocks shall function under all control modes while logic-based interlocks shall operate only under remote (manual and auto) control modes. Maintenance mode, if included, may function for override of interlocks if specified in the functional description documentation. Maintenance mode shall be assessed for risk of interlock override during the design process and shall be approved by the Principal.

All logic-based interlocks shall be capable of override. In such cases a Management of Change shall be raised. Preference is to bridge at the field equipment instead of the PLC.

If overriding logic-based interlocks, the maintenance function must be configured to allow for this functionality to occur. When configured it needs to comply with this standard.

Override shall require an Operations Supervisor or above privilege level. Interlock overrides will place the process into an abnormal operation with removed protections of design limits. Therefore, overriding an interlock should be assessed prior to implementation and tracked while unavailable.

9.5. Interlock Assurance

9.5.1. Testing

Interlocks should be tested on a nominal biannual basis. More frequent testing may be more necessary depending on the nature of the interlock and the reliability of the equipment as part of the interlock. To physically simulate the interlock, the cause of the interlock can be forced (e.g., through a calibrate function on instruments) or be a real value (e.g., a low level in a tank). Care must be taken that damage does not occur if the interlock fails the test.

9.5.2. Reporting

Interlock action frequency should be reported. Override of interlocks shall also be assessed. Key Performance Indicators (KPIs) for interlocking frequency shall be developed as bespoke to each interlock. The nominal reporting frequency shall align with interlock testing on a biannual basis.

10. Definitions & Abbreviations

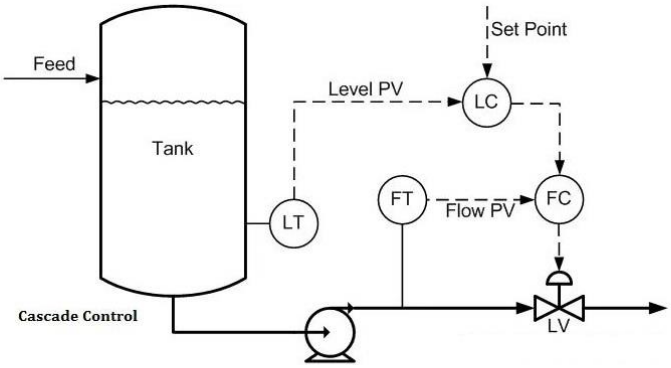
The following definitions apply to this Standard Specification:

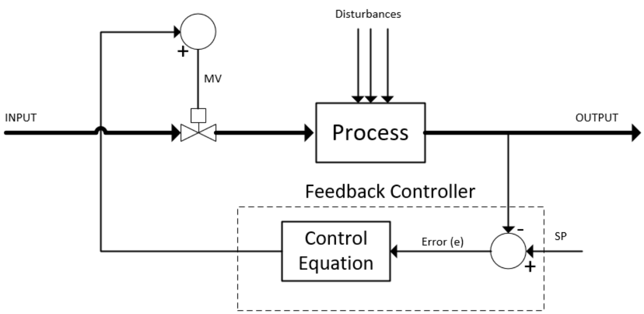
Table 5 General Definitions

Term	Definitions
Alarm	An audible and/or visible means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response.
Contractor	An entity engaged by Seqwater to undertake work in accordance with an agreed contract and defined scope of work.
Control Systems	A system that responds to input signals from the equipment under control and/or from an operator and generates output signals that cause the equipment under control to operate in the desired manner. Components of control system include but are not limited to PLC, SCADA, network switches, fibre optic or Ethernet communication network, historian, engineering station, operation station, software server, IO modules, remote IO nodes, control panels, relay panels, real time clock (GPS), switchboard, AC and DC UPS and AC and DC distribution system.
Device	Any single logical or physical item at single functional unit. Instument, motor, PID, Supervisory Controller.
Disturbance	A variable that we have no control over in the process but affects the process. An example could be a change in the raw water quality.
Group controller / Supervisory controller	A supervisory control block provides a method for controlling groups of equipment or other control blocks. It is designed to initiate and monitor groups of devices that function together.
Maintenance	Selected functions in auto mode are bridged to allow abnormal operation associated with maintenance activities
Manipulated Variable (MV)	Is the variable used to adjust the process to maintain the process variable (PV) at its setpoint (SP). Examples of manipulated variables include pump speed or valve position. The manipulated variable (MV) is sometimes referred to as the control variable.
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.

