Engineering Standard

B-SPE-STD-012

Lime Storage, Mixing and Dosing System

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SOURCE STORE SUPPLY

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Contents

1 Purpose 8

2 Application of Engineering Standards 9

3 Definitions 10

4 Abbreviations 12

5 Reference Documents 14

6 Applicable Chemical Used 18

6.1 Hydrated Lime (Calcium Hydroxide) 18

7 General Requirements 20

7.1 Safety in Design 20

7.2 Engineering Units 20

7.3 Design Life 20

7.4 Site Conditions 20

7.5 Materials 21

7.6 Colour and Coatings 22

7.7 Pipework, Fittings, Valves and Isolation 22

7.7.1 Pipework sizing and Line velocity 22

7.8 Civil Works 23

7.9 Mechanical and Structural Works 23

7.10 Electrical Works 23

7.11 Instrumentation Works 24

7.12 Control Systems 24

7.13 Cyber Security 25

7.14 Safety Showers and Eyewashes 25

7.15 Signage, Tagging, Marking and Labelling 25

7.16 Design Philosophy 25

8 Lime Delivery and Unloading System 27

8.1 Modes of Lime Powder Delivery 27

8.2 Bulk Delivery 27

8.2.1 Unloading Bay 28

8.2.2 Transfer / Fill Point 29
8.2.3 Transfer Fill Line 29
8.2.4 Local Control Panel 30
8.3 Large Bag Delivery 31
8.3.1 Large Bag Unloading 31
8.3.2 Discharge Hopper System 31
8.3.3 Conveyance System to Storage Silo 32
8.3.4 Local Control Panel 35
9 Lime Storage System 37
9.1 Storage Silo 37
9.1.1 Number and Size of Silos 38
9.1.2 Silo Labelling 39
9.1.3 Design Pressure and Temperature 39
9.1.4 Silo Materials 39
9.1.5 Fill Line Connection 40
9.1.6 Weight Measuring Device 40
9.1.7 Level Switch 42
9.1.8 Silo Access 42
9.1.9 Dust Collector and Vent Filter System 43
9.1.10 Pressure/Vacuum Relief Devices 44
9.1.11 High Pressure Switch 45
9.1.12 Dehumidifier 45
9.1.13 Bin Activator or Bin Vibrator 45
9.1.14 Silo Aeration 46
9.1.15 Knife Gate Isolation Valve 47
9.1.16 Rotary Valve 47
9.2 Intermediate Hopper 47
9.3 Temporary Storage of Large Bags 49
10 Lime Mixing/Batching System 50
10.1 Lime Powder Feeding System 50
10.1.1 Transition Hopper 51
10.1.2 Agitator 51
10.1.3 Screw Feeder System 51
10.2 Lime Mixing/Batching Tank System 52
10.2.1 Lime Mixing/Batching Tank 52
10.2.2 Powder Fill Line 57
10.2.3 Mixing/Batching Water Supply 57

10.2.4 Tank Outlet and Transfer Line 58
11 Lime Slurry Dosing System 60
11.1 Eductor System 60
11.1.1 Motive Water System 61
11.2 Pumped System 62
11.2.1 Variable concentration and fixed flow system 62
11.2.2 Fixed concentration and variable flow system 63
11.2.3 Batching Transfer System 64
11.3 Lime Slurry Dosing Line 64
11.3.1 Dosing Spears 64
11.4 Buried Pipes and Dose Pits 65
11.4.1 Buried Pipes 65
11.4.2 Dosing Pits 66
12 Lime Saturator System 67
12.1 Lime Saturator 67
12.1.1 Size and Number 68
12.1.2 Saturator Materials 68
12.1.3 Saturator Feed Line 69
12.1.4 Feed well 69
12.1.5 Overflow Launders 70
12.1.6 Saturator Rake Mechanism 70
12.1.7 Saturator Drain 71
12.1.8 Sample Collection Ports 71
12.1.9 Saturator Access 71
12.1.10 Saturator Instrumentation 71
12.2 Lime Slurry Feed Line 73
12.3 Dilution Water Supply 74
12.4 Lime Sludge Recycling System 74
12.5 Polymer Dosing System 75
12.6 Limewater Outlet Line 75
12.7 Lime Sludge Removal 76
12.8 Saturator Bypass Line 77
13 Limewater Dosing System 78
13.1 Limewater Holding/Dosing Tanks 78

13.1.1 Tank Number and Sizing ... 79
13.1.2 Level Devices ... 79
13.2 Limewater Dosing System Details ... 80
13.2.1 Suction Lines ... 81
13.2.2 Calibration Cylinders ... 81
13.2.3 Dosing Pumps ... 81
13.2.4 Pressure Relief Valves ... 82
13.2.5 Pulsation Dampeners ... 83
13.2.6 Pressure Transmitter ... 83
13.2.7 Flow Meter ... 83
13.2.8 Pressure Sustaining Valve / Back Pressure Valve ... 83
13.2.9 Chemical Return Line ... 84
13.2.10 Dosing Lines ... 84
13.2.11 Skid and Dosing Line Draining and Flushing ... 85
13.2.12 Dosing Spears ... 86
13.2.13 Duty Rotation ... 86
13.3 Chemical Mixing ... 86
13.3.1 Channel Mixing ... 86
13.3.2 Static Mixing (Pipe) ... 87
13.3.3 Recirculation / Jet Mixing ... 88
13.3.4 Mechanical Mixing ... 88
13.4 Buried Pipes and Dose Pits ... 88
14 Acid Flushing System ... 89
14.1 Acid Storage System ... 90
14.2 Acid Batching Tank System ... 91
14.2.1 Tank Number and Sizing ... 92
14.3 Acid Recirculation System ... 93
14.4 Water Flushing ... 94
15 Chemical Enclosures, Buildings, and Bunds ... 95
15.1 Lime Storage Building ... 95
15.2 Acid Storage Building ... 96
15.3 Access and Layout ... 96
15.4 Ventilation ... 97
15.5 Compressed Air Room ... 97
15.6 Bund Arrangement ... 97

15.6.1 Bund Sumps ... 98
15.6.2 Safety Showers and Eyewashes ... 98

16 Standard Designs ... 99

17 Process Control Requirements ... 100

17.1 Process Control Narratives ... 100

17.1.1 Delivery / Unloading System ... 101
17.1.2 Powder Transfer to Intermediate Hopper ... 103
17.1.3 Lime Slurry Mixing System ... 104
17.1.4 Lime Slurry Batching System ... 105
17.1.5 Lime Slurry Dosing System ... 106
17.1.6 Lime Saturator System ... 109
17.1.7 Limewater Dosing System ... 110
17.1.8 Acid Batching and Flushing System ... 111

17.2 Control Modes ... 112

17.2.1 Lime Slurry Mixing System ... 114
17.2.2 Lime Slurry Batching System ... 116
17.2.3 Lime Slurry Dosing System (fixed flow) ... 117
17.2.4 Lime Saturator ... 118
17.2.5 Limewater and Lime Slurry Dosing System (variable flows) ... 118
17.2.6 Actuated Isolation Valves ... 121

17.3 Batching and Dosing Calculations ... 121

17.3.1 Lime Slurry Dosing ... 121
17.3.2 Saturator and Limewater Dosing System ... 122

17.4 Alarms ... 123

17.5 Interlocks and Trips ... 123

18 Testing and Commissioning ... 124

19 Performance Testing ... 125

20 Changes from previous version ... 126

21 Verification ... 126

22 Further Information ... 126

Appendix A Lime Powder Information and Sample Calculations ... 127

Appendix B Typical Trips and Interlocks for Lime System ... 132

1 Purpose

Seqwater Engineering Standards 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 and safe.

This Engineering Standard provides the minimum requirements and recommendations for all Seqwater works relating to the design and construction of lime powder chemical delivery, storage, mixing, batching and dosing systems used in drinking water treatment. This document must be used in conjunction with the documents it references in order to assist in ensuring a fit for purpose asset.

This Engineering Standard is not intended to be relied upon solely for design, supply, and installation works; advice from specialist engineers and/or Manufacturers may be required on a case-by-case basis.

This document provides specific information in relation to Seqwater's requirements, preferences and best practices for lime storage, mixing, batching and dosing system that have been obtained over years of experience.

The standard shall apply to lime chemical delivered to Seqwater as powder. Refer to Section 6 of this document for specific detail of lime and its application. The standard shall apply to the following sub-systems:

- Lime powder unloading from bulk trucks and large bags.
- Lime powder storage.
- Lime slurry dosing system.
- Lime saturator system to produce saturated limewater solution.
- Limewater dosing system.
- Acid storage and batching to clean a lime system.
- Process control narratives and sample dosing calculations for the above systems.

The standard does not specify the requirements of:

- Trucks/tankers specifications to deliver lime powder to storage silos/hoppers.
- Lime sludge handling facilities.
- Acid used for other purposes except lime system cleaning.

2 Application of Engineering Standards

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

Seqwater Engineering Standards detail Seqwater's minimum requirements and recommendations to provide infrastructure that will be fit for purpose, and safe to operate and maintain. However, at all times the designer remains responsible for ensuring infrastructure designed is fit for purpose and safe to construct, operate, maintain, and demolish. In doing so 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 WSAA). Where no Australian Standard exists for a particular application, work must conform to the most current version of an industry accepted international standard.

Deviation from the requirements in this standard requires written agreement from Seqwater as per the deviation process detailed in Procedure X-PRO-STD-008 Asset Standards Management and Application. This process includes completion of an Asset Standards Deviation Request Form and submission via the Seqwater Project Representative (for external parties) or via Seqwater's Engineering Mailbox (engineering@seqwater.com.au) (for internal parties).

Where noted in this Engineering Standard that Seqwater approval or acceptance shall/must be sought, approval or acceptance must be gained through the Seqwater Asset Standard Deviation Request process, as identified 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 assets. This includes modifications to the functional design of an asset including technical changes made which would extend an asset outside of its design operating envelope and/or approved operation and maintenance practices.

In the case that it is identified that a specific requirement within this Engineering Standard does not meet the requirements of project specific documents, another Seqwater Asset Standard or Australian Legislation, Standards, Codes or Guidelines, the conflict must be brought to the attention of the Seqwater Principal Engineering Standards and Assurance (or their delegate) via the Engineering Mailbox (engineering@seqwater.com.au), and written agreement must be gained prior to application of the requirement.

Advice must be sought from Seqwater to clarify any ambiguities regarding this Engineering Standard.

Seqwater undertakes regular updates of Asset Standards. Before utilising this Engineering Standard, the complete list of Seqwater Asset Standards should be reviewed, to ensure currency and applicability of standards applied to the works.

3 Definitions

The following definitions (Table 3-1) apply to this Engineering Standard.

Table 3-1 – Definitions

Term	Definitions
Ambient Conditions	Refers to the weather-related conditions of the Site, including minimum, maximum and average values and durations of the following: temperature, UV exposure, humidity, rainfall.
Contractor	An entity engaged by Seqwater to undertake work in accordance with an agreed contract and defined scope of work.
Coefficient of Variation (CoV)	The CoV describes the deviation of local concentration from the mean within a cross section of a radial mixing device such as a pipe or channel. The lower the value of CoV, the better the mixing quality. A CoV of between 0.01 to 0.05 is a reasonable target for most mixing applications.
Critical Control Point	A point (setpoint) where failure of standard operation procedure could cause harm to customers, the environment, or the business.
Designer	An entity engaged by Seqwater to produce or modify a design for a project (including the design of temporary works); or who provides instructions to another party to complete works in a described manner. May also be the Contractor.
Design Life	The design life of equipment is the period of time during which the item is expected by its designers to provide the required functionality and availability, for the specific operating conditions.
Froude number	It is a dimensionless number that compares the ratio of the inertia forces of a unit of fluid to the weight of the unit of fluid – the inertial force divided by gravitational force.
Lime	Refers to hydrated lime powder (also known as slaked lime or calcium hydroxide - $Ca(OH)_2$).
Lime Slurry	A suspension of hydrated lime in water, also known as Milk of Lime.
Lime Utilization Factor	A factor that represents percentage utilization of lime powder to produce saturated lime solution in a lime saturator.
Limewater	Saturated aqueous solution of calcium hydroxide or hydrated lime produced in a lime saturator.
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.
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).
Process Conditions	Refers to the conditions that assets may be subject to as a result of operating plant and equipment.

Term	Definitions
REX	Seqwater's electronic document and records management solution (eDRMS) that provides for the capture, management, security, and access to non-controlled documents and records. REX is the location for the creation, preparation and revision of Controlled Documents.
SCADA	The system which acquires data from remote devices such as valves, pumps, instruments, transmitters etc. and provides overall control remotely from a host software platform. The host platform also provides functions for graphical displays, alarming, trending and historical storage of data
Seqwater Engineering Approval / Acceptance	Written sign-off gained via the Deviation Request process, as detailed in X-PRO-STD-008 Asset Standards Management and Application.
Shall / must	Indicates a mandatory requirement.
Should	Indicates a recommendation or guidance.
Site	Refers to the location at which the treatment work exists or is to exist.
Site Conditions	Means any of the ambient conditions, process plant, ground conditions and operating conditions that may be reasonably expected to occur during normal operation.

4 Abbreviations

The following abbreviations (Table 4-1) apply to this Engineering Standard.

Table 4-1 – Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods (Code / Regulations)
ADWG	Australian Drinking Water Guidelines
AS	Australian Standards
CCP	Critical Control Point
CoV	Coefficient of Variation
GRP	Glass-fibre Reinforced Plastic
HACCP	Hazard analysis and critical control points
HDPE	High Density Polyethylene
HMI	Human-Machine Interface
IBC	Intermediate Bulk Container
IP	Ingress Protection
LCP	Local Control Panel
LAHH	Level Alarm High High
LALL	Level Alarm Low Low
LIW	Loss-in-Weight
LSHH	Level Switch High High
LSLL	Level Switch Low Low
MCS	Master Control System
OHL	Operational High Level
OLL	Operational Low Level
OHW	Operational High Weight
OLW	Operational Low Weight
PID	Proportional–Integral-Derivative
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
P&ID	Piping and Instrumentation Diagram
SCADA	Supervisory Control and Data Acquisition
SME	Subject Matter Expert
TSI	Technical Support and Improvement
VSD	Variable Speed Drive

Abbreviation	Description
WSAA	Water Services Association of Australia
WTP	Water Treatment Plant

5 Reference Documents

The documents listed in Table 5-1,

Table 5-2, and Table 5-3 and the requirements therein, are relevant to this Engineering Standard. In their latest editions, these documents form a part of this Engineering Standard. Note that this is not an exhaustive list of documents relevant to the works.

Current Seqwater Standards and Procedures can be found in the internal document database REX, and Seqwater Standards and Drawings in the internal Waternet page using the following link:

https://waternet.corporate.local/AssetMan/Engineeringservices/Pages/Engineering%20and%20Asset%20Standards.aspx

Table 5-1 – Reference Seqwater Documentation

Asset Standard Document Number	Document Title	Controlled Document ID
B-PRO-STD-003	Piping and Instrumentation Diagram Drafting Procedure	PRO-02320
B-SPE-STD-003	Commissioning Requirements	SPE-00346
B-SPE-STD-005	Functional Description Documentation	SPE-00349
B-SPE-STD-007	Process Flow Diagram and Piping and Instrumentation Diagram Requirements	SPE-00351
B-SPE-STD-009	Liquid Chemical Storage and Dosing	SPE-00445
B-SPE-STD-011	Polymer, PAC, Pot Perm and Soda Ash Systems	SPE-00481
D-SPE-STD-001	Water Supply Networks Planning, Design and Construction (Seqwater Supplementary Manual to WSAA, Water Supply Code of Australia WSA03-2011)	SPE-00395
E-SPE-STD-001	Electrical Design and Construction	SPE-00352
I-SPE-STD-015	Instrumentation	SPE-00353
I-SPE-STD-005	High Priority Alarms & Interlocks Management	SPE-00356
I-SPE-STD-006	Monitoring and Control System Alarm and Event Management	SPE-00357
I-SPE-STD-009	Control Systems Architecture	SPE-00358
I-SPE-STD-010	Tag Naming Convention	SPE-00359
I-SPE-STD-011	Control System Testing	SPE-00360
I-SPE-STD-013	Control Systems Design and Construction	SPE-00361
I-TMP-STD-001	Functional Description Part A	TEM-00221
I-TMP-STD-005	Functional Description Part B	TEM-00222
M-SPE-STD-001	General Mechanical Specification	SPE-00367
M-SPE-STD-002	Fixed Platforms, Walkways, Stairways and Ladders	SPE-00366
M-SPE-STD-003	Valves for Water Applications	SPE-00323
M-SPE-STD-004	Protective Coatings	SPE-00348
M-SPE-STD-009	Flow Meters	SPE-00434
M-SPE-STD-010	Chemical Dosing Skids	SPE-00435
M-SPE-STD-012	Chemical Dosing Pumps	SPE-00430
M-SPE-STD-013	Chemical Dosing Piping	SPE-00355
X-LST-STD-002	Seqwater Preferred Equipment	REG-01074

Asset Standard Document Number	Document Title	Controlled Document ID
X-PRO-STD-001	Asset Standards Document Classification and Naming Structure	PRO-01873
X-PRO-STD-002	Engineering Drawing Number Procedure	PRO-01872
X-PRO-STD-004	Development and Review of Asset Standards	PRO-01874
X-PRO-STD-006	Equipment Numbering and Naming 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, Construction, Operation and Maintenance	PRO-01617
X-PRO-STD-013	Engineering Technical Hazard Study	PRO-02140
X-TMP-STD-022	Asset Standards Deviation Request	TEM-00224
N/A	Control Systems Cyber Security Technical Guidelines	GDE-00326
N/A	Operational Sites – Chemical Quality Specification – Hydrated Lime (Graymont)	SPE-00469
N/A	Chemical Quality Specification – Hydrochloric Acid 32% w/w [as HCl] (Coogee Chemicals)	SPE-00464
N/A	Chemical Quality Specification – Citric Acid 50% By Weight [as C6H8O7] (Coogee Chemicals)	SPE-00468
N/A	Enterprise Risk Management Framework	FRA-00014
N/A	WHS Hazardous Chemicals Procedure	PRO-00008
N/A	WTP and Supply System Process Validation	SPE-00320
N/A	Commercial Services – Chemical Supplier Matrix	REG-00250
N/A	Powder Chemical Storage and Batching Asset Class Plan	PLN-00402
N/A	Seqwater Energy Management System and Plan	PLN-00393
N/A	Seqwater Corporate Energy Strategy	PLN-00452
N/A	Powder Chemical Storage and Batching Asset Class Plan – Assessment	(REX D15/117201)

Table 5-2 – Reference External Standards, Specifications and Codes

Standard/Specification	Document Title
API 620	Design and Construction of Large, Welded, Low-Pressure Storage Tanks
API 650	Welded Tanks for Oil Storage
AS 1000	International System of Units (S.I.) and its Applications
AS/NZS 1170	Structural Design Actions (set)
AS 1216	Class Labels for Dangerous Goods
AS 1319	Safety Signs for the Occupational Environment
AS/NZS 1477	PVC pipes and fittings for pressure applications
AS 1418	Cranes, Hoist, and Winches Set
AS 1554	Structural Steel Welding
AS 1657	Fixed platforms, walkways, stairways and ladders - Design, construction and installation
AS 1668	The Use of Ventilation and Air-conditioning in Buildings set
AS 1680	Interior and Workplace Lighting
AS 1768	Lightning Protection
AS 2118	Automatic Fire Sprinkler System
AS 2312.1	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings - Paint coatings
AS 2312.2	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Hot dip galvanizing
AS 2359	Powered Industrial Trucks
AS 2566.1	Buried Flexible Pipelines Part 1: Structural Design
AS 2566.2	Buried Flexible Pipelines Part 2: Installation
AS 2809	Road Tank Vehicles for Dangerous Goods (series)
AS/NZS 3000	Wiring Rules 2007, Electrical Installations
AS 3600	Concrete Structure
AS 3774	Loads on Bulk Solids Containers
AS 3780	The Storage and Handling of Corrosive Substances
AS/NZS 3833	The Storage and Handling of Mixed Classes of Dangerous Goods in packages and IBCs
AS 3959	Construction of Building in Bushfire-prone Areas
AS 3990	Mechanical Equipment – Steelwork
AS 3996	Access Covers and Grates
AS/NZS 4020	Testing of products for use in contact with drinking water
AS 4100	Steel Structures
AS 4766	Polyethylene storage tanks for water and chemicals
AS 4775	Emergency Eyewash and Shower Equipment
ADG Code	Australian Code for the Transport of Dangerous Goods by Road & Rail
ASTM D1998	Standard Specification for Polyethylene Upright Storage Tanks
ANSI/AWWA B202	Quicklime and Hydrated Lime
UN Model Regulation	Recommendations on the Transport of Dangerous Goods
WHS Act 2011	Work Health and Safety Act 2011
WSA 01 - 2004	Polyethylene Pipeline Code V 3.1

Standard/Specification	Document Title
WSA 03 - 2011	Water Supply Code of Australia V 3.1
WSA 201-2017	Manual for Selection and Application of Protective Coatings
WSAA Guidance Manual	Water Services Association of Australia *Manual for the application of Health-Based Target's for Drinking Water Safety, September 2015.*
Water Corporation - DS 72-01	Lime Storage Dosing and Mixing System – Basis of Design

Table 5-3 Seqwater Standard Drawings

Drawing	Description
B-DWG-STD-001	P&ID Legend - Sheet 1 of 5, Symbols
B-DWG-STD-002	P&ID Legend - Sheet 2 of 5, Codes and Abbreviations
B-DWG-STD-003	P&ID Typical Details - Sheet 1 of 2, Instrumentation Valve
B-DWG-STD-004	P&ID Typical Details - Sheet 2 of 2, Motor Control
B-DWG-STD-005	P&ID Legend – Sheet 3 of 5, Material Codes
B-DWG-STD-006	P&ID Legend - Sheet 4 of 5, Symbols
B-DWG-STD-007	P&ID Legend - Sheet 5 of 5, Symbols
B-DWG-STD-016	Standard P&ID Liquid Chemical Ring Main Dosing System
B-DWG-STD-027	Standard P&ID Polymer, PAC, Pot Perm and Soda Ash Storage, Batching and Dosing System – Sheet 1 of 2
B-DWG-STD-028	Standard P&ID Polymer, PAC, Pot Perm and Soda Ash Storage, Batching and Dosing System – Sheet 2 of 2
B-DWG-STD-021	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)
B-DWG-STD-022	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 2 of 6 (Lime Saturator System)
B-DWG-STD-023	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 3 of 6 (Limewater Dosing System)
B-DWG-STD-024	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 4 of 6 (Lime Slurry Pumped Dosing System)
B-DWG-STD-025	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 5 of 6 (Lime Slurry Eductor Dosing System)
B-DWG-STD-026	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 6 of 6 (Acid Flushing System)

6 Applicable Chemical Used

This section provides a brief overview on hydrated Lime (Calcium Hydroxide) particularly its properties, as well as why and how it is used at Seqwater.