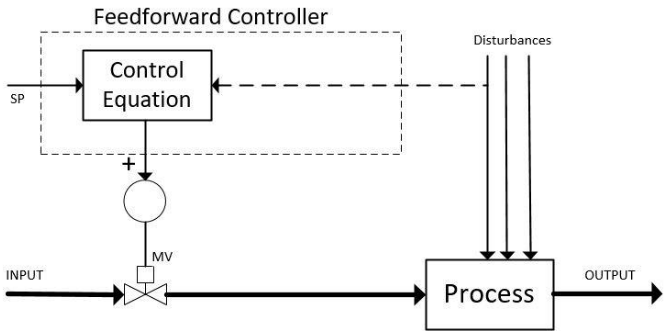
Term	Definitions
Owner / Principal / Seqwater	The entity that engages the Contractor to undertake the work and takes custody of the outcome. The Owner may delegate responsibilities to other entities to act on its behalf (e.g., a consultant).
PLC	PLC stands for programmable logic controller. It is a digital computer used for automation of electromechanical process such as control of machinery on assembly lines or in manufacturing plants (like power stations or water treatment plants etc.)
Process Variable (PV)	Is the variable in the system or process that we desire to control. Examples include flow, level, pressure, temperature. Process variables can be measured using instruments and a signal is sent from the instrument transmitter to the controller to compare to the setpoint (SP). The process variable (PV) is sometimes referred to as the controlled variable.
REX	Seqwater Electronic Document and Records Management System.
SCADA	SCADA stands for supervisory control and data acquisition system. The major function of SCADA is for acquiring data from remote devices such as valves, pumps, transmitters etc. and providing overall control remotely from a SCADA Host software platform. SCADA Host platforms also provide functions for graphical displays, alarming, trending, and historical storage of data.
Sequencer	A sequencer is classified as a device, that indicates the functions/logic to transition between states.
Seqwater Approval / Acceptance	Written sign-off gained via the deviation process, as detailed in X-PRO-STD-008 Asset Standards Management and Application.
Setpoint (SP)	This is a target or desired value of the process variable (PV). The controller compares the setpoint (SP) to the process variable (PV).
Shall / must	Indicates a mandatory requirement
Should	Indicates a recommendation
Tag	The unique identifier assigned to a process measurement, calculation, or device within the control systems. The same definition applies to “Point” in the Control Systems.
Trim	Trim is dynamic clipping of the PID controller output to the feed forward value (FFWD) plus or minus a defined percentage of the feed forward value. The bounds will dynamically change as the feed forward value (FFWD) changes.

Table 6 Control Definitions

<table>
<tr><th>Term</th><th>Definitions</th></tr>
<tr><td>Cascade Control</td><td>
Cascade control involves two (or more) controllers of which one controller’s output drives the set point of another controller. Cascade Control improves dynamic response to load changes.
For example: a level controller driving the set point of a flow controller to keep the level at its set point. The flow controller, in turn, drives a control valve to match the flow with the set point the level controller is requesting.


The controller driving the set point (the level controller in the example above) is called the primary, outer, parent or master controller.
The controller receiving the set point (flow controller in the example) is called the secondary, inner, child or slave controller.
</td></tr>
<tr><td>Feedback controller</td><td>
The objective of a feedback controller is to make a decision by solving an equation based on the difference between the process variable (PV) and the setpoint (SP). The control block diagram below demonstrates a feedback controller.


The difference between the process variable (PV) and the setpoint (SP) is the error (E):
$$E(t) = SP(t) - PV(t)$$
The controller acts to alter the manipulated variable (MV) in such a way as to minimize the error (E).
</td></tr>
</table>

Term	Definitions
Feedforward Control (FFWD)	Applying a pre-calculated value, usually the output of a feedforward controller, as bias or offset for feedback control. For example, Feed Forward control can be implemented with the PID controller. Feed Forward PID control uses an estimate of the output as a starting point, without waiting for the PID algorithm to respond. The feedforward value is an input to the PID from external logic. (For example, from the flow paced dosing control calculation) The PID controller will then start from a predicted value, rather than zero and then adds the result of the PID algorithm to the feedforward value. Feed Forward PID control can reduce the error faster or keeps the error smaller rather than relying on a single PID algorithm with no FFWD alone, because it can act proactively if there are known upcoming disturbances. Feed Forward PID control can combine the benefits of feedforward and feedback control. NOTE: PID control does not always use Feed Forward Control (FFWD). If not required, FFWD is set to zero.
Feedforward Controller	The objective of a feedforward controller is to measure the upstream disturbances and compensate for them by changing the manipulated variable (MV) before they impact the process variable (PV). The control block diagram below demonstrates a feedforward controller. 