Other powder chemicals may be considered or required for the application of this Engineering Standard. Approval shall be sought from Seqwater Principal Engineering Standards and Assurance for the validity and application of this standard in such circumstances.

For key risks associated with lime chemical, and for generic requirements and considerations, Seqwater PRO-00008 *WHS Hazardous Chemicals Procedure* shall be referred.

Seqwater only uses hydrated lime that it has procured under contract to ensure that the quality of this product meets our specifications. Seqwater document SPE-00469 *Chemical Quality Specification – Hydrated Lime* shall be referred for the product quality of hydrated lime. Some details of hydrated lime are also provided in Appendix A.

6.1 Hydrated Lime (Calcium Hydroxide)

At Seqwater sites, hydrated lime is typically used for pH correction, alkalinity increase and corrosion control. Hydrated lime will predominantly be used at sites that are medium to large capacity to be cost effective.

Where used at Seqwater sites, lime shall be hydrated lime (also known as slaked lime or calcium hydroxide, $Ca(OH)_2$). Quicklime (CaO) or unslaked lime shall not be used as it reacts aggressively with water and generates significant heat which poses a heightened safety risk.

At Seqwater sites, hydrated lime is supplied as a white finely powdered material. Depending on the site-specific demand, it is delivered to Seqwater sites with large package bag (500 kgs) or bulk delivery by trucks.

Lime is dosed into the process system either as a slurry or as a saturated chemical solution, known as limewater. Lime slurry contains additional water to create a suspension of hydrated lime.

Lime slurry is typically used for dosing into raw water, sludge treatment process and treated water to correct pH or increase alkalinity or control corrosion. When lime slurry is dosed into the treated water, build-up of lime scale in the pipelines and lime sludge in the treated water reservoirs often become significant operational issues.

Limewater is used as an alternative to lime slurry for dosing into the treated water. Limewater is a saturated aqueous solution of calcium hydroxide produced in a lime saturator. The resultant saturated limewater solution concentration will mainly depend on the process temperature.

Lime solubility decreases as temperature increases, i.e. lime solution concentration at the saturation point increases as temperature is lower, as indicated below in

The following table . Considering South East Queensland's ambient temperature range, the lime saturator is expected to produce limewater with the concentration of around 1.5 gm/L.

The following table provides lime solubility data considering South East Queensland water temperature.

Table 6-1 Solubility of Hydrated Lime with Various Temperatures

Temperature (°C)	Hydrated Lime solubility ($Ca(OH)_2$) (mg/L)
10	1750
20	1650
30	1520
40	1400

Limewater dosing instead of lime slurry dosing will offer several operational and safety benefits. It does not increase treated water turbidity like lime slurry and significantly reduces the lime scaling and blockage in pipelines and lime sludge build up in storage tanks or reservoirs. Hence, it reduces or eliminates the maintenance requirement to remove lime build up in the pipeline and reservoir and the safety hazards associated with inhaling lime dust in a confined space area. However, the design and installation of a limewater dosing system with a lime saturator requires significantly high capital cost.

7 General Requirements

This section provides a number of general requirements for the design and installation of lime powder chemical systems specified in this standard with reference to other applicable standards.

7.1 Safety in Design

In order to incorporate safety in design, Seqwater has a number of standards that shall be used in the design and review of new assets and installations and modification to existing systems:

i. *X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance*

ii. *X-PRO-STD-013 Engineering Technical Hazard Study*

These standards include discussion of the various risk assessments/reviews, studies, and management systems that must be in place/demonstrated and used in order to satisfy legislative and Seqwater requirements.

All designs and installations shall ensure due consideration of reliability, accessibility, maintainability, buildability and operability is undertaken. This shall be demonstrated through auditable design documentation, reviews, communication, meetings, processes/procedures etc.

Design decisions and residual risks in design shall be supported, reviewed and accepted in accordance with *FRA-00014 Enterprise Risk Management Framework.*

For key risks associated with lime, generic requirements and considerations, refer to *PRO-00008 Hazardous Chemicals Procedure,* Safety Data Sheets (SDS) and this Engineering Standard. The details of chemical provided in this standard are non-exhaustive and the designer shall consider industry and supplier expertise in the design, handling and management of lime and lime systems.

7.2 Engineering Units

Where not specified in this document, equipment and instrument units shall be in accordance with the requirements of *AS 1000 International System of Units (S.I) and its Applications* and *I-SPE-STD-013 Control Systems Design and Construction.*

7.3 Design Life

Seqwater *PLN-00402 Powder Chemical Storage and Batching Asset Class Plan* shall be referred to for the design life of silos, hoppers, mixing/batching tanks and dosing tanks.

Seqwater relevant *Asset Class Plans* and standard specification *M-SPE-STD-001 General Mechanical* shall be referred for the design life of valves, pumps, flow meters, pipework and protective coatings. For the design life of electrical equipment refer to *E-SPE-STD-001 Electrical Design and Construction.*

7.4 Site Conditions

The term Site Conditions is intended to mean any of the ambient conditions, process conditions, ground conditions and operating conditions that may be reasonably expected to occur during normal operation.

Ambient conditions for mechanical, electrical and control equipment shall be specified from the following documents:

i. *E-SPE-STD-001 Electrical Design and Construction*

ii. *I-SPE-STD-013 Control System Design and Construction*

iii. *M-SPE-STD-013 Chemical Dosing Piping*

Design and construction shall allow all assets to operate continuously and uninterrupted between the minimum and maximum Site Conditions specified.

If not defined by Seqwater, Site Conditions for design and construction of process equipment shall be determined by the Designer or Contractor and submitted to Seqwater for approval.

7.5 Materials

Materials selected for silos, hoppers, mixing/batching and storage tanks, screw feeder, saturator, piping and equipment shall be appropriate to the applications and compatible to lime, acid and Site Conditions for which they are intended. If stainless steel is used, the passivation must be carried out correctly to protect fabricated welded areas.

Where not specified, requirements shall be sought from the following sources as a minimum:

i. Relevant Australian and industry standards and specifications for the material(s) selected

ii. Vendor and supplier recommendations and experience

iii. Safety Data Sheet (SDS)

iv. *M-SPE-STD-001 General Mechanical*

v. *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

vi. *M-SPE-STD-004 Protective Coatings*

vii. *M-SPE-STD-010 Chemical Dosing Skids*

viii. *M-SPE-STD-013 Chemical Dosing Piping*

ix. *D-SPE-STD-001 Water Supply Networks Planning, Design and Construction*

x. *PLN-00402 Powder Chemical Storage and Batching Asset Class Plan*

xi. *Powder Chemical Storage and Batching Asset Class Plan – Assessment (REX ID – D15/117201)*

Note that where lime powder, lime slurries and lime solutions are corrosive to a particular material, a protective lining can be provided for storage, mixing/batching and dosing tanks to inhibit corrosion.

Equipment and materials that will be in contact with applicable drinking water treatment chemicals must be of a quality that will not leach substances in quantities capable of producing adverse health effects on those consuming the water or that would otherwise render the water treated properly with these chemicals unfit for public use.

Materials used in equipment, piping, coatings, joining and others which may come in contact with drinking water must have an appropriate certification to AS/NZS 4020, refer to *M-SPE-STD-001 General Mechanical* for further details.

In general, this engineering standard does not specify the type and manufacturer of equipment (pumps, valves, mixers, instruments etc.) for a design. Where not specified, requirements shall be sought from the followings as a minimum:

i. *X-LST-STD-001 Seqwater Preferred Equipment*

ii. *M-SPE-STD-012 Chemical Dosing Pumps*

iii. *M-SPE-STD-009 Flow Meters*

iv. *M-SPE-STD-001 General Mechanical*

v. *I-LST-STD-001 Control System Prescribed Equipment*

Improved energy performance of new equipment shall be considered in the equipment selection process as specified in the following documents:

i. *PLN-00393 Seqwater Energy Management System and Plan*

ii. *PLN-00452 Seqwater Corporate Energy Strategy*

7.6 Colour and Coatings

Buildings, enclosures and shelters, pipes, tanks, silos, lime saturator, fittings, fixtures, equipment and surfaces shall be coloured / coated in accordance with:

i. *M-SPE-STD-001 General Mechanical*
ii. *M-SPE-STD-004 Protective Coatings*
iii. *WSA 201-2017 Manual for Selection and Application of Protective Coatings*
iv. *AS 2312.1 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings - Paint coatings*
v. *AS 2312.2 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Hot dip galvanizing*
vi. Other relevant legislation and Australian Standards, especially those referenced in the above documents.

Note that where acid solutions used for cleaning are corrosive to a particular material, a protective lining can be provided for the tanks to inhibit corrosion.

7.7 Pipework, Fittings, Valves and Isolation

i. All pipework and fittings shall comply with the requirements of the following standards, and the relevant industry and Australian standards referenced within:

   a. *M-SPE-STD-STD-001 General Mechanical*
   b. *M-SPE-STD-003 Valves for Water Applications*
   c. *M-SPE-STD-010 Chemical Dosing Skids*
   d. *M-SPE-STD-013 Chemical Dosing Piping*

ii. Any flexible connecting sleeves will be designed and installed as best as practical to avoid large losses of lime powder in the case of failure.

iii. For the lime system, generally, diaphragm valves should be used for all applications unless specified otherwise.

iv. Mechanical isolation of piping and dosing systems shall be in accordance with *M-SPE-STD-001 General Mechanical*.

7.7.1 Pipework sizing and Line velocity

Suitable line velocities must be maintained in all pipework to manage stagnation, settlement and degradation of chemical as well as maintain the integrity of assets. Line velocities should generally comply with the requirements in Table 7-1 and

Table 7-2.

Table 7-1 Recommended Line Velocities for Fluids

Purpose	Pipe Material	Maximum (No Fast Opening / Closing Valves)	Maximum (Fast Opening / Closing Valves)	Minimum pipeline velocity
General	Plastic, GRP	2 m/s	1.5 m/s	0.5 m/s
	Metallic	3 m/s	2.5 m/s	0.5 m/s
Pump suction	All	1 – 1.5 m/s		0.5 m/s

Table 7-2 Recommended Line Velocities for Lime Slurries

Purpose	Pipe Material	Maximum line velocity	Minimum line velocity
General	Plastic, GRP	2.5 m/s	2 m/s
	Metal Pipes	3 m/s	2 m/s
Pump suction	All	1.5 m/s	1 m/s

The pipework layout for lime slurries shall be designed to minimise solid deposition. As far as practicable, it should avoid any vertical drops of pipe to avoid solid settling in the bottom and plug the pipe when not used continuously. To avoid pipe clogging, a minimum line velocity of 2 m/s is recommended for lime slurries and suspensions. However, the design may select a lower minimum line velocity considering project specific design constraints.

The pipework used to transfer and dose lime slurries is required to be designed to be flushed afterwards with water (i.e. raw water, or site service water or potable water depending on the application) and periodic acid cleaning.

For pneumatic conveyance, the design velocity shall prevent settlement of lime powder in conveying system and erosion of conveying pipework / materials. A line velocity within the range of 15-20 m/s is recommended for the lean phase lime powder conveying system. It is important to note that higher line velocity with low material/air ratio can cause build-ups of $CaCO_3$ into initial pipe sections.

7.8 Civil Works

Civil works shall comply with the requirements of *WSA 03-2011 Water Supply Code of Australia* as amended by *D-SPE-STD-001 Water Networks Planning, Design and Construction*, and relevant Seqwater, Australian and industry standards, specifications and codes.

All concrete shall be suitably finished and coated for the application and in accordance with *M-SPE-STD-004 Protective Coatings.*

7.9 Mechanical and Structural Works

Mechanical and metal structural design, construction and equipment selection shall be completed in accordance with the requirements of Seqwater's Specifications, Australian and industry Codes, Specifications and legislative requirements.

Refer to *M-SPE-STD-001 General Mechanical Specification* for further guidance.

7.10 Electrical Works

All electrical works shall comply with the requirements of *E-SPE-STD-001 Electrical Design and Construction*, the standards referenced within, and relevant Seqwater, Australian and industry Standards, Specifications and Codes.

7.11 Instrumentation Works

Instrumentation shall comply with the requirements of *E-SPE-STD-001 Electrical Design and* Construction, *I-SPE-STD-015 Instrumentation,* and relevant Australian and industry standards, specifications and codes. Instrumentation shall include the following:

i. Transmitters and control circuits shall comply with the voltage requirements of *E-SPE-STD-001 Electrical Design and Construction*.

ii. Where analogue instruments are used:

    a. Analogue signal transmission shall be linear, 4-20 mA DC proportional to the range of measured variable.

    b. Shall be capable of delivering a “fault” signal.

iii. Safety devices or switches used for equipment protection or critical process safety or protection against environment release or personal safety shall be hardwired and fail-safe with the requirements of *I-SPE-STD-013 Control Systems Design and Construction*.

iv. Flow meters shall comply with the requirements of *M-SPE-STD-009 Flow Meters* for the selection and installation.

v. Indicators shall comply with the requirements of the *Instrumentation Indicators* section of *E-SPE-STD-001 Electrical Design and Construction*.

vi. Displays shall be digital and suitably weatherproof to the Site Conditions and shielded to prevent glare.

vii. Radar type level transmitters should be generally used in lime silos, lime slurry and limewater tanks.

viii. Vibrating fork level switches should be used in powder silos, lime slurry and limewater tanks.

ix. Appropriate cover including PVC sleeve extending into the liquid surface should be considered to maintain the performance of level instruments in high dust conditions.

7.12 Control Systems

Control systems shall comply with the requirements of the standards listed below, the requirements of this standard, and relevant Australian and industry Standards, Specifications and Codes:

Table 7-3 Key standards for Control Systems

Document number	Document Title	Waternet Referecne
I-SPE-STD-005	High Priority Alarms & Interlocks Management	SPE-00356
I-SPE-STD-009	Control Systems Architecture	SPE-00358
I-SPE-STD-013	Control Systems Design and Construction	SPE-00361

Standards noted in the above table are the key standards relevant to this standard, but the standards noted within these key standards shall also apply and must be considered as part of the design.

7.13 Cyber Security

For all units associated with lime powder storage, transfer, batching or dosing, whether supplied as a package unit or not, the vendor shall comply with Seqwater cyber security requirements as specified in the GDE-00326 *Control Systems Cyber Security Technical Guidelines.* The vendor shall provide sufficient information as requested by Seqwater to allow the assessment of cyber security risks.

7.14 Safety Showers and Eyewashes

Where required, safety showers and eyewashes shall comply with the requirements of *AS 4775 Emergency Eyewash and Shower Equipment.*

In addition to the requirements of *AS 4775 Emergency Eyewash and Shower Equipment,* potable water pipework and materials installed for use in supplying water to emergency showers and eyewashes shall:

i. Be installed out of direct sunlight, or

ii. Where not practicable to install out of direct sunlight, be insulated and lagged to ensure the safety of personnel and prevent excessive water temperature.

Safety showers and eyewashes shall be fitted with a flow switch and flow alarm to identify when these devices have been activated.

7.15 Signage, Tagging, Marking and Labelling

All equipment, instrumentation, and pipework should be numbered and labelled, and include nameplates in accordance with:

i. *M-SPE-STD-001 General Mechanical*

ii. *E-SPE-STD-001 Electrical Design and Construction*

iii. *I-SPE-STD-010 Control System Tag Naming*

iv. *X-PRO-STD-006 Equipment Numbering and Naming Conventions*

v. *PRO-00008 WHS Hazardous Chemicals*

7.16 Design Philosophy

The key emphasis of any lime system design shall be the minimisation of maintenance requirements and whole of life cycle cost. This is due to the difficulties associated with the handling of lime powder and lime slurries.

In this standard, the design and construction requirements both for lime slurry and limewater dosing systems have been provided. A system consisting of a single storage silo, an intermediate hopper, two duty/standby screw feeders and two duty/standby mixing/batching tanks are proposed for lime slurry feeding into a saturator or dosing into a main or reservoir. This standard does not propose using a wetting system to pre-wet the lime powder for the mixing/batching system as Seqwater's current experience suggests that a wetting system is prone to blockages and unreliable. In general, the use of a Loss-in-Weight (LIW) feeder is preferred over a volumetric feeder due to its self-calibration feature and capability of complete control over product quality variations.

For lime slurry dosing directly into a main or reservoir, design options for the mixing/batching and dosing system are provided in Section 11. These options have been specified based on Seqwater's current experience and shall be followed. A system of fixed concentration and variable flows is recommended where quick response time is needed due to changes in water quality and/or production flow rates. In addition, Seqwater has experienced fewer operational issues from pipe and valve blockages from a fixed concentration and variable flow rates system than that of a variable concentration and fixed flow rate system.

For a lime saturator and limewater system, a variable concentration and fixed flow system has been proposed as the preferred option for saturator feed considering the buffering capacity of a lime saturator from the changed lime slurry concentrations. In addition, a usual short feed line between a mixing tank and a lime saturator reduces the likelihood of lime blockages in the presence of automated water flushing and acid cleaning systems.

For the design of a limewater dosing system, in addition to the above requirements, a single lime saturator is suggested considering the high capital cost and maintenance requirements. However, two limewater holding/dosing tanks are recommended to achieve improved operational flexibility for maintenance and cleaning requirements.

Redundancy requirements for all other essential equipment have not been specified in this standard. The project shall determine the final number and redundancy requirements for equipment on a case-by-case basis considering the site's size, availability, criticality requirements, lime supply chain risk, usage, site location and staffing, reliability, operability, maintainability, other Seqwater standard requirements and any other relevant issues.

The designer shall assess the operational benefits, cost implication and alternate chemical dosing systems prior to the selection of a lime slurry or limewater dosing system.

8 Lime Delivery and Unloading System

The lime chemical delivery and unloading system mainly includes the following:

i. Modes of lime chemical delivery

ii. Unloading bay, filling point and control panel for bulk delivery

iii. Lime powder transfer from large bulk bags

This section should be read in conjunction with standard P&ID *B-DWG-STD-021 Lime Storage, Mixing/Batching, and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)* as referenced in Section 0.

8.1 Modes of Lime Powder Delivery

Seqwater receives lime powder chemical through several acceptable delivery modes including:

i. **Bulk powder chemical delivery**: delivered by trucks and pneumatically transferred into storage silos.

ii. **Large bulk bag delivery**: delivered with 500 kg bags on pallets, and temporarily stored in a storage area prior to transfer into a storage silo/hopper.

Lime is normally delivered at Seqwater sites in bulk by trucks with the exception of smaller sites where delivered with large bulk bags. Lime delivery using small bags (e.g. in 25 kgs) is not practical and cost-effective and therefore should not be considered as an alternative delivery mechanism.

In general, the lime powder delivery mode will be determined by site and process specific requirements, lime physical and chemical properties, site staffing, frequency of use, economy of scale, cost, protection against shortage, transportation difficulty (e.g. in fair and poor weather), and by average consumption rates. The mode of delivery selected should reduce the frequency of unloading due to health and safety concerns.

When the average consumption rate is considered in determining the mode of lime powder delivery, the following guidelines should be used:

i. Sites actively using >1000 kg/week or more than two large lime bags per week should receive as bulk delivery from trucks.

ii. Sites actively using <1000 kg week of dry lime powder should receive as large package bags.

Irrespective of the delivery mechanism, the operation of the plant and lime systems shall not be interrupted during lime delivery and unloading.

8.2 Bulk Delivery

Bulk delivery using delivery trucks shall use a pneumatic transfer system to load lime powder directly into a storage silo.

The bulk delivery system shall generally include:

i. Unloading Bay

ii. Transfer / Fill Point

iii. Transfer Fill Line

iv. Local Control Panel (LCP)

The road tankers for bulk delivery have their own power supply for pneumatic transfer. Therefore, the requirement of site power supply for bulk delivery is not considered in this standard.

8.2.1 Unloading Bay

A lime unloading bay shall be designed and constructed to transfer lime powder directly to storage silos from trucks. The unloading bay is needed to provide safe arrival, parking, unloading, vehicle turning and departure for delivery trucks.

The design shall consider lime suppliers' requirements which may be obtained directly from the suppliers.