Term	Definitions
Proportional Controller (P)	Simplest of the feedback controls. It is a controller that responds in proportion to the error (E) which is the difference between the desired setpoint (SP) and the current value of the process variable (PV). $$MV(t) = FFWD + K_p E(t)$$ Where: MV(t) = manipulated variable FFWD = feedforward value (Commonly referred to as bias, this is the starting point for the controller instead of starting at zero. The use of a feedforward value is optional. Refer to definition below) Kp = Proportional Gain Constant E(t) = Error
Proportional Integral Controller (PI)	Is another form of feedback control where the actuating signal consists of a proportional error signal added to the integral of the error. $$MV(t) = FFWD + K_p E(t) + \left(\frac{K_p}{T_I}\right) \int E(t)dt$$ Where: TI = Integral Time in sec (i.e. delay seconds per repeat of integral calculation)
Proportional Integral Derivative Controller (PID)	Is another form of feedback control. The PID controller produces an output which is the summation of the proportional error signal, integral of the error and derivative of the error. $$MV(t) = FFWD + K_p E(t) + \left(\frac{K_p}{T_I}\right) \int E(t)dt + K_p T_D \frac{dE(t)}{dt}$$ Where: TD = Derivative Time in sec (i.e. repeats of derivative calculation per second)
Ratio Control	The setpoint of the dependent process is set by a ratio factor applied to the setpoint of the independent process. SP(Dependent) = Ratio x SP(Independent)

Table 7 - Abbreviations

Abbreviation	Description
HACCP / CCP	Hazard Analysis and Critical Control Points / Critical Control Points
LOPA	Layer of Protection Analysis
OT&E	Operational Technology & Energy

Abbreviation	Description
oPRPs	Operational pre-requisite programs
PHA	Process Hazard Analysis
PID	Proportional–Integral–Derivative
PLC	Programmable Logic Controller
QCP	Quality Control Points
SCADA	Supervisory Control & Data Acquisition
SIF	Safety Instrumented Function (a safety function with specified SIL required to achieve functional safety. It consists of sensor(s), controller and a final element)
SIL	Safety Integrity Level (defines the safety integrity requirements of a SIF, derived from risk assessment)

11. Roles and Responsibilities

Table 8 Roles and Responsibilities

Role	Responsibility
Leaders	In addition to the responsibilities of a worker, ensure compliance with this Standard Specification by those they lead.
Workers / Employees	Be aware of and comply with this Standard Specification

12. References and Related Materials

The documents listed in Table 9 and Table 10 below, and the requirements therein, are relevant to this Standard Specification In their latest editions, these documents form a part of this document. Note that this is not an exhaustive list of documents relevant to the works.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this document, the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability for the proposed works.

Table 9 – Reference Seqwater Documentation

Document number	Document Title	REX ID
X-PRO-STD-001	Asset Standards Document Classification and Naming Structure	PRO-01873
X-PRO-STD-002	Drawing Number Procedure	PRO-01872
X-PRO-STD-004	Review Procedure for standards	PRO-01874
X-PRO-STD-006	Equipment Numbering Convention	PRO-02190
X-PRO-STD-007	Drawing & Spatial Data Standards	PRO-02187
X-PRO-STD-008	Asset Standards Management & Application	PRO-02205
X-PRO-STD-009	Engineering Design, Review and Approval	PRO-01617
X-TMP-STD-022	Asset Standards Deviation Request	TEM-00224
I-SPE-STD-013	Control Systems Design and Construction	SPE-00361
I-SPE-STD-006	Monitoring and Control System Alarm and Event Management	SPE-00357
I-TMP-STD-008	Master Alarms Template	TEM-00254
	Site Specific HACCP Plans	Various
	Water Treatment Plant and Supply System, Process Validation Standard	SPE-00320

Table 10 – Reference External Standards, Specifications and Codes

Description	Document Title
IEC 61508	Functional Safety of Electrical / Electronic / Programmable Electronic Safety-related Systems
IEC 61511	Functional safety - Safety instrumented systems for the process industry sector
International Standard detailing best practices for presenting control system information to Operators in Industrial Settings.	ISA101, Human-Machine Interfaces
Process Control and automation text of expertise active and influential within ICHEME community and material taught engineering coursework.	Process Control: A Practical Approach by Myke King (2016)
Standard defining many common terms across industry.	ISO14224: Petroleum, petrochemical and natural Gas industries – Collection and exchange of reliability maintenance data for equipment

13. Changes from previous version

This Standard Specification will be regularly reviewed in accordance with the requirements of the Seqwater Controlled Document Management Procedure. Reviews will include consideration of suggestions for alteration or improvement made in accordance with Seqwater Procedure X-PRO-STD-004 Development and Review of Asset Standards. Changes made from the previous version are summarised below.

Section Number	Change
Whole Document	Major update. Content from I-SPE-STD-013 Section 7 combined with previous version of this document and other updates made including addition of Appendix A – Typical Control Details.

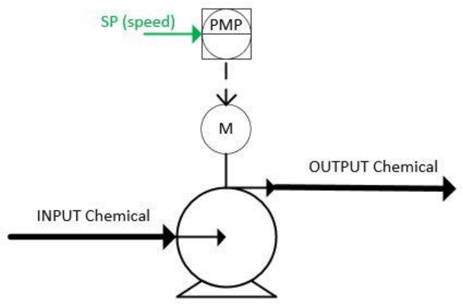
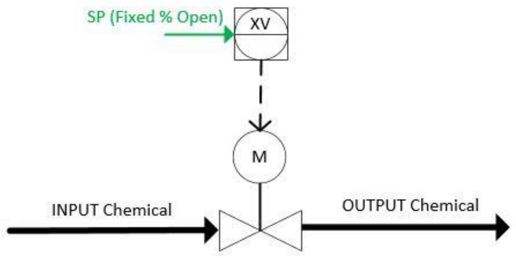
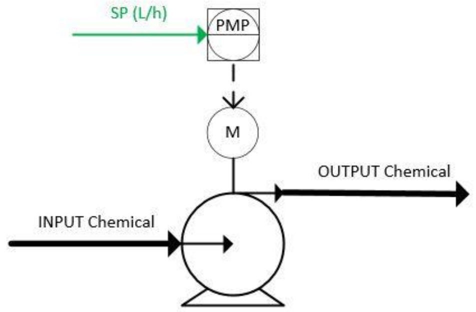
Appendix A – Typical Control Examples

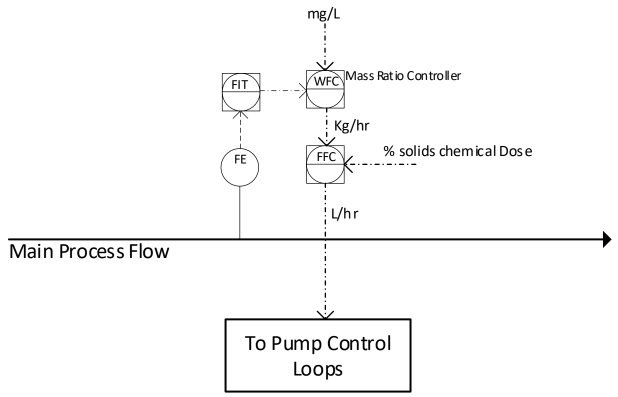
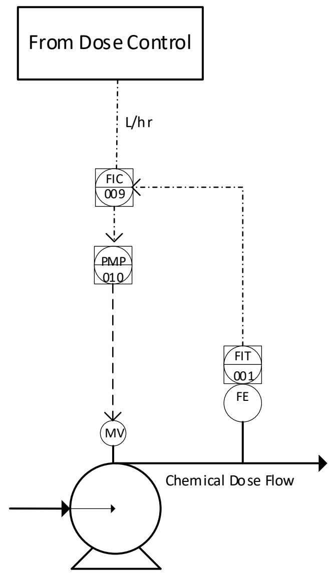
The table below lists Control Objectives & Methods with typical examples of how they are implemented at Seqwater.