The bulk lime unloading area shall include the followings:

i. A design that avoids the reversing of delivery vehicles. If reversing cannot be avoided, the design should allow the driver to reverse the vehicle into the unloading area and leave the site in a forward direction.

ii. Delivery apron not to be located on the main plant access unless sufficient road access space for other vehicles to safely pass during chemical unloading is provided.

iii. Appropriate markings and signs to identify the entry and exit of the unloading bay.

iv. Unloading platform with a suitable level hardstand area for lime delivery trucks.

v. Be isolated from liquid chemical systems and areas likely to be subject to liquid spills from chemical or water.

vi. Refer to Section 8.2.1.1 for the information whether trafficable lips or delivery bunds should be used in the delivery area.

8.2.1.1 Lime Spillage and Capture

Lime powder spillage must be contained and controlled to prevent any discharge into sewers, stormwater drains, basements, confined spaces or the environment.

For a small-scale spill, and where appropriate, lime powder is to be swept or collected with appropriate absorbent and stored in a chemical waste bin. For a largescale spill, lime powder is preferably to be removed from site by an approved industrial vacuum system either installed permanently in the unloading area or provided by a waste removal specialist company.

A risk assessment should be used to determine whether trafficable lips or delivery bunds should be used in the delivery area for spillage control. The risk assessment should also assess the need of a sump, drainage and underground spillage tank in the unloading area. This is to manage the washdown water when used to prevent the potential spread of airborne dust from a spillage or to manage spillage during a rain event.

The risk assessment should consider the followings:

- Likelihood of spillage.
- Chemical properties of lime powder and lime slurries.
- Operational issues to manage the sump, drainage and underground tank in presence of potential lime slurry.
- Additional control requirements to isolate the stormwater system during a delivery.

- Availability of suitable spill kits to contain lime powder during a rain event.
- Stormwater management.
- Site emergency plan.
- Industry best practice.

8.2.2 Transfer / Fill Point

The transfer/fill point is the connection point at which the delivery truck connects the delivery hose to transfer lime powder chemical into the storage silo using the transfer line.

Fill points shall be located adjacent to the unloading area such that a tanker hose should not generally exceed 6m, but this length should be confirmed with the supplier. Hose lengths shall be sized such that they can be connected in a straight line with no bends or kinks.

Each storage silo (where applicable) shall be filled individually, having its own fill line and fill connection point. Fill points for the same chemical shall be separated by a minimum of 400 mm and for different chemicals by a minimum of 5 m.

Fill points shall:

i. Be clearly labelled, including a nameplate/identification plate above each filling point defining its name and grade, and the silo into which it feeds.
ii. Include a mechanical coupling for connection to a tanker delivery hose and:
    a. The connection type shall be confirmed based on consultation with the specific supplier and Seqwater. Where this cannot be confirmed, a 100mm male camlock mechanical coupling type can be considered.
    b. Be fitted with a dust cap capable of being locked (via padlock), if necessary.
    c. The material should preferably be galvanised carbon steel or stainless steel.
    d. Be preferably connected to the fill line with a flanged connection to allow for easy replacement if damaged.
iii. Be positioned above ground level at a height per lime suppliers' requirements. If not stipulated by the supplier, between 800-1200 mm above ground level at the point of connection to a tanker hose.
iv. Be installed between 45° and 90° to the vertical (in a horizontal to downward orientation).
v. Include a safety shower and an eye wash facility located between 2 m and 7 m from the transfer point and compliant with Section 7.14 of this standard.

8.2.3 Transfer Fill Line

The lime powder chemical transfer line(s) shall:

i. Be minimum of 100 mm diameter and constructed of appropriate pipe *material as specified in M-SPE-STD-013 Chemical Dosing Piping.*

ii. Use short and straight lengths as much as possible, minimise the use of sharp and right-angle bends and be kept as short as is practicable. Where using bends, use only sweeping, long radius bends. Bends should generally be a minimum of 10-12D radius. If consecutive bends are required, provide a minimum of 30 pipe diameters distance between bends or use specially designed bends for abrasive powder conveyance system from suitable suppliers. Where needed, the design should consider including wear boxes to minimize bend wear.

iii. The line shall be designed to withstand the pressure generated in the system and should include a safety factor of 2x of the pressure rating of the blower.

iv. Enter the storage silo from the top and centre of the vessel to maximise silo storage volume.

v. Include an actuated valve which should be opened automatically during filling operation and closed by the operator at the end of filling procedure (only when the filling operation is not running). The valve should

  a. Be fitted with limit switches to obtain open and close position feedback.

  b. Preferably be a fail-safe diaphragm or pinch valve with pneumatic actuation.

  c. Be accessible from the ground level and should be located within 400 mm from the filling point.

vi. Be considered to include a thermostatically controlled heat trace to reduce moisture in the transfer line and actuated valve to prevent clogging.

vii. Be provided appropriate earthing and bonding to avoid any static electricity build up.

viii. Be included disassembly points and/or connection ports for safe cleaning of powder scaling or blockage.

ix. Maintain the line velocity and material to air ratio as recommended in Section 8.3.3.2.

8.2.4 Local Control Panel

A Local Control Panel (LCP) shall be provided for lime bulk delivery location. Where multiple silos and fill points exist, a single LCP shall be provided and be clearly labelled and identified for which silo they apply to.

The LCP arrangement shall, as a minimum:

i. Be clearly labelled with the panel ID, chemical, all dials, buttons and displays as per Seqwater's labelling requirements.

ii. Include:

  a. An Off / On Filling switch to initiate the panel. The status shall be viewable remotely via SCADA.

  b. A ready indicator (e.g. Green Light) – indicating all pre-requisites to fill the silo are met.

  c. A not ready indicator (e.g. Amber Light) – indicating it is not safe to fill.

  d. Filling line actuated valve position indication.

  e. A running indicator.

  f. An alarm test button.

  g. A lamp test button.

iii. Include a local warning device providing visual and audio alert if the chemical delivery exceeds the high weight in the storage silo or high-pressure differential across the filter at a pre-set time or high pressure in the silo:

  a. At least one amber beacon type warning light shall be attached to the top of the LCP. Additional beacons may be included in the chemical storage area based on the requirements of any risk assessment.

iv. Included a switch to close the filling line actuated valve, the switch shall only work when the filling operation running indicator is off. The switch is to close the valve quickly and prevent any potential backflow and spillage through loose connections when the blower is stopped.

v. Be designed such that only one storage silo may be filled at a time.

vi. Include a digital readout of silo weight (kg). Additional parameters may be provided and selectable as fill weight percentage, available weight for fill (kg) and full weight (kg). Displays shall:

   a. Be fitted with a sunshade to provide protection and prevent glare.

   b. Be sufficiently weatherproof to meet operational requirements and required design life.

   c. Be designed with an appropriate IP rating in accordance with the requirements provided in *E-SPE-STD-001 Electrical Design and Construction.*

   d. Be visible and readable from at least 5m.

LCP operation may include operator initiation of silo filling procedure via SCADA in addition to selection of “filling” setting on the LCP.

It is assumed that all lime deliveries will be undertaken with supervision and attendance of a site operator as an additional layer of protection.

8.3 Large Bag Delivery

The large bag delivery shall include facilities and unloading equipment required to transfer bags from the delivery truck into the storage area and/or filling point and transfer powder into storage silos/hoppers. The large bag delivery shall include:

i. Large Bag Unloading

ii. Discharge Hopper System

iii. Conveyance System

iv. Local Control Panel

8.3.1 Large Bag Unloading

The design shall include the following requirements to transfer lime powder bags into the storage area and filling point:

i. The ability to drive the delivery vehicle as close as practicable to the storage area and filling point.

ii. Delivery vehicles are preferably equipped with lifting appliances including mobile trollies and forklifts to minimise manual handling.

iii. Forklift trucks shall comply with the relevant requirements of *AS 2359 Powered Industrial Trucks*.

If package storage area is not within the same level as the delivery truck, an inclined conveyor, dock leveller, hoist, or an elevator shall be considered.

8.3.2 Discharge Hopper System

Lime powder from large bags is transferred into storage silos by a suitable large (bulk) bag discharging system. The system shall be designed to empty a large bag directly into a discharge hopper and then transfer into the storage silo. This should minimise manual labour requirements, ensure reliable material flow, and minimise dust generation.

The discharge hopper system shall include the following:

i. A supported safety platform frame to securely position the lime powder large bags over the top of the discharge hopper.

ii. A gantry crane and electric hoist controlled by an operator via a remote controller connected via a cable to manoeuvre the package bag into and out of the transfer hopper discharge point. The hoist must be suitable for the design lifting capacity and comply with *AS 1418 Cranes, hoist and winches set.*

iii. A safety gate to access hoist operation and be fitted with a safety guard switch and local reset push button to de-energise/re-energise the hoist motor operation. Safety gate must be closed, and the reset button activated prior to the start of the unloading sequence.

iv. A safety door to access the discharge hopper and be fitted with a safety guard switch and local reset push button to de-energise/re-energise the conveyance system, dust extraction fan, and dust extraction valve operation (if actuated). Safety door must be closed, and the reset button activated prior to the start of the unloading sequence.

v. A pneumatically operated mechanical paddle as a bag massager or a vibrating pan or other types of bag flow activators to overcome bridging and ratholing and thus assist powder flow from the package bag to the unloading/discharge hopper.

vi. A bag cincher mechanism to allow the bulk bag to be opened without product discharging.

vii. A mechanism to seal the package bag discharge spout and prevent dust escape during emptying. An extendable flexible tube fitted with a clamp ring may be used for the application.

viii. A suitable mechanism to collapse the bag during bag removal and minimise dust emission to the working environment.

ix. Pneumatically or manually operated knife gate valve at the bottom of the discharge hopper to provide positive isolation during maintenance. Designer should include the provision to close the valve from LCP after completion of powder transfer to avoid the risk of moisture entering the storage silo.

x. Dust extraction line connection from the discharge hopper to the storage silo / hopper or to the central dust collection system. The dust extraction line should have a solenoid valve to open/close automatically during unloading operation.

xi. Vibrator or other type mechanism is to assist in lime powder flow from the discharge hopper to the conveyance system. When used, vibrator operation must be prevented in an empty hopper.

xii. A low-level switch in the discharge hopper shall trigger an alarm on the LCP and stop the unloading sequence with time delay.

8.3.3 Conveyance System to Storage Silo

The designer shall select the preferable conveyance system between mechanical and pneumatic systems to transfer lime powder from the discharge hopper to the storage silo considering the material properties, distance, reliability, and safety.

8.3.3.1 Mechanical Conveyance

Mechanical conveyance should generally be selected for a short conveyance distance. Where selected, mechanical or screw conveyance system shall consider the following requirement:

i. A single or multiple helical flight of a shaftless conveyor or mounted on a central shaft aligned vertically/horizontally or combination, depending on the requirement.

ii. Include an enclosed fabricated casing comprising standard lengths bolted together as required. Riveted sections should not be used for maintenance access.

iii. Discharge into the centre top part of the storage silo to allow for an equal distribution of powder chemical.

iv. Provide interlocking of the screw conveyor motor to the high-high weight and/or high-high level of the storage silo.

v. Where applicable, interlocks shall be included to prevent the operation of horizonal screw conveyor when vertical screw conveyor failed to operate. This is to avoid any powder compaction within the screw conveyors and any damage to the conveyance system.

vi. Provide access hatches to allow maintenance personnel to inspect conveyance system and remove blockages.

vii. A mechanism that prevents the operation of screw conveyor when the conveyor housing is left open to avoid an unsafe condition.

8.3.3.2 Pneumatic Conveyance

Pneumatic conveyance system utilises motive air to carry and transfer the lime powder from the unloading or discharge hopper to the storage silo. The lime powder is transferred through an enclosed pipeline in air suspension (i.e., Positive Pressure System) or pulled by vacuum (i.e., Negative Pressure System).

The pneumatic conveyance design criteria include:

- Minimum and optimum air flow rate
- Optimum pipeline diameter
- Powder to air ratio
- Pressure gradient along the pipeline

Where selected, the system shall use dilute phase conveyance either with positive or negative pressure (i.e., vacuum) system.

Positive Pressure System

The positive pressure system operates at above the atmospheric pressure conveying material from the unloading bag discharge to the storage silo. The lime powder enters the transfer line at a higher pressure via a special feeding device, typically a rotary airlock valve. The suspended powder-air stream is separated by a dust collection and vent filter system fitted in the storage silo. Lean phase positive pressure system shall be used for lime powder transfer and recommended for the transfer distance up to 150 m.

The lean phase positive pressure system comprises of the following:

- Air blower
- Transfer line

- Rotary valve
- Dust collection and vent filter (discussed in Storage Silo Section 9.1.9)

The air blower shall have the following requirements:

i. Use either centrifugal or positive displacement type blower.

ii. Use a Variable Speed Drive (VSD) blower driven by an electrical motor. A VSD will assist to optimize the system. The blower should be sized:

    a. To prevent powder settlement in the conveying system.

    b. To prevent erosion of conveying pipework / materials.

iii. Be designed to operate at positive pressure up to 100 kPa. The design should consider online pressure monitoring to ensure reliable operation.

iv. Be fitted with a filter on the suction side with a maximum pore size of 10µm. Filter shall be easily removed and replaced for maintenance.

v. Appropriate protection device for blower protection against excessive discharge pressure and inlet pressure loss (e.g., due to inlet filter blockage) including mechanical relief valve, temperature switch, and pressure switch should be considered. The relief valve should consider venting at ground level to reduce dust cloud when it operates,

vi. Base and supporting frame design must be rigid and mounted on a flat surface to minimise the possibility of piping deflection.

vii. Be designed to mitigate any possible ignition or detonation points.

viii. The design shall comply with the requirements of *M-SPE-STD-001 General Mechanical.*

The requirements of conveyance system transfer line shall follow the requirements of the bulk truck delivery transfer line as mentioned in Section 8.2.3 without the need of an actuated valve. Additional requirements are provided below:

ix. The line velocity should be limited to 15-20 m/s as higher velocity can lead to the formation of $CaCO_3$ scaling into initial pipe sections from the reaction of hydrated lime and CO_2 present in air.

x. To minimize potential $CaCO_3$ scaling, lime powder to air weight ratio should be maintained as high as possible.

When used, the rotary valve in the powder feeding should include the following requirements:

xi. Be an airlock rotary valve properly designed to minimise the air leakage. Suitable vent ports on the housing of the rotary valve or vent box shall be provided to discharge the leaked air into atmosphere before entering the unloading hopper. Air leakage rate should be accounted into the blower sizing calculation.

xii. Include a fixed speed drive and be capable to discharge powder chemical at a rate as determined from the process requirement.

xiii. Include a durable and dust tight seal on the rotating shaft and external fittings to prevent lime powder emission to the atmosphere.

xiv. Be designed to provide easy and safe cleaning of both the external and internal surfaces, including a provision of simple extraction of rotor/end cover assembly.

xv. Be constructed of materials compatible with lime powder.

Vacuum System

Vacuum transfer system may be used as an alternative to positive pressure system for a transfer distance up to 50 m. The system operates by using vacuum pump to create vacuum in the transfer line allowing chemical powder to be drawn into the transfer line and vacuum filter receiver prior to discharge into the storage silo via an airlock rotary valve. The vacuum filter receiver is fitted with the dust collection and vent filter system to extract and collect the powder dust generated. Vacuum system is generally used when the required conveying rate is less than 10 tonnes/hr.

The vacuum system comprises of the following main components:

- Vacuum generator
- Transfer line (see above for positive pressure system but the velocity should be kept within the range of 20-25 m/s.)
- Vacuum filter receiver
- Airlock rotary valve (for feeder and vacuum receiver)

The maximum vacuum generated, the overall capacity and general operating characteristics of the systems, are determined by the type of vacuum generator used.

The vacuum generator should generally have the following:

i. A fixed speed, positive displacement vacuum pump.

ii. Be sized for appropriate conveying velocity to prevent powder settling and avoid erosion of pipework.

iii. Be designed to mitigate any possible ignition or detonation points.

The vacuum filter receiver should have the following:

iv. Generally, be installed on the top of the storage silo.

v. Be designed to separate the lime powder from the air stream using filter media and gravity.

vi. Be fitted with reverse-pulse jet filter cleaning system to dislodge accumulated powder into the storage silo.

vii. The dust and vent filter design requirement shall follow requirements provided in Section 9.1.9.

An airlock rotary valve separates the storage silo from the vacuum receiver. When used, it should comply with the general requirements provided in the above section.

8.3.4 Local Control Panel

A Local Control Panel for bulk bag unloading shall be provided to operate the bag discharge and conveyance systems locally.

The LCP arrangement should, as a minimum:

i. Be clearly labelled with the panel ID, chemical, all dials, buttons and displays as per Seqwater's labelling requirements.

ii. Include:

a. An On / Off unloading switch to initiate the panel. The status shall be viewable remotely via SCADA.

b. A ready indicator (e.g. Green Light) – indicating all pre-requisites to fill the silo are met.

c. A not ready indicator (e.g. Amber Light) – indicating it is not safe to fill.

d. An Unload Start / Unload Stop Pushbutton to initiate the bag discharge and conveyance system. The status shall be viewable remotely via SCADA.

e. A running indicator.

f. An amber beacon type lamp to alert the operators to alarm conditions.

g. An alarm test button.

h. A lamp test button.

iii. Include an audible alarm to alert the operators if the storage silo reached high weight/level; or the discharge hopper becomes empty or high-pressure differential across the filter at a pre-set time or high pressure in the silo.

iv. Include one latched, twist to release Emergency Stop Pushbutton and an illuminated Emergency Stop Reset Pushbutton located in front of the panel. The emergency stop shall:

a. Be clearly labelled.

b. Trigger a local alarm (visual and audible) and telemetry alarm visible from the control room.

c. Be designed with the appropriate category of emergency stop circuit as decided by the designer.

d. Be detailed with the functionality by the project specific design team. But, as a minimum, this shall isolate power to all drives in the unloading and conveyance system upon activation.

The design may also consider an alternative suitable location instead of LCP for the Emergency Stop Pushbutton.

As a minimum, the design shall include the following signals related with the operation of large bag discharge and conveyance system viewable remotely via SCADA:

- Unloading sequence status.
- Safety door and gate limit switch indicator.
- Motor running status, motor temperature, and fault status. This may include vibrator, hoist / gantry crane, screw conveyor / blower, and dust extraction fan operation.
- Any valve position status includes but not limited to bag massager solenoid valve, knife gate valve, dust extraction line valve, airlock rotary valve and filling line actuated valve (where applicable).
- Discharge hopper low-level switch indicator.
- Emergency stop status.

9 Lime Storage System

This section describes the requirement for the design and construction of lime powder storage system.

The main components of lime powder storage system include:

- Storage Silo / Hopper
- Intermediate Hopper
- Temporary storage of large bags

This section should be read in conjunction with standard P&ID *B-DWG-STD-021 Lime Storage, Mixing/Batching and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)* as referenced in Section 0.

The requirements for chemical enclosure, building and access are discussed separately in Section 0.

9.1 Storage Silo

Storage silo(s) shall be used for the storage of lime powder prior to mixing/batching.

Storage silos shall be above-ground, fixed, well-supported, permanently positioned silos that are filled and discharged in situ and if possible be located inside a building.

The storage silo shall be designed to provide a flow pattern that ensures flow of all materials whenever any solid is withdrawn to avoid ratholing, short circuiting or retention, aging of pockets of lime powder, powder sidewall hang-ups and cohesive arching under all conditions.

The lime storage silo shall have a supporting structure and foundations. The silo structure is to be designed to ensure the strength and stability to withstand any relevant load including the load exerted by the bulk solid on the silo walls, the impact stress caused by large portion of lime powder falling from the top of the silo, pressure caused by wind, and asymmetrical loading from the contents.

The design of the silo cap shall be with a slight radial downward slope or crowned from the centre to prevent pooling of water and allow drainage.

The design and construction of the storage silo should follow the appropriate standards, those of which are acceptable to Seqwater as listed below in Table 9-1. Designer can apply additional standards as required.

Table 9-1 Recommended standards for the design and construction of storage silos

Standard Number	Standard Title
AS/NZS 1170	Structural Design Actions (set)
AS 3774	Loads on Bulk Solids Containers
AS 1657 and M-SPE-STD-002	Fixed Platforms, Walkways, Stairways and Ladders
AS 3990	Mechanical Equipment – Steelwork
AS 4100	Steel Structures
AS 1554	Structural Steel Welding

All silo equipment and instruments should be fitted such that they may be removed without draining the silo contents, e.g. compressed air fluidisation inlet pipe may be fitted with an isolation valve.

The storage silo, at a minimum, shall include the following main equipment, instruments and fittings:

i. Silo fill line
ii. Weight and level monitoring device
iii. Silo access (both internal and external)
iv. Dust filter and extraction fan
v. Pressure/vacuum relief device
vi. Bin activator or vibrator
vii. Aeration system
viii. Dehumidifier
ix. Knife gate isolation valve
x. Rotary valve

9.1.1 Number and Size of Silos

The number and size of storage silos shall be determined by the following requirements:

i. Generally, include one (1) storage silo. But if a site requires both lime slurry and limewater dosing, then two (2) independent storage silos may be required. The determination of the final number should consider the site's availability and criticality requirements, the stored chemical properties, the site's size and powder usage rate, site staffing, site location and access (e.g. in fair and poor weather), reliability, operability and maintainability considerations.
ii. Where lime powder chemical is delivered in bulk, should provide a minimum demand quantity by sizing based on the greater of:
    a) 14 days storage at maximum dose rate, average plant flow; or
    b) 28 days storage at average dose rate, maximum plant flow

Where there are significant variations in dose rates due to changes in water quality, maximum dose rate shall be determined from 1-2 weeks of historical average dose data from water quality event periods rather than using an instantaneous maximum dose rate.