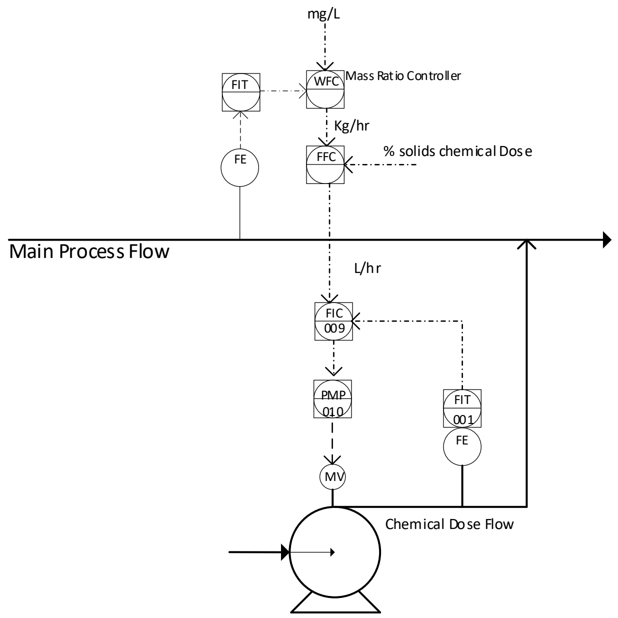
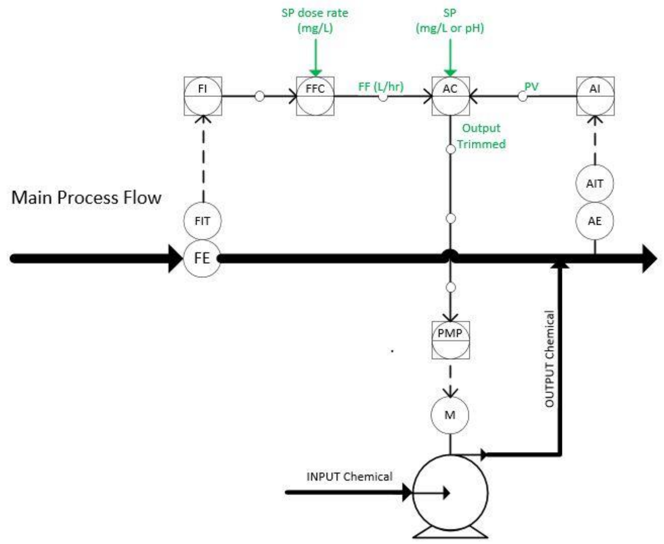
Note: The guidance below is intended as a visual aid in understanding the implementation of different control methods. Correct control philosophy standards and datasheets must be followed.

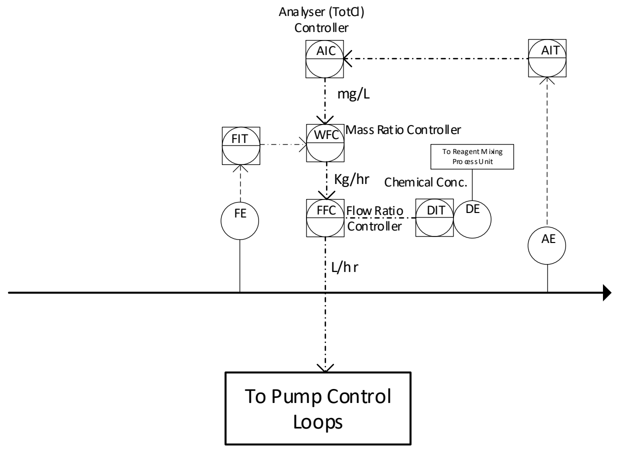
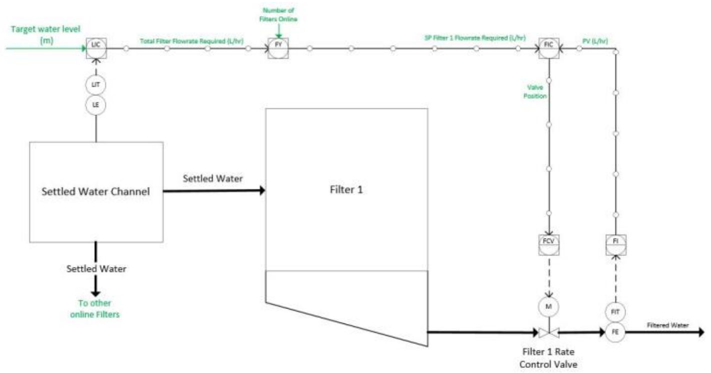
This guide uses Seqwater Design Control Mode as per B-SPE-STD-009 as a control narrative for the examples.

* Seqwater Control Mode process functionality is defined in B-SPE-STD-009 Liquid Chemical Storage and Dosing.

Control Objective	Control Method	Seqwater Dosing Control Mode as per B-SPE-STD-009*	P&ID representation
To directly control equipment based on an operator selected fixed setpoint regardless of upstream and downstream process changes. This could be required due to a lack of upstream or downstream instrument availability temporarily or permanently.	**Direct Control** Direct control of equipment based on fixed operator entered setpoint. Alternatively direct control can be achieved by forcing the output of a feedback controller to an operator entered fixed setpoint.	Fixed Speed	
		Fixed Percentage	
		Fixed Flow	
To precisely control a process by responding to upstream changes before they impact downstream processes. For example, reacting to changes in the main process flowrate before it reaches the	**Feedforward Control** Control that predicts the effect of disturbances on the process output and adjusts the input to compensate for them. Feedforward ratio Control of chemical dosing	Flow Paced without any feedback	

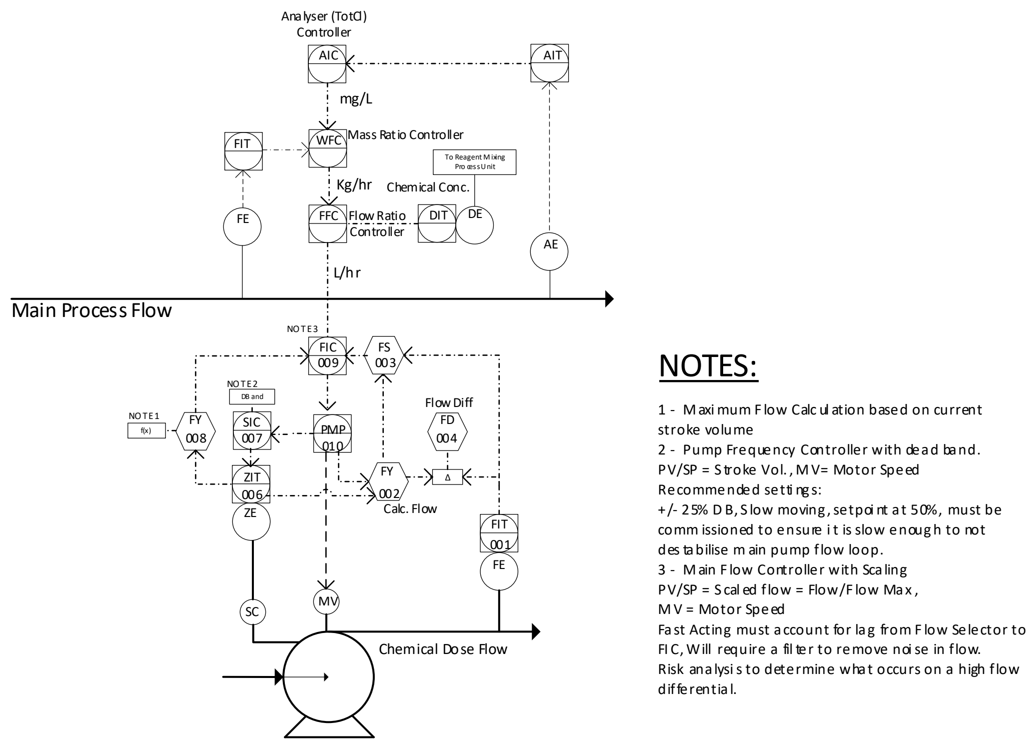
Control Objective	Control Method	Seqwater Dosing Control Mode as per B-SPE-STD-009*	P&ID representation
dosing point to avoid under or overdosing.			 FFC = Flow Ratio Controller (Flow pacing calculation)
To precisely control a process by correcting based on downstream monitoring to account for inaccuracies in the process model, measurement error and unmeasured disturbances. In the water industry common control objectives are to correct for pump curve inaccuracy and the limitations of chemical dosing calculations and changes in water chemistry.	**Feedback Control** Control that adjusts the process input based on feedback from sensors that measure the actual process output. Feedback Flow Control	Fixed flow with chemical flowmeter feedback	 Automated dosing pump flow control with: FIT 001 - Measured Flow FIC 009 - Dosing Pump Flow Controller PMP 010 – Dosing Pump
To precisely control a process by responding to measurable upstream	**Combination of feedforward and feedback control**	Flow Paced with Chemical Flowmeter Feedback (Optional trim)	FFC = Flow Ratio Controller (Flow pacing calculation, DOSE_CALC block) FIC = Flow Indicator Controller