The silo sizing should also consider the following:

iii. The silo size should be able to take at least more than 1 truck volume.
iv. All equipment plus one (1) m additional height under the outlet should be considered as a future contingency
v. Where lime powder is delivered in large package bags, the storage silo/ hopper should be sized based on the capacity to hold 4-5 days of storage at the maximum dose rate with average plant flowrate.

The final storage silo's size should be determined considering lime chemical properties, general availability of lime including the supplier's location and reliability of supply during any period of shortage, delivery time delay due to natural or human-caused emergencies, availability of operators to fill silo (for large bags), site's availability and criticality requirements.

9.1.2 Silo Labelling

All silos shall have placarding and be labelled in accordance with *PRO-00008 WHS Hazardous Chemicals*, Work Health and Safety Regulation 2011, Globally Harmonised System of Classification and Labelling of Chemicals (GHS), *AS 60079 Explosive Atmosphere*, Australian Dangerous Goods Code and relevant legislative requirements.

Where multiple silos are installed, each silo shall be labelled with the silo number (i.e. Silo 1, Silo 2 etc) such that it is clearly visible and readable from the silo fill point. This labelling convention should also be carried over into SCADA.

Each silo shall include a name plate printed on stainless steel and intended to remain in place and clearly legible for the design life of the silo. It shall be positioned to allow visibility from the ground level, if adhered to the silo surface.

Each nameplate shall include the following information:

- Manufacturer
- Manufacturer's details (name, address, contact number)
- Design Code
- Date of manufacture
- Serial Number
- Silo Number (if applicable)
- Materials of construction
- Product / content (including chemical name, formula).
- Design Mass Capacity
- Height, Diameter and Volume
- Design Temperature and Pressure
- Powder Chemical Bulk Density
- Maximum Specific Gravity (of powder to be contained)
- Mass of empty silo.

9.1.3 Design Pressure and Temperature

Silos shall be designed for Site Conditions, Atmospheric Conditions and Process Conditions as defined in Section 7 of this document.

The pressure or vacuum resulting from filling, emptying, thermal inbreathing and outbreathing, or atmospheric change shall not exceed the maximum design stress of the silo. The silo shall be designed to withstand the pressure generated in the system and shall include a safety factor of 2x of the calculated possible built-up pressure.

Storage silos shall generally be designed and constructed to operate at near atmospheric pressure and slightly negative pressure for silo filling and discharge operations.

9.1.4 Silo Materials

Materials for silo construction shall ensure silos and their fittings and attachments are suitable for use under the Site Conditions. Where materials require additional protection as a result of Site Conditions, adequate protection, appropriate shelter, painting or coating, or other fit for purpose means of ensuring the required design life is achieved shall be provided.

Materials for silo construction shall ensure silos and their fittings and attachments that are likely to come into contact with lime are substantially immune from attack by the lime under all service conditions. They must be of a quality will not leach any substances in quantities capable of producing adverse health effects for drinking water applications

Mild steel should be the preferred material for bulk storage silos filled from bulk trucks. Stainless steel should be considered for small silos/hoppers.

9.1.5 Fill Line Connection

This section builds on the requirements of Transfer Fill Line discussed in section 8.2.3 for bulk delivery, section 8.3 for large bag transfer. The battery limit drawn from the flange connection at the silo nozzle to the silo internal. This shall:

i. Include a separate flanged nozzle/connection on the topside (roof) of each silo with the same diameter as the fill line.

ii. Enter the roof of the silo in a vertical orientation and connected through the centre of the storage silo roof to maximise storage volume.

iii. Provide a minimum 100mm straight funnel discharge pipe connection from the silo flanged nozzle connection on the internal topside roof to direct the discharge orientation.

9.1.6 Weight Measuring Device

Silo weight shall be the primary monitoring and control parameter for the operation of the storage silo. The designer may also consider silo level monitoring as a backup of weight monitoring to identify ratholing if cannot be eliminated with aeration and bin activator or bin vibrator systems.

The silo shall be mounted on load cells to measure the silo weight with the following requirement:

i. A silo weighing system should consist of three or four load cells, each with a weighing module. Each load cell should be connected to a junction box and a transmitter with the ability to send the weight signal to the site PLC/SCADA.

ii. The silo stairs and platforms shall not be structurally connected to the silo otherwise the performance of silo load cells can be affected.

iii. Load cells shall be installed in such a way that they can be removed without emptying the silo for jacking or lifting purposes.

iv. The vibration of bin activator or vibrator shall not affect the performance of load cells.

v. The load cells shall have combined accuracy within ±0.5% across all design conditions (i.e. temperature and silo content weight).

vi. Electrostatic charges must be discharged to the ground without crossing the load cells. Earthing shall be provided according to the requirements in *I-SPE-STD-015 Instrumentation*.

vii. Load cells shall be equipped with calibration hooks for hanging weights.

viii. The load cell types, and their components shall be suitable for Site Conditions.

ix. Silo weight shall be readily viewable as an electronic digital readout at:

   a. Local to the silo and viewable at ground level

b. Local to the silo filling Control Panel, and viewable by Operator / Delivery Staff during filling operation.

c. Remotely at SCADA.

9.1.6.1 Alarms and Trip Setpoints

The following provides guidance as to Seqwater's requirements for alarms and trips from the weight measuring device for the operation of storage silos.

The following high weight setpoints shall be available for storage silo operation:

- Maximum Operating Weight / Operation High Weight (OHW): This operator settable setpoint provides no alarm. The process will continue to run with no action. Reaching this level will record as an Event[1] only in SCADA.

- High Weight (WAH) Setpoint: At this point an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

- High-High Weight (WAHH) Setpoint: At this point, **t**he alarms and interlocks are based on the delivery mechanism of the followings:

    - Bulk Delivery: At this point a further alarm will be triggered, and the Delivery Staff/Operator will be notified with a local audible alarm. The silo filling process shall be interrupted by the Delivery Staff.

    - Large Bag Discharge: At this point, a further alarm will be triggered, and the silo filling must be stopped via interlocking the screw conveyor system, blower or vacuum generator depending on the type of conveyance system. But it must be set to allow the conveyor to be emptied into the silo after the feeder has been stopped (by use of a run-on timer).

- For bulk delivery, the filling line actuated valve must not be interlocked with high-high silo weight as there are risks to the driver/operator and pipework from a sudden closure of the actuated valve before stopping the truck blower.

The following low weight setpoints shall be available for storage silo operation:

- Minimum Operating Weight / Operational Low Weight (OLW): This operator settable setpoint provides no alarm. The process will continue to run with no action. Reaching this level will record as an Event[1] only in SCADA. This may be used to fill the silo or automatically switch over to another silo where available.

- Low Weight (WAL) Setpoint: At this point an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

- Low-Low Weight (WALL) Setpoint: At this point a further alarm will be triggered, and the Operator notified. At this point Operator action has been unavailable or unable to correct the low-weight event. The lime powder transfer system should be interrupted by stopping/inhibiting the rotary valve, silo aeration, bin activator or vibrator operation and closing the knife gate valve.

[1] Events are a fifth priority alarm in the Seqwater alarm system as defined in *I-SPE-STD-006 Monitoring and Control System Alarm and Event Management.*

In addition, an alarm should be considered to identify higher rate of powder discharge from the silo indicating possible powder fluidization through the feeder. The design should also consider closing the knife gate valve for safety for such a scenario.

9.1.7 Level Switch

In addition to silo weight measurement device, the storage silo shall be fitted with level switches to provide additional control redundancy with the following requirements:

i. Two separate and independent level switch devices to provide point detection level at High-High and Low-Low Level on the storage silo.

ii. Electronic level switches must be suitable for site conditions and compatible with lime powder.

iii. The level switches must be positioned where they will provide a best representative level of the silo content.

9.1.7.1 Trip Setpoints

The following provides guidance as to Seqwater's requirements for trip setpoints and alarming from level switches for the storage silo:

Storage Silo

- High-High Level (LSHH): The High-High Level setpoint and alarm triggered on the High-High Level switch device shall provide the same action as WAHH discussed previously in Section 9.1.6.1.

- Low-Low Level (LSLL): The Low-Low Level setpoint and alarm triggered on the Low-Low Level switch device shall provide the same action as WALL discussed previously in Section 9.1.6.1.

9.1.8 Silo Access

9.1.8.1 Access Manhole

Storage silo shall be fitted with an access manhole for an inspection with requirements to include:

i. A minimum of 600mm opening mounted on the top of the storage silo. The silo should be designed in a way that the internal access is not required, or the need is minimised or restricted.

ii. Access cover shall be made from the same material as the silo and weigh no more than 15 kg. Where this cannot be practicably achieved, a lifting and support mechanism shall be supplied and mounted to the silo to facilitate access.

iii. Access cover shall be easily lifted by one person and shall be capable of being secured or locked in an open position.

iv. Access cover shall be fully sealable and airtight to prevent chemical powder escaping to the environment.

v. A hinged access cover shall be considered and shall open sideways as it can be positioned as closed to access walkway or silo side to limit the reach required. The hinged opening shall not impede safe access to the other assets.

9.1.8.2 Stairway Access

Stairway access to the top of the storage silo shall be provided. The stairs and platform structure shall not be connected to the storage silo to allow free movement of the silo and also not to impede the load cells weight measurement.

The stairway and platforms shall comply with the requirements of *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

9.1.9 Dust Collector and Vent Filter System

Storage silo shall be fitted with a vertically mounted self-cleaning dust collector and vent filter system on the top of silo. The system must be designed to vent clean, dust-free, filtered air to the atmosphere and return lime powder removed from the filter to the inside of the silo. The main components of the system shall include:

- Dust Filter
- Extraction Fan
- Reverse Pulse Filter Cleaning System

9.1.9.1 Dust Filter

The dust filter requirement shall include the following:

i. Be either bag or cartridge type of filter with filtration capacity sufficient to accommodate the maximum volume of air to be handled without over pressurising the storage silo, particularly during delivery.

ii. Be capable to remove 99% (or greater) of the smallest powder particle size as defined on the chemical Safety Data Sheet (SDS).

iii. For bulk delivery, the filter shall be sized considering the maximum air volumetric flow rate of the truck or conveyance system blower. The filter sizing should also consider line flushing at the end of the delivery.

iv. The filter shall be housed in a container with an access lid for filter replacement. The filter lid shall be sealed to prevent the escape of powder chemical dust.

v. The filter container and access lid shall be securely positioned to prevent it being dislodged in high winds and to enable maintenance access from the access stair's top platform.

vi. The filter shall be sized appropriately to allow maintenance staff to safely carry replacement filter elements to the top of silo for replacement.

vii. The filter needs to run through a cleaning cycle at the start and end of a delivery.

viii. Adequate platform shall be provided for safe access and work on the filter for maintenance/replacement.

9.1.9.2 Extraction Fan

The extraction fan requirements include:

i. Each dust filter shall be fitted with a dedicated extraction fan which should maintain a slight negative pressure in the storage silo during silo filling.

ii. Shall be vented to atmosphere outside of any building.

iii. Shall be side mounted or positioned in a way that allows for filter maintenance/replacement without the need for it to be removed.

iv. Venting from the extraction fan shall be designed to prevent vermin ingress.

9.1.9.3 Reverse Pulse Filter Cleaning

i. The reverse pulse filter cleaning system shall automatically clean the dust filter with a compressed air pulse preferably at a certain interval. The pulse cleaning system shall also be activated at a pre-set pressure differential across the dust filter. The system should trigger an alarm to the site control system for filter blockage from a high-pressure differential across the filter at a pre-set time. For large bag unloading, the operation of screw conveyor system should be interlocked from a high-high differential pressure alarm across the filter.

ii. The compressed air supply for the pulse air cleaning shall be clean, dry and comply with the pulse air cleaning system manufacturers specification. The system should raise an alarm if air pressure is insufficient to clean the filter.

iii. Air supply system should be fitted with a pressure regulator if a specific pressure is required for filter cleaning. A high-pressure switch / a pressure relief valve shall also be considered in the air supply line to isolate the air supply in the event of a pressure regulator failure.

9.1.9.4 Dust Extraction Line for Discharge Hopper

The above dust collector system can also be fitted with a dust extraction line from the discharge hopper for a large bag unloading system. The dust extraction line connection should enter the top side of the storage silo/hopper or to the central dust collection system as discussed in Section 8.3.1.

The silo nozzle shall be of the same size as the extraction line with a minimum diameter of 100 mm.

The extraction line shall be connected with a flange joint to the storage silo to allow dismantling for maintenance.

9.1.10 Pressure/Vacuum Relief Devices

A pressure/vacuum relief valve shall be mounted on the top of the storage silo to protect the silo against excessive pressure and vacuum.

The device shall protect the silo against over pressurisation from dust filter blockage during lime powder filling. It shall also protect the silo from an implosion resulting from excessive air extraction due to erroneous fan extraction operation or a sudden powder chemical discharge.

The pressure/vacuum relief device shall be sized appropriately considering:

- the maximum expected incoming air inflow during silo filling,
- maximum allowable silo and dust filter pressures.
- maximum air inflow that silo needed at the highest powder draw down rate.
- Venting capacity of the device at specific over-pressures.

The pressure and vacuum relief valve set points shall comply with the silo manufacturers recommendations.

The device relief line should be considered to extend at ground level to reduce dust cloud when the relief valve operates. Only venting of air with the filtration of powder should be considered in the selection of relief valve type but it should not create any blockage potential.

9.1.11 High Pressure Switch

In addition to a pressure/vacuum relief valve, the design shall install a pressure switch to protect the silo from overpressure during silo filling. Pressure switch must be suitable for site conditions and compatible with lime powder. For bulk truck delivery, the Delivery Staff/Operator will be notified with a local audible alarm if the pressure switch is triggered. For large bags transfer, an interlock with the conveyance system from the high-pressure switch shall be considered.

9.1.12 Dehumidifier

Storage silo(s) should be considered to be fitted with a dehumidifier to prevent condensation and moisture inside the storage silo, which may lead to caking and agglomeration of lime powder.

The dehumidifier shall include the following requirements:

i. A suitable mechanism, such as desiccant dehumidifier, to provide fresh dry air into the filling line or with a separate pipe into the storage silo head space to prevent moisture condensation.

ii. The dehumidification unit to be mounted at the silo roof or ground level depending on the accessibility, operation and maintenance requirements.

iii. Any excessive pressure build-up in the silo due to the dehumidifier operation be exhausted through the vent filter assembly.

iv. Be sized to deliver at least one air change per hour based on an empty silo. The designer shall determine the suitable relative humidity (RH) required for the inside air considering the material properties.

v. Be fitted with a mechanism to stop the dehumidifier operation or isolate the dry air supply duct during silo filling. The operation shall start again after complete stopping of dust extraction fan and reverse pulse system after finishing of silo filling operation.

vi. If an air re-circulation dehumidifier system is used, additional air filtration modules must be used to avoid dust being drawn into the dehumidifier air supply line.

9.1.13 Bin Activator or Bin Vibrator

The storage silo shall be fitted with a bin activator or bin vibrator to aid in powder flow discharge. The designer shall select suitable vibration mechanisms to aid smooth lime powder flow considering:

- Lime powder density and flow properties,
- Discharge rate and
- Silo diameter.

A bin activator shall be suspended beneath the silo with a vibrated cone powered by one or two electric motivators. The cone should be designed with a suitable cone angle to avoid arching, bridging and rat-holing for smooth powder flow. The entire bin activator unit moves horizontally in response to vibration forces generated to allow smooth materials flow through the bin activator outlet.

The bin activator design shall:

i. Ensure a consistent powder transfer.

ii. Include flexible connection between the silo and the bin activator.

iii. Include sealed connections at both ends of the bin activator to prevent lime powder escape to the atmosphere.

iv. Include an easy to fit, highly chemically resistant, food grade, seamless seal for the flexible connection between the storage silo and the bin activator.

v. Be programmed with the rotary valve operation to allow vibration to only occur during powder discharge at the required frequency and intervals. The bin activator supplier shall be consulted to determine the appropriate run and off times during powder discharge to avoid any unwanted compaction at the lower cone that may arise from excessive operation.

vi. Be constructed of materials compatible with lime powder.

Where bin vibrators are selected instead of a bin activator for a standard fixed silo cone, electric vibrators are preferred over pneumatic vibrators as any compressed air supply disruption may stop operation of the vibrator along with the silo aerator system.

For bin vibrators, the design shall consider the followings:

a. Number of vibrators required.

b. Location of vibrator installation.

c. Right force for silo cone and materials load.

d. Vibrator operations shall be kept to a minimum and operation must be prevented in an empty silo.

9.1.14 Silo Aeration

In addition to the bin activator/vibrator, the silo shall be fitted with a fluidization or aeration system to aid in powder flow.

The aeration system provides flow of pressurised air to break agglomerated powder to prevent silo arching/ratholing, and to aid and ensure smooth powder flow during discharge. The specifications shall include the following requirements:

i. Silo aerator shall only operate during the operation of rotary valve. The designer should select the option of continuous or intermittent aeration operation when the rotary valve operates.

ii. It shall not create excessive dust at all silo powder levels.

iii. The design shall ensure a consistent powder discharge.

iv. The silo aeration shall not create any excessive pressure in the silo. The designer shall determine whether operation of extraction fan is needed during aeration.

v. The aeration system shall be sufficient to break the agglomerated powder and allow powder to detach from the silo wall.

vi. The silo aerator compressed air line into the storage silo shall be fitted with a solenoid valve, a pressure regulator, a pressure relief valve / a high-pressure switch and a manual isolation valve.

vii. If used, a pressure switch shall be able to isolate the air supply line in the event of high air pressure which may arise from pressure regulator failure.

9.1.15 Knife Gate Isolation Valve

The storage silo shall be fitted with a sliding knife gate valve to provide positive isolation for downstream maintenance. The knife gate valve shall:

i. Be located underneath of the bin activator cone / silo cone and upstream of the rotary valve.

ii. Be preferably pneumatically driven.

iii. Include open and close position switches readable from SCADA.

iv. Have a suitable platform or appropriate steps for easy access.

v. Be kept closed for a specified period of time to prevent the lime powder from over aerating and flooding through the feeder nozzles when the silo is filled from empty.

vi. Have an enclosure bonnet and a leak-proof stem seal to prevent escape of powder dusts. During commissioning, where needed, the sealing procedure needs to be established to ensure a dust tight seal at the valve open position.

9.1.16 Rotary Valve

Electrically operated rotary valve shall be installed to transfer lime powder into the intermediate hopper (where applicable). The rotary valve shall:

i. Be mounted at the silo discharge chute underneath the knife gate isolation valve.

ii. Operate when the intermediate hopper calls for powder transfer, which is triggered from either of the low-level switches and stopped either of the high-level switches from the two hopper compartments as mentioned in Section 9.2 v.

iii. Have a fixed speed drive capable of delivering lime powder at a rate of 10 times the maximum feed rate of the screw feeder.

iv. Be constructed of material compatible with hydrated lime and be able to handle the abrasion from lime powder.

v. Include a durable and dust tight seal on the rotating shaft and external fittings to prevent lime powder emission to the atmosphere.

vi. Be designed to provide for easy and safe cleaning of both the external as well as the internal surface including provision of simple extraction of rotor /end cover assembly.

vii. Be preferably fitted with an open vane rotor to reduce problems with product ingress, bore wear, and product hang-up.

9.2 Intermediate Hopper

Intermediate hopper or a day hopper should be considered to provide an immediate source of dry lime powder for mixing/batching where lime is received as a bulk delivery by trucks into a storage silo. It provides better powder discharge control because the static head variation due to the changes in powder content level is not as high as for a bulk storage silo.

The design shall include an intermediate hopper to achieve better control in powder discharge and achieve redundancy requirements for silos and mixing/batching systems.

Where selected, an intermediate hopper shall be preferably located underneath of the storage silo in a vertical orientation to allow for gravity transfer. This removes the need of additional conveyance system from the silo to intermediate hopper. However, due to space constraint, if gravity transfer is not practical, then a pneumatic or mechanical conveyancing system shall be installed for the lime powder transfer. Refer to Section 8.3.3 for the design and construction requirement of the conveyancing system.

The intermediate hopper must be designed and constructed to the appropriate codes and standards as mentioned in Section 9.1 for storage silos.

The intermediate hopper as a minimum shall include the following main equipment and instruments:

a. Weight and level monitoring devices
b. Dust filter and extraction fan
c. Pressure/vacuum relief devices
d. Bin vibrator
e. Aeration system
f. Knife gate isolation valve
g. Rotary valve (where feeder transition hopper needed)
h. Intermediate hopper access

The design requirements for storage silos as provided in Section 9.1 shall apply for the intermediate hopper with the following exceptions. The intermediate hopper should

i. Be designed as a single unit with a minimum of two (2) partitions to supply lime separately to two individual lime batching/dosing systems. The partitioning number shall be the same with the number of the downstream mixing/batching stream. Each partition shall be connected to a particular mixing/batching stream.
ii. Be sized based on the capacity to hold a minimum of one day powder storage considering the average dose rate at the maximum plant flowrate.

The intermediate hopper shall:

iii. Be fitted with load cells to measure the combined weight of the hopper including partition legs.
iv. Include alarms and trip interlocks for load cells as provided below:
    1. At high-high weight alarm, the powder transfer should be interrupted and interlocked to prevent further transfer to the intermediate hopper from the silo by isolating the rotary valve and closing the knife gate valve.
    2. At low-low weight alarm, the lime batching system should be interrupted by stopping/inhibiting the agitator, screw feeder, hopper aeration, and bin vibrator. The designer may consider alternative options to stop the said system in the event of low powder level.
v. Be fitted with low-level and high-level switches in each compartment. The level switches will control the start and stop of the rotary valve to transfer powder from the storage silo into the intermediate hopper.
vi. Include a top manhole cover for visual inspection on each of the hopper partition sides and be fitted with a position switch to interlock with the silo rotary valve operation.
vii. Be installed with a knife gate valve, bin vibrator, agitator and hopper aeration system in each hopper partition.

viii. Include a dust collector and extraction fan and be sized based on the maximum air volume into the intermediate hopper.

ix. Be installed with electrically driven rotary valves in each partition and sized appropriately to fill the transition hopper quickly for LIW feeders (where applicable). The quick filling operation is important since during the filling operation the feeder transition hopper weight measurement needs to be suspended and the LIW screw feeder needs to be operated at a constant speed.