Control Objective	Control Method	Seqwater Dosing Control Mode as per B-SPE-STD-009*	P&ID representation
disturbances before they impact downstream processes and correcting a process based on downstream monitoring to correct for inaccuracies in the process model, measurement error, and unmeasured disturbances.	Implementation of this control mode at Seqwater is referred to as flow paced with various combinations as shown to the right. Feedforward ratio dosing setpoint cascaded to feedback flow control		 Automated dosing pump flow control with: FIT 001 - Measured Flow FIC 009 - Dosing Pump Flow Controller PMP 010 – Dosing Pump
	Feedforward ratio dosing setpoint and Analyser feedback with direct pump output control	Flow Paced with Analyser Feedback and trim	 FFC = Flow Ratio Controller (Flow pacing calculation) AC = Analyser Controller (PID)

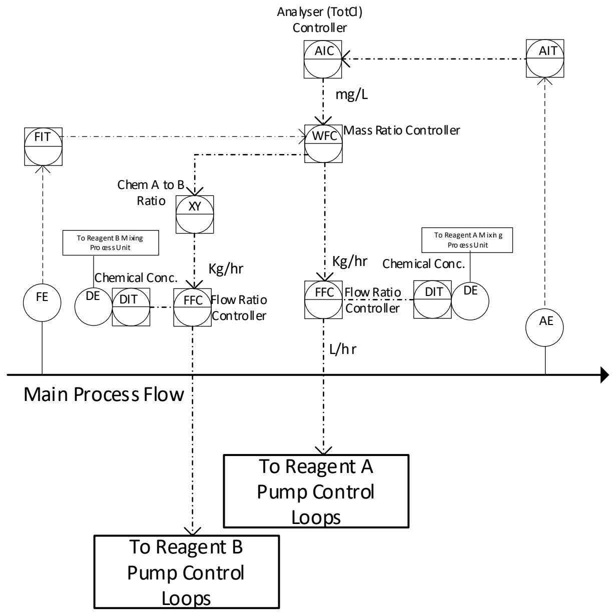
Control Objective	Control Method	Seqwater Dosing Control Mode as per B-SPE-STD-009*	P&ID representation
			 AIC Analyser Controller WFC Mass Ratio Controller FFC Flow Ratio Controller
To improve control of a process by taking into account feedback from multiple relevant process measurements.	**Hierarchical Controller with** Control strategy that uses multiple feedback control loops which cascade one into another to regulate a single process variable. Cascaded level control setpoint to flow controller	Filter Cascade Control	 FY = Flow calculation (Divides required flow by the number of online filters) LIC = Level indicator controller FIC = Flow indicator controller

<table>
<tr><th>Control Objective</th><th>Control Method</th><th>Seqwater Dosing Control Mode as per B-SPE-STD-009*</th><th>P&ID representation</th></tr>
<tr><td></td><td></td><td>Flow paced with chemical flowmeter feedback (trim optional) and analyser trim feedback

(This method uses Feedforward control in conjunction with cascade feedback control)</td><td>Control loop including full dosing control and pump control loops.
This template can be modified and, or reduced based on instrumentation and actuation available on site.



Automated dosing pump flow control with:
FIT 001 - Measured Flow
FY 002 - Calculated Flow
FS 003 - Calculated or Measured Flow Selector
FY 004 - Calculated and Measured Flow Difference Calc
SIT 005 - Motor Speed Indicator Transmitter
ZIT 006 - Dosing Pump stroke volume actuator indicator transmitter
SIC 007 - Motor Speed Controller with deadband
FY 008 - Maximum Pump Flow at current stroke volume calculation
FIC 009 - Dosing Pump Flow Controller
PMP 010 – Dosing Pump</td></tr>
</table>

Control Objective	Control Method	Seqwater Dosing Control Mode as per B-SPE-STD-009*	P&ID representation
To control one chemical addition in a ratio to another chemical addition to meet the requirements of water treatment reaction chemistry. Alternatively, the objective is to combine components in a specific ratio to prepare a batch of the required concentration.	**Ratio Control** A control strategy that maintains a constant ratio between two process variables.	Ratio	

Appendix B – Precision and Scale

The appropriate engineering expertise should specify units, precision and scale for the required units, the following provides guidance with a recommended approach.