9.3 Temporary Storage of Large Bags

This section provides the requirements of the temporary storage of large bulk bags.

Lime bulk bags shall be stored inside a building in a cool, dry, humidity controlled and well-ventilated area.

Storage of chemical package outside under a cover is not acceptable due to the adverse impacts of the environment to the lime powder (e.g. powder agglomeration due to presence of moisture). The design and construction requirements of the building is discussed separately in Section 15.1.

The sizing of large bag storage area should generally follow the same basis for the sizing of bulk storage silo as provided in Section 9.1.1.

The storage of large bags should consider the following:

i. May be stored on pallets on the floor depending on the site space availability.

ii. The layout of the package storage shall:

   a. Allow the rotation of lime bags (to manage aging) with first in, first out.

   b. Provide clear passage of personnel to locate/remove bags using delivery vehicles (where applicable).

   c. Permit full observation and provide suitable access and manoeuvrability for cleaning spills.

iii. Separation and isolation from any incompatible liquid and powder chemical or potential spills to avoid any adverse chemical reaction.

When lime powder is delivered with large bulk bags, powder needs to be transferred from the bulk bag to the storage silo/hopper via the discharge hopper system as discussed in Section 8.3.

10 Lime Mixing/Batching System

This section describes the requirements for the design and construction of lime powder mixing or batching system.

The mixing/batching system is to prepare lime slurry for dosing into the main or feeding into the lime saturator. Lime powder is transferred from the storage silo into the mixing/batching tank using the feeder to prepare lime slurry.

This section should be read in conjunction with standard P&ID drawing *B-DWG-STD-021 Lime Storage, Mixing/Batching and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)* as referenced in Section 0.

The mixing/batching system shall be fully automated. It shall be capable of automatically transferring the required lime powder and water to produce the required slurry concentration or batch strength. The design philosophy for lime slurry feeding and dosing systems has been provided in Section 7.16 and Section 0.

Lime powder mixing/batching system should include the following main components:

- Powder Feeding and Conveyance System.
- Mixing/Batching Tank System.

10.1 Lime Powder Feeding System

Lime powder feeding system is required to transfer lime powder into the mixing/batching tank(s). Each mixing/batching tank must be fed separately with a dedicated feeder.

Gravimetric Loss-In-Weight (LIW) screw feeders are recommended over volumetric screw feeders although this requirement is not made mandatory due to additional cost. LIW screw feeders work from direct continuous measurement of loss in weight of materials discharged from a system and maintain a predetermined mass feed rate or batch size.

A LIW screw feeder provides the following advantages over a volumetric feeder:

- Self-calibration or manual calibration not required.
- Complete control over product quality variations and density fluctuations.
- Not sensitive to material build-up.
- Higher accuracy, easy to operate and automatic detection of supply interruption.
- Monitoring and reporting options.

Where selected, a LIW feeder system shall include the following:

- Transition hopper (if the accuracy and objective cannot be achieved from intermediate hopper and its load cells)
- Load cells for transition hopper
- Agitator or de-lumper
- Variable Speed Drive (VSD) Screw Feeder
- Heating element

A LIW feeder shall be mounted below a transition hopper to control lime powder discharge accurately for mixing or batching. This will be achieved with continuous weight measurement of the transition hopper load cells and controlling the feeder speed accordingly.

On the other hand, volumetric feeders discharge powder at a certain volumetric feed per unit time and do not need an additional transition hopper and load cells as stated above. A volumetric feeder shall be mounted directly below to an intermediate hopper.

10.1.1 Transition Hopper

For LIW feeders, lime powder from the storage silo or intermediate hopper is transferred into a transition hopper through a rotary valve to measure loss in powder weight before feeding into a mixing/batching tank.

The transition hopper should generally be obtained as a package unit from the supplier of screw feeder.

The transition hopper design shall include the following:

i. Be fitted with load cells to measure loss in weight of transition hopper during feeding and provide signals to control the speed of the screw feeder. The other generic requirements of load cells shall be followed as mentioned in Section 9.1.6.

ii. Include an agitator as described in Section 10.1.2.

iii. Be sized that the required weight measurement sensitivity from the load cells can be achieved to control the feeder.

iv. Low-level and high-level switches shall be installed to trigger operation of the rotary valve for filling operation.

10.1.2 Agitator

An agitator or de-lumper is required in the transition hopper or intermediate hopper to achieve a uniform powder bulk density, consistent flowrate and to completely fill the screw feeder inlet and ensure an accurate feeder operation.

An agitator shall be installed at the top of the screw feeder with the following requirement:

i. Be a variable speed drive and the speed of the agitator shall match to the speed of the screw feeder to prevent inconsistent concentration or batching strength and shall be programmed to run during screw feeder operation.

ii. Should be a horizontal type of agitator with the preference of propeller type blades.

iii. Agitator current should be monitored to identity any failure.

iv. Shall be driven from an independent motorised drive to the screw feeder. The motor shall comply with the requirements of *E-SPE-STD-001 Electrical Design and Constructions.*

10.1.3 Screw Feeder System

There shall be separate screw feeder for each mixing/batching tank. The screw feeder shall include the following requirement:

i. Be sized to prepare the lime slurry concentration up to 5% (w/w) with the required turn down ratio.

ii. Be fitted with a VSD to adjust the feeder speed automatically. For LIW feeders, speed is controlled with loss-in-weight measurement feedback from transition hopper load cells whereas no feedback control available for volumetric feeders.

iii. A VSD feeder is recommended even if a system is designed with a fixed concentration with variable flow rates. Such a system should generally be operated at a particular speed using the timer approach as determined and optimized during commissioning. But a VSD will provide more operational flexibility to optimize the system and accommodate any potential changes in batching concentration, chemical properties, material flow characteristics etc.

iv. Be fitted with a timer to vary the volumetric feeder run time at a particular speed manually or automatically to change the batching concentration for a fixed concentration system.

v. Have an accuracy of ±1% by weight or better over the full operating range.

vi. Include access with sufficient space to safely measure powder discharge particularity needed for the calibration of volumetric feeders. A sliding collection tray under the feeder shall be considered. A separate calibration mode in SCADA is required to verify the discharge volume and the corresponding motor speed.

vii. Include screw feeder pitch and flight and be designed to prevent plugging and flooding.

viii. Be fully contained (including inlet and outlet connections) within a housing to prevent powder dust escaping and prevent air being drawn inside.

ix. Be preferably designed with heat tracing with thermostat to avoid powder clogging.

x. The motor drive power to be suitably sized to accommodate the bulk powder weight in the feeder inlet over the full silo operating range.

xi. Be operated with a dedicated separate motor drive not sharing with the hopper agitator.

xii. Not be fitted with slide gates underneath the discharge as it may compress the powder material and damaged the screw feeder if closed during operation.

xiii. Include a powder discharge chute at the end of the screw feeder that connects to the mixing/batching tank. The discharge chute should

   a. Be designed to discharge lime in a controlled manner to prevent unwanted dust clouds and risk of spills.

   b. Be designed with the consideration of ease of maintenance.

xiv. Motor drive design should consider the head load weight of the bulk material in the inlet section over the full silo operating range (where applicable). Where necessary, a cooling fan should be included for main motor drive cooling. The motor shall comply with the requirements of *E-SPE-STD-001 Electrical Design and Constructions.*

10.2 Lime Mixing/Batching Tank System

This section describes the requirements for the design and construction of lime powder mixing/batching tank system and shall be used in conjunction with standard P&ID drawing *B-DWG-STD-021 Lime Storage, Mixing/Batching and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)* as referenced in Section 0. The system includes mixing/batching tank, batching transfer system (where applicable) and tank bund arrangement.

10.2.1 Lime Mixing/Batching Tank

Lime mixing/batching tank(s) are required to mix the lime powder with the dilution water to prepare lime slurry for dosing into the process main or feeding into the lime saturator.

The operation of the mixing/batching tank and some construction features shall depend on the lime slurry dosing/feeding system design philosophy as discussed in Section 7.16 and Section 0

Where there is a high degree of variability with main water flow rates and water quality, Seqwater's preference is to use a system with fixed concentration and variable flow rates over the variable concentration and fixed flow rate system for lime slurry dosing into the main. For a fixed concentration and variable flows system, Seqwater's preference is to use separate batching tank(s) and dosing tank(s) and operate the dosing system with variable flow rates. For this system, the screw feeder will operate intermittently to feed powder into the batching tank only during batching. Some details of this system have been discussed in Section 0.

For a variable concentration and fixed flow system as recommended for lime slurry feeding into the saturator or dosing system into the main, the mixing tank shall be designed to operate continuously at a fixed tank level. Dilution water shall be added at a constant flowrate regardless of the lime powder introduction rate to achieve the required variable slurry concentration. A level control loop with a flow control valve in the dilution water line may be required to maintain a fixed level in the mixing tank where there is a high degree of variability in the source water pressure and the variation in outlet flowrates due to variation in line losses.

Mixing/batching tanks shall be above ground, fixed, permanently positioned tanks that are filled and discharged in situ. The mixing/batching tank should:

i. Generally, be vertically oriented cylindrical tanks and preferably located underneath of the screw feeder discharge chute.

ii. Be considered in the design for the liquid level to tank diameter ratio of 0.8 to 1 to allow proper axial mixing.

iii. Be fitted with connections for powder fill line, dilution water line, mixer, discharge line, overflow line, drain line, return line, vent, level switch and level transmitter.

iv. Have a fixed roof and if used as a working platform, it shall be designed to support the weight of a person.

v. Be considered to have a hinged top manhole cover, where applicable, with a minimum opening of 600 mm. The cover should open sideways and lay flat on the roof of the tank, have restrained option for open position, and be able to be lifted by one person.

vi. Include a suitably sized side mounted flanged and bolted access to allow easy access for maintenance for large mixing/batching tanks.

vii. Comprise internal baffles for large cylindrical tanks to avoid a swirling motion for mixing.

viii. Be considered in the design to avoid the formation of pockets of solids in the corners for slurry systems as commonly observed for rectangular tanks.

ix. Have water inlet compartment separate to the main tank to separate lime slurry from the dilution water and prevent lime accumulation in the inlet float valve.

x. Have a base that slopes to one direction to the drain outlet for complete emptying and solids removal. The tanks should be allowed to drain directly into the bund floor with a short drain line to avoid settled solids clogging the piping.

xi. Include an overflow line at least 1.5 times the diameter of the fill line with a minimum size of 80 mm and open to atmosphere with vermin proof mesh aperture < 2 mm. The overflow line must be installed below the level of the inlet line and discharge directly to the bund sump or the tank bund floor.

xii. Include a separate vent line with vermin proof mesh if the overflow line is insufficient to prevent excessive positive or negative pressures during filling/emptying and exceeding structural limitations of the tank. The vent needs to be sized considering tank inflow, outflow, thermal inbreathing and outbreathing.

xiii. Be fitted with connections for acid recirculation system including acid solution transfer line and acid recirculation line.

xiv. Be fitted with an overflow weir where the system is designed with gravity transfer for lime slurry dosing.

xv. Be designed and constructed to operate at atmospheric pressure.

xvi. Be earthed (where needed) in accordance with *E-SPE-STD-001 Electrical Design and Construction*, relevant codes and standards.

xvii. Be designed following the appropriate codes and standards. A number of standards for the tank design and construction as acceptable to Seqwater are listed below in Table 10-1.

Table 10-1 Recommended standards for the design and construction of mixing/batching and dosing tanks.

Recommended Standard(s)	Comment
AS/ANZ 4766 ASTM 1998	Applicable for Polyethylene Tanks
AS 2634 BS EN 13121-3	Applicable for Glass-fibre Reinforced Plastic (GRP) tanks
AS 1692 BS EN 14015 API 650 API 620	Applicable for Steel Tanks
AS 1170	Structural Design Actions
AS/NZS 1554	Structural Steel Welding

10.2.1.1 Tank Number and Sizing

The number of lime mixing/batching tanks shall depend on the system design. If a site requires both lime slurry and limewater dosing, then there shall be separate mixing/batching tanks for lime slurry dosing into the main and feeding lime slurry into the lime saturator. For a particular application, duty/standby mixing/batching tanks are recommended with the following.

i. Must include a minimum of two (2) mixing/batching tanks for each dosing or saturator feeding applications (i.e. two tanks for lime slurry dosing and two tanks for lime slurry feed for the saturator), in order to maintain continuity. Determination of the final number should consider the site's availability and criticality requirements, the site's size, the chemical properties and usage, site staffing, site location and access (e.g. in fair and poor weather), reliability, operability and maintainability considerations.

ii. The mixing/batching tank(s) should be sized to achieve a detention time of 15 minutes for continuous operation at the maximum lime dose and maximum plant flowrate. The proposed detention time has been considered necessary for the maximum development of salt crystals from mixing water dissolved solids in the tank, otherwise scale may build up in piping, valves, and pumps.

iii. Where designed for a fixed concentration and variable flow rates system, the tank sizing shall consider an optimum batching frequency.

iv. Where more than one mixing/batching tank is provided for a system or multiple systems, they should be capable of operating, mixing/batching and transferring simultaneously.

10.2.1.2 Tank Labelling

Mixing/Batching tanks shall be labelled and placarded in accordance with *PRO-00008 WHS Hazardous Chemicals*, Work Health and Safety Regulation 2011, Globally Harmonised System of Classification and Labelling of Chemicals (GHS), *AS 60079*, Australian Dangerous Goods Code and relevant legislative requirements. Where multiple mixing/batching tanks of lime are installed, each tank shall be labelled with the tank number i.e. Tank 1, Tank 2 etc.

i. Each tank shall include a name plate which will remain clearly legible for the design life of the tank and should be visible and legible from both within and outside of the secondary containment area where practicable. Each nameplate shall include:
   - Manufacturer's details
   - Date of manufacture
   - Tank number
   - Materials of construction
   - Product content
   - Dimensions
   - Design volume
   - Design temperature and pressure
   - Overflow level
   - Design standard
   - Specific gravity of chemical slurry etc.

ii. Chemical hazard placard shall be printed on stainless steel, adhered to the tank and intended to remain in place and legible for the design life of the tank.

10.2.1.3 Tank Materials

Refer to Section 7.5 for tank material selection. Where materials require additional protection as a result of site conditions and chemical attack, adequate protection, paint or coating, or other fit for purpose means of ensuring the required design life is achieved shall be provided in accordance with *M-SPE-STD-004 Protective Coatings.*

10.2.1.4 Tank Mixer

Each lime mixing/batching tank shall be fitted with an electrically driven mixer that adequately agitates the slurry. The tank mixer shall:

i. Enter from the top and be suitably supported and suspended from a tank roof if the tank has been structurally designed to accommodate this. Otherwise, supporting frames shall be designed and installed.

ii. Be designed to prevent solid settling and provide adequate mixing energy to homogenously mix lime slurry within the range of tank operational level and up to 5% slurry concentration.

iii. Be designed to run all times when the mixing/batching tank has contents. It is important as lime should not be allowed to settle as resuspension is difficult.

iv. Be removable from the tank without the need to remove the roof in its entirety and include a lifting mechanism if single person lifting is not appropriate.

v. Be considered to install with an offset from the tank center to avoid wave formation. For an offset mixer, any additional stress on the mixer shaft due to potential unbalanced forces shall be considered in the mixer selection.

vi. Be designed such that the mixer blades provide uniform velocity throughout the tank and operate without cavitation. Blades shall be one-piece construction and connected to the shaft via a keyway or a welded hub and retained via mechanical means that prevents detachment or loosening due to rotation and vibration.

vii. Have the option to start and stop remotely and locally. The designer shall decide the need of delivering varied shear force by the adjustable variable speed drive instead of a fixed speed motor.

viii. Include current monitoring, alarms and ability to interlock with the mixing/batching system when the mixer fails.

ix. Be designed to eliminate any chance of leakage of oil from the gearbox.

10.2.1.5 Level Devices

Each chemical mixing/batching tank shall include level control and protection. This shall be achieved by the use of:

i. An electronic level transmitter to measure the tank level/quantity. The electronic level transmitter shall incorporate:

   a. Low-Low Level (LALL) Setpoint: At this level Operator action has been unavailable or unable to correct the low-low level event. The process shall be interrupted by stopping the lime slurry feed pump or motive water pump for eductor system. A further alarm will be triggered, and the Operator notified.

   b. Alarm – Low Level (LAL)- At this level an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

   c. Where a system is designed requiring a batch transfer to a separate dosing/feeding tank (for a system of fixed concentration and variable flow rates), the following operations shall be required:

      - Batch Start (or Operational Low Level) – level that starts the batching sequence.
      - Batch Stop (or Operational High Level) – level that stops the batching sequence.

   d. Alarm – High Level (LAH) - At this level an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

   e. High-High Level (LHH) Setpoint: At this level, an operator action has been unavailable or unable to correct the high-high level event. The process shall be interrupted by stopping the screw feeder and isolating the mixing water supply line. At this level, a further alarm will be triggered, and the operator notified.

ii. Two separate and independent level devices (sensor or switch) to identify and action level events at High-High and Low-Low levels as required by the design to prevent overflow and pump protection (where available). These devices should trigger at LSHH and LSLL

   i. At LAHH (or LSHH) measured on the High-High level device, tripping of chemical mixing or batching sequence including screw feeder, mixing water supply shall occur.

ii. At LALL (or LSLL) measured on the Low-Low level device, closure of the chemical mixing or batching tank outlet valve and trip the chemical transfer pump, when used, shall occur.

iii. Where another sensor (instead of switch) is used for the purpose as stated in (ii), a dissimilar technology to the primary sensor shall be used.

iv. The design may assess the benefits and risks to operate the mixing tank for a variable concentration and fixed flow system without a level transmitter but with two high- and low-level switches. However, for a fixed concentration batching system, a level transmitter and two level switches must be used.

v. A mechanical level indicating device, preferably magnetic coupled type, with appropriate display to provide local level indication can be considered, where needed.

Tank level for primary and backup devices, where applicable, should be readily viewable as an electronic digital readout local to the tank.

10.2.2 Powder Fill Line

Each mixing/batching tank shall be fitted with lime powder feed line from the screw feeder discharge spout. The lime powder fill line and connection shall include the following:

i. The powder fill line is totally enclosed and be designed to discharge powder in a controlled manner to prevent unwanted dust clouds and risk of spills. The designer may consider to pre-wet the hydrated lime before it enters the tank to eliminate any mixing problem and keep dust levels low. However, Seqwater's experience is to operate the lime mixing/batching tank without any wetting system.

ii. The powder fill line should include heater or vibrator, or other suitable mechanism to prevent lime build-up in the discharge spout. From operational experience, blockage may occur particularly from inconsistent dosing when a big chunk of lime falls into the tank.

iii. The fill line connection to the tank uses a flanged nozzle connection from the topside (roof) of the tank with the same size as the fill line.

iv. The powder enters from the top of the mixing/batching tank in a vertical orientation and above the overflow height.

v. Provide a minimum 50 mm straight funnel discharge pipe connection from the mixing/batching tank flanged nozzle connection on the internal topside roof to direct the discharge orientation.

10.2.3 Mixing/Batching Water Supply

Mixing or dilution water is required to mix/batch lime powder in the mixing/batching tank with water and prepare lime slurry. The mixing/batching water system is designed to provide a fixed flowrate regardless of the batching or mixing concentration and achieve a constant level in the mixing/batching tank, regardless of the demand and system design. The flowrate of the water must not vary/fluctuate unless adjusted by the plant operators.

The level in the tank should be kept as high as possible. This will significantly reduce the chance of lime dust to mix with the mist above the slurry causing lime layer building up in the tank walls and covers.

The mixing/batching water may use potable water or a suitable plant water source, depending on the dosing application. The water used to prepare lime slurry for dosing to the raw water may use raw water provided that the water quality, especially during a dirty water event, does not affect the performance of the mixing and dosing system. When prepared lime slurry solution for lime saturator the water supply must be from a source that has undergone conventional treatment (or similar) to a minimum of sand/media filtration and disinfected. The water source selected must not deleteriously affect treatment or pose a risk to treated water quality.

The mixing/batching water line should:

i. Be fitted with a Y-strainer with a minimum mesh of 0.5 mm. Where raw water is used as the source, an additional automated strainer cleaning system should be used.
ii. Include a solenoid valve to open, close and interlock water supply system upon reaching high-high level in the tank.
iii. Include a booster pump when the water source does not have sufficient capacity to maintain a constant pressure and flow. The booster pump design shall provide sufficient flow and pressure for the operation with a variable speed drive where needed. Pump operation shall be interlocked with the same requirement of the solenoid valve mentioned above.
iv. Be fitted with a non-return valve and preferably be positioned downstream of the booster pump, where applicable.
v. Have a manual flow control valve, preferably a V-notch ball valve with the option of lock-in position.
vi. Have a flowmeter with the option to generate flow deviation alarm.
vii. Have a pressure sustaining valve to ensure the consistent feed pressure.
viii. Be fitted with a float valve to maintain constant level in the tank.
ix. Have a manual isolation valve upstream of the mixing/batching tank connection for maintenance.
x. Materials used in the mixing water line must be AS/NZS 4020 certified.