If the value of the process variable is higher than is allowed by the specified precision and scale, the maximum possible value shall be displayed. For example, if a value of 10000 is to be displayed with a precision of 5 and scale of 1, the displayed value will be 9999.9. If the value of the process variable is lower than is allowed by the specified scale, the value will be rounded off before display. For example, if a value of 0.008 is to be displayed with a scale of 2, the displayed value will be 0.01. Furthermore, if a value of 0.004 is to be displayed with a scale of 2, the displayed value will be 0.00.

Process variables shall use the nominal engineering units. Alternative engineering units may be used if they are 1) larger than and 2) on the same logarithmic scale as the nominal engineering unit. For example, active power, which has nominal engineering units of kW, may use MW, but not W or horsepower. If alternative units are used, the required scale increases by the magnitude of the difference between new and nominal engineering units, but the maximum precision does not change. For example, if tons are used to represent weight, which has nominal units of kg, the required scale increases from 1 to 4. This is to ensure the alternative unit is capable of displaying the full range of the process variable that is allowed under the precision and scale of the nominal engineering unit. If the engineering unit is a fraction, the numerator unit may be substituted according to the aforementioned rules. If the denominator unit is changed, the new units must be 1) smaller than and 2) on the same logarithmic scale as the base engineering unit. Alternative units that are equivalent to the nominal units shall not be used (e.g., g/m3 instead of mg/L).

The table below specifies the nominal engineering units, **maximum allowable** precision and **required** scale for each process variable.

Table 11 Precision and Scale Variable List

Process Variable	Display Unit	Precision	Scale
Air flow rate	m^3/hr	5	0
Analysers – Aluminium	mg/L	4	3
Analysers – Chlorine (free or total)	mg/L	3	2
Analysers – Conductivity	μS/cm	4	1
Analysers – Bulk Density	g/L	4	0
Analysers – Specific Gravity	kg/L	4	2
Analysers – Dissolved Oxygen	mg/L		
Analysers – Fluoride	mg/L	3	2
Analysers – Iron	mg/L	4	3
Analysers – Nitrate	mg/L		
Analysers – pH	pH	4	2

Process Variable	Display Unit	Precision	Scale
Analysers – Turbidity	NTU	6	2
Analysers - Manganese	mg/L	4	3
Analysers – MIB/Geosmin	ng/L	3	1
Analysers - Water Colour	PCU	3	0
Communication – Port Speed/In rate/Out rate	kbps	9	0
Communication – Signal Power	dBm	4	0
Delay (incl. alarm)	s	5	0
Dose Rate – Flow Paced	mg/L	4	1
Dose Rate – Fixed Speed	mL/s	4	1
Electrical – Active Power	kW	5	1
Electrical – Reactive Power	kVAR	6	0
Electrical – Total Power	kVA	6	0
Electrical – Energy	kWh	6	0
Electrical – Current	A	3	0
Electrical – Voltage	V	3	0
Electrical – Frequency	Hz	2	0
Feed rate	kg/hr	5	2
Flow – Pumps	L/s	5	1
Flow – Dosing Pumps	L/s or mL/s	4	1
Flow – Totalising / Report	ML/day	5	2
Fluid velocity	m/s		
Level (Actual volume of Vessel to be shown)	%	4	1
Noise	dBA	4	1
PLC Scan Time	ms	3	0
Pressure (for vessels, pumps)	kPa	6	1
Pressure (for Pressure gauges in pipelines)	mAHD (Meter Australian Height Datum)	5	1
Sequence time and step time	s	5	2
Slow rate	g/s	2	1
Speed – motor	rpm	5	0
Speed – VSD	%	4	1

Process Variable	Display Unit	Precision	Scale
Temperature	C	4	1
Torque – valve actuator	Nm	6	1
Vibration	mm/s^2	3	0
Weight	kg	6	1