In addition to the above requirements, where a potable water system is used as a source of mixing water, the potable water system shall be protected from the lime mixing tank by the use of a reduced pressure zone (RPZ) backflow prevention device – only proprietary back flow prevention devices shall be used. Double check valves are not considered sufficient for adequate double layer protection. Arrangement must comply with the AS/NZS 3500 and Queensland Plumbing and Wastewater Code.

10.2.4 Tank Outlet and Transfer Line

The lime slurry tank outlet line design shall depend on the system design. For lime slurry dosing into a main, the dosing line requirement is provided in Section 11.3. For lime slurry feed into a saturator, the feed line requirement is provided in Section0.

In general, the outlet line shall include the following:

i. Be sized such that it shall transfer lime slurry at a velocity not less than 2 m/s.
ii. Include an outlet connection at least 200 mm above the tank floor to prevent solid entrainment, and the outlet line to be fitted with a manual isolation valve installed close to the tank.
iii. Be run with a continuous downward gradient so chemical slurry does not accumulate in the line.
iv. In addition to the above requirement, when a mixing tank is connected to an eductor dosing system, it shall include the following:
    a. An outlet flanged connection for the insertion of suction lance. Suction lance is to minimise blockage, enhance suction and provide easy removal without requiring tank draining.

b. The suction lances must be fitted with a strainer to filter coarser solid for protection of downstream equipment against blockage.

v. When the outlet line is used to transfer lime slurry to a dosing tank, it should include an actuated isolation valve to start and stop for gravity transfer. When a transfer pump is needed, the following shall be considered:

a. Peristaltic hose pump is preferred for lime slurry due its capability to handle solids and low maintenance requirements.

b. Be capable of transferring the whole batch solution in less than 10 minutes.

c. Be fitted with a fixed speed motor with the option of a soft starter.

d. Be provided manual isolation valves at pump suction and discharge sides for maintenance. Generally, duty/standby pump arrangement is not required unless the transfer pump operation is critical for the plant continuous operation.

e. Include a pressure relief valve installed immediately at pump discharge. The relief vale shall be sized for a full flow relief and the relief line should preferably be returned on the top of the batching tank.

f. Be provided appropriate water and acid flushing connecting lines with a non-return valve, a manual isolation valve and an actuated isolation valve.

11 Lime Slurry Dosing System

This section provides the design and construction requirement for the lime slurry dosing system. Standard P&ID drawings *B-DWG-STD-024 Lime Storage, Mixing/Batching and Dosing System – Sheet 4 of 6 (Lime Slurry Pumped Dosing System) and B-DWG-STD-025 Lime Storage, Mixing/Batching and Dosing System – Sheet 5 of 6 (Lime Slurry Eductor Dosing System)* shall be used in conjunction with this section as referenced in Section 0.

Lime slurry dosing system is designed to dose lime slurry accurately into a main/reservoir. At Seqwater sites, lime slurry is dosed using eductors, dosing pumps or by gravity. In selecting the dosing mechanism, the designer shall assess the best option to minimise lime blockages and maintenance requirement with consideration of dosing accuracy, site limitations and other aspects.

The following guidelines shall be used to select the appropriate lime slurry dosing system into a main/reservoir:

I. Eductor system: Only recommended for a system where there is a minimal variability in plant production rates and water quality. This is because a variable concentration system can take longer to respond to changes in lime demand and increase the chance of blockage to eductors and lines when dosed with high concentrations. In addition, depending on water quality and residence time, this system may also increase possibilities of calcium carbonate scaling in piping and valves since motive water does not receive tank detention time for reaction. Therefore, this system should be the least preferred choice for lime slurry dosing.

II. Dosing pump system: There are two systems available for lime slurry dosing with pumps as mentioned below.

   a. Variable concentrations with fixed flow rate: Predominately suitable for a system where constant plant production rates and raw water quality (same condition applicable to eductor system). Not recommended for a system where quick process response time is required for pH change. However, the pumped system has advantages over the eductor system due to the absence of eductor and motive water.

   b. Fixed concentration with variable flow rates: Recommended for systems where dosing rates need to be varied often due to changes in water quality and/or production flow rates. This system provides quick response to process changes by changing the dosing flow rate at a particular concentration. If properly designed, this system significantly decreases chances of lime blockages and scaling in piping.

III. Gravity system: Only recommended where a sufficient gradient exists between the lime slurry mixing tank and dosing point, and the required line velocity can be achieved without the potential risk of frequent lime slurry build up inside the pipe. Gravity system is not further discussed in this section.

The reminder of Section 0 discusses the design and construction requirement for lime slurry dosing using the eductor and pumped systems, lime slurry dosing line including the requirement of buried pipes.

11.1 Eductor System

An eductor dosing system is designed to be at fixed flow regardless of the demand. The slurry concentration is automatically adjusted based on the main water flowmeters, operator dose setpoint and main water pH meter (where installed). Standard P&ID drawing *B-DWG-STD-025 025 Lime Storage, Mixing/Batching and Dosing System – Sheet 5 of 6 (Lime Slurry Eductor Dosing System) as* referenced in Section 0 shall be used in conjunction with this section.

The eductor system works on the principle of the venturi effect. High velocity motive water is passed through the eductor which creates a vacuum. The vacuum draws lime slurry from the mixing tank and mixes it with the motive water.

The eductor shall:

i. Include duty/standby arrangements to allow for continuous operation while standby eductor is offline during maintenance or cleaning. This can be achieved with either duty/standby eductors for each mixing tank or duty/standby mixing tank, dosing lines with one eductor.

ii. Be designed to provide sufficient suction and transfer at the required lime slurry flowrate and design concentration range.

iii. Be constructed of suitable material resistant to lime slurry abrasion and corrosion and degradation for flushing with dilute acid solution.

iv. Be designed to consider using union or camlock connection in the suction and discharge side for easy removal.

v. Be designed with a suitable orifice size that decreases the probability of blockage while maintaining the required dosing flow rate.

vi. Be located or positioned on top or at the side of the mixing tank to enhance suction, minimise blockage and to dismantle easily without requiring to drain the tank contents.

vii. Be fitted with the suction lance/spear and with the suction line designed as short as possible to reduce the motive water pressure requirement, minimise blockage, and ease of maintenance.

viii. Include an actuated valve upstream of the eductor for isolation while running the motive water through the eductor for a period of time for cleaning each time lime slurry dosing is stopped.

11.1.1 Motive Water System

The source of motive water will depend on the dosing location. Raw water can be used as motive water dosing lime slurry into the raw water if an appropriate screening/cleaning system can be provided particularly during dirty water events. Potable water or a suitable plant water source can also be used depending on the dosing application. The selected water source must not adversely affect the treatment or pose a risk to treated water.

The general mechanical design requirements of the motive water system shall follow the requirements as provided in Section 10.2.3 with the following additions:

i. Shall be fitted with duty/standby booster pumps when the water line does not have sufficient or consistent pressure. A flow control valve and/or pressure regulating valve should be used to control the flow and pressure to the eductor system.

   When used, the booster pump shall:

   a) Provide sufficient flow and pressure for the eductor operation to achieve the required lime slurry flowrate from the mixing tank.

   b) Consider a VSD motor to adjust the pump speed, where needed, to address the variation of source water pressure or to maintain the fixed level in the batching tank. This will assist to counteract the probable variation in line frictional losses due to pipe blockage from changing lime slurry concentrations.

c) Be capable of providing dilution and ensure the minimum velocity of 2 m/s in the dosing line can be maintained.

d) Be typically centrifugal type pumps, however, other suitable pump types can be selected.

ii. Pump discharge shall be fitted with pressure and flow monitoring devices with high- and low-pressure and flow alarms.

iii. Shall be fitted with a non-return valve upstream of the eductor.

iv. Float valve requirement for the mixing water line is not applicable for the motive water supply system.

11.2 Pumped System

Lime slurry dosing with pumps into a main can have two arrangements as outlined above in Section 0. Standard P&ID drawing *B-DWG-STD-024 025 Lime Storage, Mixing/Batching and Dosing System – Sheet 4 of 6 (Lime Slurry Pumped Dosing System)* as referenced in Section 0 shall be used in conjunction with this section.

The design and construction requirement for lime slurry dosing with pumps for both two arrangements shall generally follow the specification of limewater dosing as provided in Section 13.2. Other additional information not included in Section 13.2 are described below.

11.2.1 Variable concentration and fixed flow system

A variable concentration and fixed flow system shall pump slurry into the main or reservoir from the mixing tank. Details of the mixing tank are described in Section 10.2.1 and general requirements of pumping system are described in Section 13.2. Other design requirements for the lime slurry pumping system are described below.

11.2.1.1 Lime Slurry Dosing Pump

Seqwater generally prefers the application of peristaltic (hose) pumps for lime slurry dosing. The design shall select pump materials compatible with both lime slurry and acid solution. Other type of pumps may also be considered if suitable for the design conditions, and properties of lime slurry and acid solution.

To achieve the recommended line velocity of 2 m/sec, peristaltic pumps may generate high discharge acceleration losses particularly for long dosing lines. The peristaltic pump system design shall:

i. Select a safe operating range of discharge acceleration losses following pump manufacturers' recommendations (< 1.5 bar recommended for a PN16 system).

ii. Include inline pulsation dampeners and be recommended to ensure dampener pressure during operation to maintain its integrity.

iii. Include inlet pulsation accumulators for the damping of the pulses on the pump inlet side if recommended by the pump manufacturer.

iv. Be fitted with a float type high level switch to trip the pump if the pump internal contents become flooded when the hose bursts.

v. Comprise pump trips from high-high line pressure (from a pressure transmitter) in addition of pressure relief valves.

vi. Be fitted with flow switches in the pressure relief valve relief lines to trip pumps. A hardwired interlock is recommended for the pump trip to make the functionality available for the local control mode.

vii. Be a VSD controlled motor to achieve flexibility on the required flowrate in the event of lime blockage or increase in pressure requirement due to difference in slurry concentrations.

viii. Be limited to a certain safe pump speed limit and shall not be exceeded under all conditions including manual operation, maintenance, and testing.

Carrier water is generally not recommended to achieve the line velocity due to increased chances of calcium carbonate scaling in pipes, valves, and additional control requirements. Since carrier water is added downstream of the mixing tank, it does not receive any tank detention time for reaction and more scaling may occur in piping and valves depending on carrier water quality and pipe residence time. Where carrier water is selected to achieve the required line velocity, the design requirements as stated in the following Section 11.2.1.2 shall be followed.

11.2.1.2 Carrier Water

Where used to increase the line velocity, carrier water shall be introduced into the chemical dosing line at the end limit of the chemical dosing skid.

Carrier water lines shall generally comply with the requirements provided in Section 10.2.3 with the following additions:

i. Be fitted with a low and high flow switch and alarm which shall only be active when system dosing is active.

ii. Instead of a manual flow control valve, an automatic flow control loop can be considered where higher accuracy to a set flow is needed considering potential variability in system back pressure at different lime concentrations and operating conditions at the dosing point.

iii. Be designed such that the required water flow rate can be maintained considering the potential variations of dosing system back pressure.

The designer shall assess the need of additional mixing requirement at the meeting point of lime slurry and carrier water. Section 13.3 shall be referred for chemical mixing guidelines and the management of potential blockage of mixers from scaling.

11.2.2 Fixed concentration and variable flow system

A system with a fixed batching concentration with variable dosing flow rates shall require separate batching tank(s) and dosing tank (s). The details of mixing/batching tank as described in Section 10.2.1 shall be followed with the following additional requirements to start and stop of batching from tank level transmitter signals. The electronic level transmitter shall also incorporate:

i. Batch Start – level that starts the batching sequence.

ii. Batch Stop – level that stops the batching sequence.

Dosing tank design requirements will be like that of limewater holding tanks as described in Section 13.1. General requirements of variable flow rates pumping system as described in Section 13.2 shall be followed. In addition, provisions provided in Section 11.2.1.1 for lime slurry dosing pumps must be followed.

The design shall include operating the system at several fixed concentrations to encounter variations in water quality and plant production. This will facilitate a single pump to be operated within its turn down ratio and meet the entire dosing flow range need without exceeding the pump speed limit or discharge acceleration loss limit for all conditions applicable to peristaltic pumps as highlighted in Section 11.2.1.1.

Where a fixed concentration and variable flow rate system is used, an additional batch transfer step is required after completing a batch.

11.2.3 Batching Transfer System

The batch transfer system transfers the lime slurry from the batching tank(s) to dosing tank(s) and shall operate automatically.

Batch transfer may be achieved via gravity or pumping. Where gravity transfer can be achieved by positioning the batching tank at a level above the dosing tank, this shall be the preferred method.

The batch transfer system shall follow the requirements provided in Section 10.2.4.

11.3 Lime Slurry Dosing Line

Dosing lines include pipework, equipment and instrumentations required to deliver lime slurry from the eductor discharge or pump dosing skid boundary to the dosing point. Dosing lines shall comply with the requirements of *M-SPE-STD-013 Chemical Dosing Piping Standard Specification.*

Redundancy requirements (duty/ standby) for dosing lines are not specified. However, these redundancy requirements should be assessed on a project-by-project basis to ensure the required availability and reliability criteria can be achieved.

The dosing lines shall include the following:

i. Piping to be designed as short as practically possible with one continuous run, minimum joints and with a continuous downward gradient.

ii. Piping to be sized to achieve a recommended minimum line velocity of 2 m/s for lime slurry.

iii. Be double contained after exiting the bunded area to prevent environment release. A leak detection system should be included at the lowest point. Where needed, the design should allow access for maintenance.

iv. Be connected with water flushing and acid recirculation lines for acid cleaning. The design shall include appropriate provisions not to be flushed or cleaned to trunk mains to cause water quality problems.

v. All dosing equipment including pipework, valves, and instrumentation from the acid flushing point to the recirculation point shall be constructed of suitable corrosion resistant material and be resistant to abrasion from lime slurries and resistant to degradation from the acid solution.

vi. Be fitted with retractable duty/standby dosing spears for a single dosing line when dosing into pipes.

For the lime slurry dosing system, downstream pH analysers must be installed at suitable locations so that meaningful pH readings can be obtained to effectively control the process considering lime slurry reaction time with process water and the main line velocity.

11.3.1 Dosing Spears

Dosing spears shall be used to dose lime slurry where injection into pipes is required. Dosing spears shall:

i. Include protection from being ejected from the pipeline during operation and extraction.
ii. Pass through a valve which allows process lines to continue in operation while dosing spears are removed for maintenance.
iii. Be installed penetrating 30-50% of the internal diameter of the line being dosed.
iv. Be retractable / removable from a pressurised process line.
v. Not be installed immediately downstream of an isolation or modulating valve that may create significant stresses to the assembly during the valve operation.
vi. Be generally included with a check valve. However, the spear assembly can also be considered to install without a check valve since the dosing spear generally cannot be included into the automatic acid cleaning loop for descaling. If the dosing spear assembly is installed without a check valve, an external check valve must be installed upstream to prevent water backflow into the dosing line.
vii. Be recommended with open ended discharge to reduce the chance of blockage from particles accumulation.
viii. Be selected with materials between stainless steel and polyethylene materials considering operating conditions and installation locations.
ix. Be included in the list of periodic cleaning to remove scaling.

Where dosing spears are used in horizontal pipes and mains that may not always be fully flooded while in operation:

i. Dosing spears should be installed in the lower half of the pipe, preferably at a 45-degree angle from the bottom part of the pipe, protruding 30% of the internal diameter of the pipe.

When dosing is not injected into pipes, provision shall be made to use spray bar or other methods to provide adequate mixing into process water. If additional mixing is necessary, mixing options as provided in Section 13.3 should be considered. Potential build-up of lime slurry shall be considered in the selection of mixing system.

11.4 Buried Pipes and Dose Pits

Further considerations for below ground assets, including buried pipes and dose pits, are discussed in the following two sections.

11.4.1 Buried Pipes

All chemical dosing pipework required to be installed below ground shall consider the following requirements:

i. Be buried for the minimum distance necessary to minimize the risk of identifying and finding leaks.
ii. Be double contained. Any double containment pipe or system shall be suitable for burying.
iii. Minimise the use of joins as far as practicable to mitigate the potential for leaking.
iv. Eliminate low points in the chemical pipe as well as dual containment pipe to prevent chemical pooling.
v. Drain to a sump or pit. Pipes shall be run such that dual containment and buried chemical pipes run to a sump or pit and can be freely drained at this location.
    a. Sumps and pits shall include a level switch to indicate a leak event which shall trigger a remote alarm.
    b. Sumps and pits shall be covered and sealed (or installed to eliminate ingress of stormwater) with the ability for operators and maintenance personnel to access and view inside for inspection purposes.

c. Sumps and pits shall be able to accommodate a small submersible pump or similar for draining, or an alternate means of draining shall be proposed.

vi. For both metallic and non-metallic pipes, include a continuous detectable marker tape placed in the trench 350 mm above the pipe, installed in accordance with the manufacturer's guidance. The tape should indicate the pipe content whether by printing the chemical name on the tape or using an agreed colour coding.

vii. It is also recommended to use above ground markings at a suitable interval and at changes in direction to identify the buried dosing lines.

viii. Buried pipelines design and installation must conform to *AS 2566.1, AS 2566.2* and *M-SPE-STD-013 Chemical Dosing Piping*.

11.4.2 Dosing Pits

Dosing Pits shall refer to pits used for dosing into or sampling from any buried pipes.

Dosing Pits shall:

i. Be made of concrete (pre-cast or formed in situ), and sealed to provide chemical protection, leak tightness, and water tightness.

ii. Be readily accessible to operators and maintenance personnel as required for normal operation.

iii. Be designed to allow easy access for pump installation and be fitted with an appropriate power outlet to run the pump.

iv. Include a level switch to indicate ingress of liquid from stormwater or leaking assets. Level switches shall:

  a. Be installed as low as possible to indicate ingress of liquid.

  b. An additional high-high level switch may be necessary to trigger a shutdown at remote sites, or where submersion of the pit equipment, dosing/sampling points and instrument connection points would lead to damage of equipment, contamination of water, or an environmental release.

Where sampling from a Dosing Pit is required, Seqwater's preference is to use an off-take tube or sampling pump to pass process water to an external analyser. This is to reduce the requirement for access into Dosing Pits as far as practicable. Where this would result in excessive sample time delay, instruments may be installed in the Dosing Pit. All analysers and transmitters shall be installed outside of Dosing Pits in appropriate shelters, kiosks, or buildings.

12 Lime Saturator System

This section provides the design requirements for the lime saturator system. Standard P&ID drawing *B-DWG-STD-022 Lime Storage, Mixing/Batching and Dosing System – Sheet 2 of 6 (Lime Saturator System)* as referenced in Section 0 shall be used in conjunction with this section.

The purpose of the lime saturator system is to prepare saturated lime solution in the saturator tank from the lime slurry which is free from suspended solid. The saturated lime solution is then transferred into the limewater holding tank / dosing tank (s) for dosing. The lime slurry feed and dilution water line enter into the saturator via the feed well. Polymer is added into the feed line to assist for flocculation and reduce the supernatant turbidity. The undissolved lime, carbonate solids and impurities settle down to the bottom of the saturator, leaving a clear saturated limewater which rises to the top, spills over weirs into the collection launders and flows by gravity into the limewater dosing tank (s).

The sludge rake collects the lime sludge into the bottom towards the centre of the saturator. A portion of the lime sludge is recirculated back to the feed line allowing solid contact with incoming lime slurry and dilution water to increase the flocculation and sedimentation rates. Another portion of lime sludge is periodically removed as waste sludge from the saturator.

The lime saturator system shall include the following main components:

- Lime Saturator.
- Lime Slurry Feed Line.
- Dilution Water Supply System
- Lime Sludge Recirculation System.
- Polymer Dosing System.
- Limewater Outlet Line.
- Lime Sludge Removal System.
- Lime Saturator Bypass.

The lime saturator system shall be fully automated.

12.1 Lime Saturator

The lime saturator is generally a circular thickener/clarifier-type tank with a settling area and an underflow cone or sludge hopper. The lime saturator shall be above-ground, fixed, well-supported structure that is filled and discharged in situ. The product limewater shall be collected via the overflow launders at the top of the saturator and flow by gravity to the limewater dosing tank(s).

The saturator as a minimum shall include the following:

- Saturator Feed Line.
- Centre Feed Well.
- Overflow Launders.
- Sludge Rake Mechanism.
- Drain Line.
- Full Span Bridge for Saturator Access.
- Saturator Instrumentation.
- Sample Collection Ports.

The lime saturator shall be supported with legs and a strong ring beam supporting the walls and conical base. The support shall be able to accommodate the full content of the tank and at the highest underflow specific gravity. The design shall not impede access to the underflow equipment located under the clarifier for maintenance. The saturator shall be structurally designed with the appropriate standards including *AS/NZS 1170 Structural Design Actions* and *AS/NZS 1554 Structural Steel Welding*.

The saturator shall be covered with lids to prevent ingress of contaminants. The lids must be capable of being lifted manually using hand winches located in the walkway bridge. The material of construction of the lids/covers shall be weather and corrosion resistant.

The designer shall consider the required elevation level of the saturator to ensure saturated limewater solution can overflow through the weir across the whole hydraulic operating range and flows by gravity into the limewater holding tank without intermediate pumping. If the elevation level impacts ground level access to the outlet piping and valves, a suitable work platform shall be provided.

The lime saturator system shall be designed to achieve saturated lime solution with variable dosing flowrates. Provision to include a trim control based on the limewater holding tank level to prevent a continuous start/stop and allow smoother operation of the saturator.

All instrumentation and drive mechanisms installed in the saturator shall be protected with a weather canopy. The canopy shall be designed with a slight radial downward slope to prevent pooling of water. It shall be large enough to protect the instrument display and drives and provide adequate working space for maintenance.

The saturator shall be installed on a concrete bunded pad graded to a sump. Refer to Section 15.6 for additional information on the secondary containment.

The saturator mush be labelled with relevant similar information as provided in Section 0.

12.1.1 Size and Number

Lime saturator number and size shall include the following requirements:

i. Generally, include one (1) saturator because of its high capital investment. Determination of the final number should consider the site's availability and site's criticality requirements, the stored chemical properties, the site's size and usage, site staffing, site location and access (e.g. in fair and poor weather), reliability, operability and maintainability considerations.
ii. In determining the saturator size, the following should be considered:
    a. The saturator clarifier maximum hydraulic loading rate should be 1.5m/h and maximum solid loading rate should be 2.25 kg dry-solid/h. The lime water turbidity target should be 15 NTU and limewater should be a saturated solution, refer to Table 6-1 for saturated solution concentration at various temperatures.
    b. In determining the loading rates of the saturator, the centre feed well area must be excluded.
    c. The minimum lime powder utilisation should be about 85% considering the losses from lime impurities and lime losses in the saturator through the sludge removal.
    d. Determination of the final saturator clarifier size should consider the construction methodology adopted, footprint restrictions, and ease of manufacturing and transport.

12.1.2 Saturator Materials

Materials for lime saturator construction shall ensure tanks and their fittings and attachments are suitable for use under Site Conditions and ensure it is substantially immune from attack by chemicals under all service conditions. Where materials require additional protection because of Site Conditions, adequate protection, paint or coating, or other fit for purpose means of ensuring the required design life is achieved shall be provided. For coatings, it is important for all sharp edges to be removed and adequate radiuses applied.

Refer to Section 7.5 and 7.6 for the materials of construction for the lime saturator and coatings.

12.1.3 Saturator Feed Line

The saturator feed line is basically the continuation of saturator lime sludge recirculation line after receiving lime slurry and polymer. Seqwater's experience is to feed the recirculated sludge, lime slurry and polymer combinedly into the feed well with the feed line. The lime sludge external recirculation offers the main benefit of improved lime utilization which is further discussed in Section 12.4.

The designer may also consider connecting lime slurry line, lime sludge return line and polymer dosing lines separately into the saturator feed well if additional benefits can be obtained. The polymer dosing directly into the feed well can offer optimum results as it is generally known to dose polymer after all other chemicals added and once the pin flocs have formed.

The saturator feed line shall consider the following:

i. Be fitted with line connections with appropriate sizes for the lime slurry and polymer dosing lines.

ii. Be sized to ensure that sufficient velocity is achieved to provide an effective mixing in maximising the flocculation across the full operating hydraulic range.

iii. Be sized to ensure that a minimum velocity of 2 m/s is achieved after the lime slurry injection points to prevent settling and deposition of lime.

iv. The feed line should enter the saturator via the feed well in tangent to promote mixing.

v. Include an actuated isolation valve positioned upstream of the lime saturator connection point for isolation purpose.

vi. Be designed such that the line blockage can be cleared using high-pressure water stream (jet rodding).

vii. Be fitted with a line connection water flushing for acid recirculation upstream of the isolation valve.

12.1.4 Feed well

Feed well shall be installed at the centre of the lime saturator where lime slurry mixed further with the dilution water, returned sludge and polymer. The feed well shall have the following requirements:

i. A deflector cone, or other suitable mechanism, shall be installed at the bottom of the feed well to promote an even distribution of feed across the entire bed at a slow rate and minimise short circuiting.

ii. Include appropriate baffles to promote mixing.

iii. Include a flange connection on the side wall of the feed well for the incoming line.

iv. The feed well shall be sized to allow for de-aeration of the incoming feed.

12.1.5 Overflow Launders

The lime saturator shall have overflow launders installed at the top to collect limewater supernatant prior to transfer into the holding tank by gravity.

The overflow launders requirement to include the following:

i. Should be designed as a circumferential v-notch weir and include an overflow box for discharge. Radial launders may be considered; however, a suitable walkway and platform shall be provided to allow access for maintenance and cleaning.

ii. Strainer shall be positioned in the outlet of the overflow box to prevent foreign materials to be carried over into the limewater holding tank.

iii. Shall be sized and positioned to ensure limewater supernatant can overflow without overfilling the saturator across the full hydraulic operating range.

12.1.6 Saturator Rake Mechanism

The lime saturator shall be fitted with a sludge rake mechanism to collect the settled sludge towards the underflow cone at the centre of the clarifier. The saturator rake shall run 24 hours even if the saturator is offline.

The sludge rake mechanism requirement to include the following:

i. Shall be supplied with drive shaft, rake arms, underflow cone scrapper, gearbox with electric motor and drive, and automatic lift/lower mechanism.

ii. The sludge rake should consist of two rotating arms with scrapper blades with the rake arms positioned parallel to the clarifier bottom. The sludge rake arms shall be designed to sweep the entire clarifier bottom clean twice per minute.

iii. The sludge rake arms shall be constructed from materials compatible to handle lime and acid solution.

iv. Be designed to operate continuously when the saturator is online, and the level of saturator is above the low level setpoint and not being disabled. The saturator shall be kept online even if the saturator operation is terminated or there is a power outage. This is to prevent the settling of lime sludge in the saturator.

v. Be rigidly supported to hold the rake arms in an alignment.

vi. The rake drive mechanism shall be designed to provide the required power to drive the rake arms over the required speed range and load.

vii. The rake be preferably designed to monitor rake torque as it gives an indication of sludge bed depth/thickness.

viii. The rake drive mechanism must be suitable for operating under the Site Conditions and be installed within a sealed conduit box.

ix. Be designed with ease of maintenance and maintainability taken into consideration.

x. The motor and gearbox shall use food grade oil and a catchment tray shall be provided to prevent oil spills into the saturator.

12.1.7 Saturator Drain

The lime saturator shall be fitted with at least three DN100 nozzles from the underflow cone to facilitate saturator draining, sludge removal and an extra nozzle for emergency dumping. The drain line shall:

i. Discharge directly to the bund floor and allow discharge washdown to the bund sump. Piping the drain outlet to the sump should be avoided as the settled lime will tend to clog up the pipe.
ii. Be isolated via a drain valve, located as close to the tank body as possible.
iii. Be adequately protected, sized and of suitable construction to prevent inadvertent damage resulting from drainage.

12.1.8 Sample Collection Ports

The lime saturator shall be fitted with sample line(s) or ports from suitable locations to collect lime slurry solution at levels determined by the process requirement for clarifier performance monitoring purposes. The sample lines/ports shall:

i. Be installed in the observation trough and be discharged into the bund floor and allow discharge washdown to the bund sump. Piping the sample lines to the sump should be avoided as the settled lime tends to clog up the pipe.
ii. Be isolated via isolation valve connected to the saturator body through flanged connections.

12.1.9 Saturator Access

Stairway access from the ground level to the top of the lime saturator shall be provided. The stairway and platforms shall comply with the requirements of *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

The lime saturator must have a full span bridge access walkway for access and maintenance purposes to the rake drive and any instrumentation fitted on the top of the saturator.

The lime saturator shall be provided with a peripheral walkway span across complete circumference of the saturator with handrails to allow cleaning and inspection of the launders. When radial launders are used, a suitable walkway and platform shall be provided to allow access for maintenance and cleaning.

All bridges and walkways shall be designed to prevent tools falling from heights and to prevent pooling of water in the low points.

To gain access into the saturator internals, access ladder and handrails shall also be provided for maintenance and cleaning purposes. Saturators should be covered with large, hinged lids to gain access and inspect internals. Lids with ¼ of top surface area which can be winched open from the central bridge should be considered.

A fixed davit arm, or other suitable mechanism, mounted on the saturator for emergency rescue shall be provided.

12.1.10 Saturator Instrumentation

The lime saturator shall be equipped with instruments to provide monitoring, control and alarming purpose. It shall include the instruments for the measurement of:

- Saturator level
- Saturator sludge bed level

- Limewater concentration (by measuring conductivity of limewater)
- Limewater turbidity.

The trends of the above instruments shall be recorded in SCADA to optimize the performance of the saturator.

The followings shall be considered for the instrument devices:

i. Measurement of Sludge Bed Level: The instrument shall be installed for the purpose of de-sludge pump timing, limewater turbidity monitoring and alarming. This is an important parameter to monitor and control to achieve the required limewater turbidity and filtering benefits of the bed. Due to lack of reliability, this instrument should not generally be used for automatic control of sludge pumps. The sludge blanket monitoring device shall:

    a. Be either an ultrasonic or an optical level sensor which has proven to be reliable in detecting the lime sludge blanket interface.

    b. Be installed with the appropriate mounting method, typically the device is mounted from the clarifier bridge.

    c. Be installed at a suitable location to obtain representative measurement of sludge bed level.

    d. The operation and measurement must not be inadvertently affected by the presence of other equipment or instrumentation located in the vicinity.

ii. Measurement of Saturator Level: The device shall be installed to provide saturator level for monitoring and alarming purpose. The level device should:

    a. Preferably be an ultrasonic or radar type level sensor.

    b. Be installed with an appropriate mounting method, typically the device is mounted on the clarifier bridge.

iii. A conductivity meter shall be installed to obtain information of the produced limewater concentration. The conductivity meter should be suitable for measuring limewater conductivity with a suitable range to detect slight changes in lime concentration.

iv. A turbidity meter shall be provided to monitor the carryover of suspended solids from the saturator. The turbidity meter should generally be suitable for measuring the limewater turbidity with the range between 1 to 30 NTU.

v. The conductivity and turbidity meters shall be located to provide representative measurements. Typically, samples are taken from the saturator outlet lines and connected to analysers for measurements. The sampling system shall be provided with flow monitoring provisions or flow switches to identify no flow scenarios to the instruments as specified in standard specification *I-SPE-STD-015 Instrumentation*. The system must be constructed with materials suitable to handle limewater and dilute acid solution.

vi. Electronic level sensors/transmitters must be suitable for Site Conditions and compatible with the chemical in service.

vii. Be provided with appropriate display to provide local indication and remotely in SCADA.

viii. Shall generally include high/low setpoints to trigger alarms to notify operator(s) and trigger actions to correct any issues if the trigger does not self-correct. Saturator high level alarm may indicate blockage in pipe between the saturator and limewater tank. Low Saturator Level alarm setpoint shall interlock the lime sludge pump, lime recirculation pump, and the saturator rake.

12.2 Lime Slurry Feed Line

The lime slurry feed line starts from the lime mixing/batching tank and ends into the sludge recirculation line before entering the saturator. The designer alternatively may consider ending the lime slurry feed line directly into the saturator feed well if the precipitation of calcium carbonate after adding lime slurry into the dilution water create significant scaling issues or create ineffective flocculation in the saturator.

The slurry feed line comprises of equipment and instruments necessary to accurately feed lime slurry into the saturator. The lime slurry feed line design shall include the followings:

i. Be designed in duty/standby configuration to allow for continuous operation while the standby line is offline for cleaning or maintenance.

ii. Be sized to ensure that a minimum velocity of 2 m/s can be achieved.

iii. The line and valves shall have a constant diameter throughout.

iv. Piping and fittings shall be designed to prevent settling or deposition of lime solids.

v. The length of the lines shall be kept to an absolute minimum and use long radius elbows wherever practical.

vi. Be fitted with lime slurry feed pump (s) with requirements including:

   a. Use of a peristaltic hose pump, other suitable pumps are acceptable if they can reliably pump lime slurry within the design envelope. Where a peristaltic pump is selected, additional requirements provided in Section 11.2.1.1 must be followed.

   b. Be preferably designed to deliver a constant flowrate of lime (variable concentration) slurry into the sludge recirculation line regardless of the demand with a fixed speed motor. A VSD controlled motor may be considered to provide more flexibility to achieve the required flowrate in the event of lime blockage or increase in pressure requirement due to difference in slurry density. However, a constant concentration and variable flowrates may also be considered for lime slurry feed if a better turndown from the screw feeder cannot be achieved to meet the process demand.

   c. Be flanged connected and include manual isolation valves at both suction and discharge ports.

   d. Be fitted with interlocking with mixing/batching tank low level.

   e. Pump materials shall be resistant against abrasion from lime slurries and be resistant against corrosion from the diluted acid solution.

   f. Comply with the requirements of standard *M-SPE-STD-012 Chemical Dosing Pumps.*

vii. Be fitted with a full flow sized safety relief valve and the relief line returning back to the mixing/ batching tank wherever practical, or alternatively returning to the pump suction side is also acceptable. The relief return line should include a flow switch to identity the event of a relief.

viii. Be fitted with an actuated valve upstream of the pump for isolation and line selection and a non-return valve immediately upstream of the injection point.

ix. Include a pressure transmitter to interlock the pump on high-pressure which may arise from pipe blockage.

ix. Include a flow meter and raise alarms from flow deviations. Flow meters shall comply with the requirements of *M-SPE-STD-009 Flow Meters* for the selection and installation.

x. Include a manual isolation valve upstream of the injection point and downstream of the non-return valve to provide positive isolation for maintenance.

xi. The line, equipment and all fittings shall be constructed from material resistant against abrasion and suitable with the chemicals handled including lime slurry and diluted acid solution.

xii. Include an appropriate isolation valve and line connection to allow for water flushing and acid cleaning of the lime slurry feed line.

12.3 Dilution Water Supply

Dilution water supply is required to dissolve and dilute the lime slurry to make limewater solution at or close to its saturation point.

The dilution water shall use potable water or a suitable plant water as the water source depending on the application.

The design requirements of the dilution water supply system, shall generally follow the same requirements as provided in Section 10.2.3 for mixing water system, with the following additions:

i. The dilution water supply line shall end at the top of the saturator with an air gap to avoid entrance of lime powder into the dilution water line.

ii. Include duty/standby centrifugal pumps with the design to maintain sufficient flow and pressure for the operation with a variable speed drive where needed. Pump operation shall be automated with the saturator operation. Where source water is available with sufficient flow and pressure, the dilution water supply should be managed with control valves.

iii. Be fitted with a flow measurement device and include flow deviation alarms.

iv. Float valve requirement for the mixing water line in Section 10.2.3 is not relevant and therefore not applicable.

12.4 Lime Sludge Recycling System

Lime sludge recycling system shall be installed to draw lime solid from the underflow cone and recirculate back to the saturator feed well to provide additional residence time for improved lime utilisation.

Seqwater's preference is to utilise an external pump recirculation system to recirculate the lime sludge into the saturator feed line rather than an internal recirculation system which relies on a recirculation impeller to lift the solid from the underflow cone by the draft tube. Seqwater has several installations using an internal recirculation system and has found that the pipework and impeller can easily get blocked causing high operational downtime. In addition, it is also difficult to monitor the flow from the draft tube of the internal recirculation system and hence the solid recirculation ratio may not be determined.

An external recirculation system has been found to be more effective and reliable. The recirculation line can be cleaned using acid and flushing water. It also provides better monitoring and control since the flow in the recirculation line can be measured and hence provides ability to control the ratio of lime sludge to the feed flowrate. It also offers better operational performance flexibility because the pump intake is located in the bottom of the underflow cone, hence it recirculates the higher concentration sludge and does not require a high sludge blanket level for recirculation.

The lime sludge recirculation line shall have the following design requirements:

i. The recirculation pump must be designed to provide a maximum recycling rate of approximately equal to the feed rate to the lime saturator. The pump shall run 24 hours even if the plant is offline.

ii. The recirculation pump is typically a rotary lobe or peristaltic pump, but other suitable pump types may be considered if they are capable for pumping lime sludge at the required design envelope.

iii. Must be a VSD controlled motor to adjust the pump speed manually depending on the saturator performance.

iv. Be fitted with a full flow sized safety relief valve and the relief line preferably returned to underflow cone to reduce the disturbance to the sludge blanket.

v. Pipework shall have long radius bends and be suitably sized so as to maintain suitable velocity and minimise lime build-up / settling over the proposed flow rate range.

vi. Include a flow meter for monitoring and alarms, and a pressure transmitter to interlock the recirculation pump on high-pressure which may arise from pipe blockage.

vii. Pipework must be designed to be efficiently cleaned and disassembled if required to gain access for pressure cleaning. Include an appropriate isolation valve and line connection to allow for water flushing and acid cleaning in the lime sludge recirculation line.

12.5 Polymer Dosing System

The design shall include the installation of a polymer dosing system to assist in the formation of flocs and improve the performance of the saturator. The polymer dosing is also needed to reduce the supernatant limewater turbidity and hence reduce the lime sludge build up in the limewater holding tank(s).

The designer shall consider the best dosing location for polymer either in the saturator feed line downstream of the lime slurry injection point or directly into the saturator feed well. Polymer dosing is more effective to dose once pin flocs have been formed. The design shall optimise the amount of polymer used as overdosing may cause operational issues. The design shall also ensure that additional monomer loading from polymer dosing will not have a detrimental effect on treated water quality.

The design and construction requirement of the polymer dosing system including polymer storage, batching and dosing shall comply with the requirements as specified in Engineering Standard *B-SPE-STD-011 Polymer, PAC, Pot Perm and Soda Ash Systems.*

It is not mandatory to include a dosing spear to enhance mixing since the lime sludge recirculation velocity is designed to provide sufficient mixing. The feed well allows for gentle mixing to occur which promotes flocculation.

The dosing line shall however be fitted with a non-return valve immediately upstream of the injection point to prevent backflow to the polymer system and a manual valve to provide positive isolation for maintenance.

The polymer dosing shall be based on the lime powder discharge rate and operator dose setpoint. The dosing system shall be capable of delivering polymer solution over the design envelope range.

12.6 Limewater Outlet Line

Limewater outlet line shall be installed to transfer limewater to the limewater holding/dosing tank(s) by gravity. The limewater outlet line(s) shall be connected from the saturator overflow box.

The system should include as a minimum two (2) limewater outlet lines on duty/standby arrangement to allow for continuous lime saturator operation when standby line is offline for cleaning or maintenance.

The limewater outlet line(s) requirements shall include the following:

i. Be sized appropriately with minimum flow resistance. The length of the lines shall be kept to an absolute minimum and use fittings that minimise pipe frictional losses.

ii. Be designed with continuous downward gradient for gravity transfer.

iii. Be fitted with actuated isolation valves on each line installed as close as possible to the lime saturator.

iv. Be included connections for sample water collection for turbidity and conductivity meters.

v. Be installed appropriate isolation valves and line connections to allow for acid cleaning and water flushing.

12.7 Lime Sludge Removal

Lime sludge shall need to be removed periodically from the saturator. The lime sludge removal system includes a pump to remove lime sludge which mainly comprises of lime impurities, carbonate solids and lime wastage. Lime sludge removed from the saturator will need further treatment before disposal due to high water content. This standard does not specify preferable sludge handling or treatment methods before disposal.

It is important to maintain an optimum sludge bed level in the saturator to ensure sufficient sludge volume for recirculation and preventing solid carried over into the overflow. Lime sludge should be removed from the saturator on a timed basis to maintain an optimum sludge bed level. Automatic de-sludging based on the sludge bed level of the saturator has not been recommended due to unreliability of sludge bed level instruments.

If a change in sludge bed level is found outside the operational range, an operator can change the time interval for de-sludging to achieve the optimum sludge bed level.

The lime sludge removal system generally includes a lime sludge pump and a scour line to transfer the lime sludge from the saturator to the onsite sludge handling facility. The Saturator design needs to ensure lime sludge has no un-dissolved lime solids or else it will affect onsite sludge processing.

The design requirements of the lime sludge removal line shall generally adhere to the requirements as provided in 0 with the following additions:

i. The de-sludging valve installed upstream of the pump shall be automated and preferably be a straight through diaphragm valve.

ii. Be fitted with a full flow sized safety relief valve and the relief line preferably returning back to the saturator underflow cone, wherever practical to reduce the disturbance to the sludge blanket. Alternatively, the relief line can be returned to the suction side of the pump(s).

iii. Flow measuring device may be required depending on the process requirement of the sludge handling facility.

iv. Include an appropriate isolation valve and line connection to allow for complete acid cleaning and water flushing in the lime sludge line.

v. Recommend to use the de-sludge pump to supply the acid solution to flush the de-sludging line. When used, the de-sludge pump shall be capable of delivering the acid solution at the required flow and pump material must be compatible with the acid solution.

12.8 Saturator Bypass Line

A saturator bypass connection shall be considered to allow lime slurry to be dosed directly to the dosing point during an extended period of shutdown of the lime saturator.

An offtake from lime slurry feed line may be made and connected to the limewater dosing point. The line must include an isolation valve to open and close when the bypass line is needed and a non-return valve before the dosing point.

13 Limewater Dosing System

This section describes the requirement for the design and construction of limewater dosing system and shall be read in conjunction with standard drawing *B-DWG-STD-023 Lime Storage, Mixing/Batching, and Dosing System – Sheet 3 of 6 (Limewater Dosing System)* as referenced in Section 0.

The main components of limewater dosing system shall include the following:

- Limewater holding/dosing tanks.
- Dosing skid and control.
- Dosing line, dosing point and chemical mixing.
- As required, tank and dosing containment and bunding requirements.

13.1 Limewater Holding/Dosing Tanks

Limewater holding tank(s) or limewater dosing tank(s) are used to store saturated lime solution for dosing into the process system as transferred from the lime saturator. Limewater holding tank(s) acts as a buffer tank while limewater is prepared separately in the saturator. The limewater holding tank(s) shall be positioned at a level below the limewater outlet line to allow gravity transfer under all operating conditions.

The limewater holding tanks shall be above ground, fixed, permanently positioned tanks. All tanks should be designed and constructed to the appropriate standards as detailed in Section 10.2.1.

The mechanical requirements for the limewater holding tank(s) as provided in Section 10.2 for lime slurry mixing/batching tank shall apply, with some exceptions and requirements as listed below:

i. Be vertically oriented unless instruction otherwise is given by Seqwater, or design requirements dictate a horizontal orientation.

ii. Include a top manhole cover as the per tank design and construction standard, hinged manhole is not required like lime mixing/batching tank.

iii. Be fitted with connections for limewater inlet line, outlet line, overflow line, drain line, level switch and level transmitter.

iv. The tank does not require mixer because the lime powder has been fully dissolved in the solution.

v. The inlet water compartment requirement is not applicable.

vi. Be fitted with limewater recirculation line connections from the dosing pump relief valve and commissioning lines.

vii. Include actuated isolation valves and bypass lines in the inlet limewater connection upstream of the tank connection point to allow bypass of limewater holding tank for acid cleaning of limewater dosing line.

viii. Additional requirements for the limewater holding tanks(s) as detailed in Sections 0 and 13.1.2 below shall be followed.

13.1.1 Tank Number and Sizing

There should be a minimum of two (2) holding tanks to maintain a continuity in dosing. However, the determination of the final number should consider the site's availability and criticality requirements, the site's size, the chemical properties and usage, site staffing, site location and access (e.g. in fair and poor weather), reliability, operability and maintainability considerations.

When sizing the holding tank, the design shall consider the following:

i. The tank sizing should consider balancing inflows and outflows over the full operational ranges of the lime saturator and lime water dosing system.

ii. The tank sizing design should consider providing minimum one-hour storage of limewater solution at the average dose rate with maximum plant flow.

13.1.2 Level Devices

Each limewater holding/dosing tank that is filled via gravity shall include level control and protection. This shall be achieved using:

i. An electronic level transmitter is to control and measure the tank level/quantity. It is an important instrument to provide feedback at a pre-set tank level for the trim control of dilution water flow to the lime saturator. In addition of this pre-set tank level control, the electronic level transmitter shall incorporate the followings:

   a. Low-Low Level (LALL) Setpoint: At this level Operator action has been unavailable or unable to correct the low-low level event. The process shall be interrupted by stopping the limewater dosing pumps. A further alarm will be triggered, and the Operator notified.

   b. Low Level (LAL) Setpoint: At this level, an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

   c. High Level (LAH) Setpoint: At this level, an Operator alarm shall be triggered requiring operator action to correct any issues if the trigger does not self-correct. The process shall continue to operate.

   d. High-High Level (LHH) Setpoint: At this level, an operator action has been unavailable or unable to correct the high-high level event. The process should be interrupted by stopping the feed to the saturator system and isolating the tank inlet actuated valve. At this level, a further alarm will be triggered, and the operator notified.

   e. As discussed above, a level set point as determined by the design is needed for the trim control of the dilution water flowrate to the saturator. This set point and limewater dosing flow rates or tank outflow will eventually determine the tank incoming flowrate.

   f. In addition of the above level setpoints, the operator may select two additional operational high and low level setpoints (operator adjustable) to operate the tanks. These setpoints will provide no alarms, at these levels the process will continue to run with no action, and this will be recorded as Events only in SCADA.

ii. Two separate and independent hardwired level devices (sensor or switch) to identify and action level events at High-High and Low-Low levels as required by the design. These devices shall, as a minimum, trigger at LSHH and LSLL

   a. At LSHH measured on the High-High level device, stopping the feed to the saturator shall occur and isolating the tank inlet valve.

   b. At LSLL measured on the Low-Low level device, tripping of the lime water dosing pumps shall occur.

iii. Where another level transmitter (instead of switch) is used for the purpose as stated in (ii), a dissimilar technology to the primary sensor shall be used.

iv. A mechanical level indicating device, preferably magnetic coupled type, with appropriate display to provide local level indication can be considered, where needed.

Tank level for primary and backup devices, where applicable, shall be readily viewable as an electronic digital readout local to the tank.

13.2 Limewater Dosing System Details

The limewater dosing arrangement with positive displacement pumps should be used in most circumstances with 100% duty/standby capability.

The other dosing arrangement referred as pressurised ring main arrangement with control valves is generally not recommended for limewater dosing. However, the arrangement may be considered where dosing is required to multiple locations separated over a large distance, which would otherwise require excessive number of positive displacement pumps. The detailed requirement of pressurised ring main dosing system is not covered in this standard. Where needed, Seqwater standard specification *B-SPE-STD-009 Liquid Chemical Storage and Dosing* and standard P&ID *B-DWG-STD-016* can be used as a guideline for the design of a pressurised ring main system.

Dosing systems employing dosing with positive displacement pumps shall include the following (refer to the subsequent sections for more detail on each item):

i. A manual and actuated isolation valve on the outlet of the limewater dosing tank(s)

ii. Where multiple tanks are used, the designer may choose either a combined inlet manifold to the dosing pump skid or dedicated pumps for each tank.

iii. A dosing skid generally includes the following, in order of upstream to downstream relative to the limewater dosing system P&ID:

   a. Dosing skid manual isolation valve.

   b. Suction-side calibration cylinder for suitable systems, refer to Section 13.2.2.

   c. Suction-side manual isolation valve for each pump.

   d. Suction-side pulsation dampener only if required or recommended by pump manufacturer.

   e. Flushing and drainage points for skids and ancillary pipework.

   f. Duty / standby positive displacement pumps to deliver limewater.

   g. A pressure relief valve, preferably returning to dosing tank (in addition to any pump internal pressure relief valves).

   h. Discharge-side manual isolation valve for each pump

   i. Discharge-side pulsation dampener if required or recommended by pump manufacturer.

   j. A pressure transmitter installed upstream of pressure sustaining valve.

   k. Flowmeter. An alternative location for flowmeter other than dosing skid may be preferred, see Section 13.2.7.

   l. Discharge side pressure sustaining / backpressure valve for certain pump types, refer to Section 13.2.8.

   m. Pump commissioning and calibration return line connected to the return line manifold fitted with locked close valve and flushing point.

   n. Discharge side flushing points for skids and ancillary pipework.

   o. Chemical mixing device arrangement for chemical mixing – refer to Section 13.3 for further details.

p. Appropriate automated isolation valves and line connections to allow for acid cleaning and water flushing.

q. Dosing skid shall be installed in a suitably bunded area, preferably with the applicable lime building or mixing tank or dosing tank bunding area. Any possible spillage from the skid must be contained within the skid bund.

iv. Generally, two dosing lines for each dosing point fitted with dosing spears and flushing capability. A single dosing line can be considered where a facility can accept an extended period of dosing system shutdown for dosing line maintenance and acid cleaning.

Refer to *M-SPE-STD-010 Chemical Dosing Skids* for detailed mechanical requirements of the chemical dosing skid design and construction. Seqwater standards *M-SPE-STD-012 Chemical Dosing Pumps* and *M-SPE-STD-013 Chemical Dosing Piping* shall also be used in the design and installation of chemical dosing systems.

The remainder of Section 13.2 shall be used to identify other further requirements of dosing system components.

13.2.1 Suction Lines

The suction line supplies limewater from each tank to the duty dosing pump(s).

i. Suction lines shall minimise or eliminate the use of right-angle bends.
ii. Include both a manual and actuated isolation valve.
iii. Refer Section 7.7.1 for suction line sizing and velocity requirements.

13.2.2 Calibration Cylinders

Designer to consider the installation of calibration cylinder when it is practical considering the required dosing flow rate. For large to mid-sized WTPs, the limewater flow requirement may be generally high such that the installation of calibration cylinders may not be practical.

Where installed, a suitably protected, capped, graduated, transparent and calibrated cylinder should be provided on the suction side of the pumps for pump calibration. This is particularly important for a system where the pump curve needs to be calibrated at periodic intervals in absence of a flowmeter and flowmeter control feedback. Appropriate isolation valves shall be provided to allow the calibration of each pump to be checked. The calibration cylinder outlet shall be fitted with an overflow/vent line with an isolation valve and returned into the top of the dosing tank.

Refer to *M-SPE-STD-010 Chemical Dosing Skids* for further detail on calibration cylinder requirements.

13.2.3 Dosing Pumps

A minimum of one (1) duty and one (1) standby pump shall be provided in all circumstances. Standby capability shall ensure 100% of the duty arrangement can be achieved.

Seqwater prefers the application of diaphragm or progressive cavity positive displacement pumps for limewater dosing where suitable for the design flow range. Other type of pumps may also be considered if suitable for the design conditions and limewater properties.

The pump capacity and pressure rating must be suitable for the whole dosing range, with a strict avoidance of prolonged operation within undesirable operating zones to maximize the pump design life.

Pump materials shall be compatible with the chemical handled including limewater, the acid solution and other requirements included in Section 7.5.

Dosing pumping systems shall be designed to provide duty rotation which shall comply with the requirements detailed in *I-SPE-STD-013 Control Systems Design and Construction*.

SCADA shall be capable of displaying each pump's speed (Hz), stroke, and derived flow.

Dosing pumps shall comply with the requirements of *M-SPE-STD-012 Chemical Dosing Pumps.*

13.2.4 Pressure Relief Valves

External pressure relief valves shall be included on the discharge line of all positive displacement pumps, positioned near to the pump outlet.

This requirement also applies to positive displacement pumps with integral pressure relief valves. This is intended to prevent short circuiting of limewater from the discharge port of positive displacement pumps, immediately to a suction port by internal relief valves in case of a blocked discharge. External pressure relief valve also provides additional barrier in against of high pressure and gives operational flexibility to set the relief valve pressure according to the system need whereas internal relief valves is often required to use the pressure set by the pump manufacturer.

Pressure relief valves shall:

i. Include provision for the attachment of a hand-held pressure gauge to test the valves operation.

ii. Be set to relieve pressure:

    a. At approximately 100 kPa below the pump internal pressure relief valve.

    b. Regardless of the point above, be set at least 10% below the pressure rating (after any design de-rating for Site Conditions) of the lowest pressure rated fitting or item in the system.

    c. Designers should ensure there is sufficient margin between the pressure relief setpoint of pressure relief valves and the set pressure of pressure sustaining valves (where used) to ensure pressure relief valves are not subjected to 'chatter'.

iii. Include the set pressure recorded on a valve tag attached to the valve. This tag shall be separate from the naming tag.

iv. Discharge to the dosing tank. Where a return line to the storage tank may be an excessive length, introduces a process or safety risk, or inhibits safe access, return to the pump suction side will be acceptable if it does not create unacceptable back pressure from tank head.

v. Where the discharge line is returned to the dosing tank, it is recommended to connect the discharge line to the outlet of the calibration cylinder (where available) to identify a leak or relief of the pressure relief valve (i.e., liquid accumulation in the calibration cylinder will confirm a leak or relief from the pressure relief valve).

vi. Consider including a flow switch in the discharge line to identity the event of a relief.

vii. Be sized for the full flow relief.

viii. Be lockable (e.g., locking nut) such that the setpoint pressure cannot accidentally be changed e.g., by vibration in pipelines.

ix. Be installed immediately after pump discharge and shall not be any isolating valve between the pump and the relief valve.

13.2.5 Pulsation Dampeners

A suitably sized pulsation dampener shall be provided inline or on a branch line from the suction or discharge sides of dosing pumps to reduce pressure fluctuations, if required, as per the pump manufacturers' recommendations.

Refer to *M-SPE-STD-010 Chemical Dosing Skids* for further detail on pulsation dampener requirements.

13.2.6 Pressure Transmitter

Pressure transmitter shall:

i. Be installed on each discharge line to monitor pressure in the dosing line. This can provide indication of lime scaling/settling in the line and acid cleaning can be programmed accordingly.
ii. Be installed upstream of pressure sustaining or back pressure valves, where available.
iii. Include an isolation valve to allow easy replacement and maintenance.
iv. Include a chemical barrier diaphragm to protect the transmitter.
v. Be provided with high-pressure alarm for dosing pump interlock.

13.2.7 Flow Meter

Flow meters shall be installed in accordance with *M-SPE-STD-010 Chemical Dosing Skids* and comply with the requirements of *M-SPE-STD-009 Flow Meters*. Consideration should be given to installing flow meters near to injection points to provide indication of failed dosing lines. The transmitter should be installed at the dosing skid.

If design requires flowmeters to be installed on dosing skids or elsewhere in a dosing line, the installation of flow switches should be considered at the dosing point particularly for long dosing lines. This will provide a means of detecting flow failure in critical systems, and where dosing lines span long distances.

13.2.8 Pressure Sustaining Valve / Back Pressure Valve

Systems using diaphragm pumps, a pressure sustaining valve (also known as back pressure valve or loading valve) is recommended in the dosing skid to provide a minimum backpressure for effective pump operation and control, and to assist in providing accurate flow meter readings. For other types of positive displacement pumps, the pump manufacturer's recommendation should be followed for the requirement of a pressure sustaining valve in the dosing skid.

Pressure sustaining valves shall:

i. Be installed in accordance with and comply with *M-SPE-STD-010 Chemical Dosing Skids*.
ii. Be set in accordance with the Designer or Suppliers' recommendations or requirements. Where this is not provided, or is unclear, these valves should:
    a. Typically, be set at 100 kPa above the maximum required dosing injection pressure.
    b. Be set at a minimum of 200 kPa regardless of point (a) above. Pump supplier recommendations should always be followed.
iii. Be operator adjustable while in operation.
iv. Include a pressure gauge/transmitter installed upstream to verify operation.

An additional pressure sustaining valve is also recommended near to a dosing point particularly for a long dosing line to encounter fluctuations in the main process line and provide steady chemical flow. Generally, the pressure may be set to approximately 50 kPa above the maximum operating pressure of the process line.

13.2.9 Chemical Return Line

Chemical return line to the limewater dosing tank should be included to accommodate chemical return from the pump discharge during commissioning, calibration cylinder and pressure relief valve discharge.

When installed, the chemical return line should:

i. Include a separate flanged nozzle/connection on the topside (roof) of each tank.

ii. Enter the roof of the tank in a vertical orientation and above the overflow crown height.

iii. Be minimum of 25 mm to prevent blockage. The small pipe size may cause lime settling and block the line.

iv. Chemical return lines should avoid low points and, if possible, transfer upward then with a single slight decline into the tank.

v. Include a flow switch in the pressure relief line to identity the event of pressure relief.

vi. Include a section of removable spool to facilitate tank maintenance.

vii. Include a flushing point to flush the line.

13.2.10 Dosing Lines

Dosing lines include pipework transferring limewater from the dosing skid to the dosing point. Dosing lines shall comply with the requirements of *M-SPE-STD-013 Chemical Dosing Piping.*

Dosing lines shall:

i. Be sized following the velocity requirements provided in Section 7.7.1.

ii. Be double contained from the outside of dosing skid boundary. At the lowest point, the outer covering should be fitted with a sight glass with level indication or connected to a pit or a bund or other suitable mechanism to identity any potential leak.

iii. Comprise non-return valves installed immediately upstream of the dosing point.

iv. Include manual isolation valves upstream of dosing spears and downstream of the non-return valve to allow maintenance of individual lines/spears without affecting dosing capability.

v. Include actuated isolation valves positioned as near as possible to the dosing point for automated acid cleaning and water flushing. If needed, this valve can also be used to prevent probable siphoning after stoppage of dosing. This should comprise the following requirements:

   a. Should be upstream of the non-return valve.

   b. Be fitted with open and close position switches.

   c. Should have fail-to-open type of valve.

   d. Appropriate valve opening and closing times need to be considered to start and stop the dosing pump.

   e. The design shall assess any potential pressure increase in a section of piping from trapped acid solution gasification or thermal expansion due to the closing of actuated valve and diurnal temperature change. Where needed, the design should include necessary pressure relief arrangements for such scenarios.

vi. Consist of the ability to flush with water, clean with acid and drain the lines.

Where the dosing line is long and chemical injection points are installed with pipework of a negative grade or entering significantly above the injection point, a pressure sustaining valve should be considered for diaphragm dosing pumps. This should be near the injection point to provide dosing stability for pressure fluctuations in the main process line and to reduce potential siphoning effects. Refer to Section 13.2.8 for guidance in setting such a pressure sustaining valve.

The design shall assess and include appropriate arrangements to contain any foreseeable chemical spills during operations and maintenance of the valves and instruments installed outside the chemical skid near to the dosing points.

13.2.11 Skid and Dosing Line Draining and Flushing

The requirements for draining and flushing of dosing skids and dosing lines shall generally comply with *M-SPE-STD-010 Chemical Dosing Skids* and *M-SPE-STD-013 Chemical Dosing Piping*.

The design should include suitable water flushing and acid cleaning systems for dosing and tank return lines and include the provision to flush dosing lines both from the suction and discharge sides of dosing pumps. Drain lines should be installed near to dosing points to collect flushed water where the flushed water cannot be directed to the process due to adverse impact to water quality.

The design should consider an automatic water and acid flushing system to flush dosing lines at periodic interval or when the dosing system is offline. This is needed to prevent lime solid deposition or calcium carbonate scaling in the piping.

An automatic flushing system design should consider:

i. Isolating the dosing tank by closing the tank outlet actuated valve (applicable to an offline system).

ii. Permanent service water connections on the suction and/or discharge end of the pump with the following requirements:

   a. A check valve in the water line immediately upstream of the flushing connection.

   b. A manual isolation valve upstream of the check valve.

   c. An actuated valve in the water line for water supply automation as per the design.

iii. An actuated valve on the drain line to open and close automatically as per the design to collect flushed water.

iv. Flushing points located such that they can flush the entirety of the intended segment and do not leave chemical in the line.

The design shall consider using the dosing pumps for flushing. The maximum pressure built up in the piping during flushing must be considered in the design considering the site maximum service water pressure.

Check valves on the dosing pump suction lines are generally not recommended to achieve inadvertent service water flow back to chemical dosing tanks during flushing. Where considered, the check valve should be installed at a location that allows duty pump to remain operational while standby pump is flushed. The design should also consider an appropriate location of the check valve to prevent inadvertent flushed water dosed into a main through the duty dosing line when the standby dosing line is flushed.

If check valves are installed on the suction side, the pump manufacturer should be consulted for suitable valve types. The check valves shall include low pressure springs to reduce pump suction side pressure losses. The spring opening pressure should be within the range of 0.1 to 0.2 bar.

A further detail of acid flushing system is covered in Section 0.

13.2.12 Dosing Spears

Dosing spears shall be used to dose limewater where injection into pipes is required. The design mechanical requirements for the dosing spear as provided in Section 11.3.1 shall apply.

13.2.13 Duty Rotation

Dosing systems, including pumps, shall be provided with duty rotation in accordance with *I-SPE-STD-013 Control Systems Design and Construction.*

13.3 Chemical Mixing

This section refers to hydraulic mixing for ensuring uniform dispersion of limewater solution in water.

The following primary modes of mixing apply to existing Seqwater sites:

i. Channel Mixing
ii. Static Mixing
iii. Recirculation / Jet Mixing
iv. Mechanical Mixing

The designer should assess the need of additional mixing and select the most appropriate mixing mode for the application based on supplier advice and recommendations.

All mixer installations must be effective across the range of operational plant flows for maximum/minimum turndown.

All modes of mixing should generally achieve a Coefficient of Variation (CoV) of 0.05 or less within five pipe or channel diameters downstream of the mixer.

13.3.1 Channel Mixing

Channel mixing may include:

i. Flume or weir used to produce a standing wave (hydraulic jump)
ii. Static mixer installed in a channel.

<u>Flume / Weir (Hydraulic Jump)</u>

Mixing in a channel may be achieved through either local restriction (e.g. flume / weir) and change in floor level to achieve a supercritical flow (via hydraulic jump).

A hydraulic jump and standing wave must exist at all times under all flow conditions. A Froude Number (Fr) of at least 2.5 should be achieved for all flow conditions.

The dosing point should be into the base of the weir where plunging water flow enters the receiving volume. If the weir width exceeds 500 mm, a sparger with multiple dosing points along the width of the weir may be required.

Static Mixer (Channel)

Channel mixing may be improved or achieved over a shorter distance if a static mixer is installed in the channel. A CoV of 0.05 or better should be achieved within five channel widths downstream of the mixer.

Advice should be sought from the static mixer supplier for sizing, spacing and design requirements.

Static channel mixers should only be used if the design guarantees debris and blockage of the mixer can be prevented.

13.3.2 Static Mixing (Pipe)

Static mixing should be the preferred method for chemical dosing systems into pipes.

Static mixers shall:

i. Be installed downstream of injection points in accordance with the manufacturer/supplier's requirements for upstream and downstream diameter clearances from injection points and other fixings. Proprietary integrated dosing points are acceptable.

ii. Be designed to achieve a CoV of at least 0.05 at the mixer outlet across the required process operating range.

iii. Be designed to minimise head loss across the mixer.

iv. Include flanged connections to facilitate easy removal and maintenance or replacement.

v. Include manual isolation valve upstream and downstream of static mixer for maintenance.

Care should be taken to ensure good dispersion and rapid mixing is achieved when mixing limewater solution in water where alkalinity and pH may increase locally. This may result in calcium carbonate scale forming on the mixer vanes.

Seqwater has a history of chemical deposition in static mixers affecting performance. Static mixers shall therefore include provision for visual monitoring of pressure drop across the static mixer body. Monitoring of pressure drop shall be visible locally, and consideration should be given to making pressure drop visible remotely. The provided delta pressure methodology shall not negatively influence the operation of the static mixer.

The selection of large static mixers should consider the inclusion of nozzles to be used for the removal of scale and fouling as a means of cleaning during maintenance. Physical removal and access for cranes, cradles or similar may be difficult or introduce unnecessary manual handling.

Static mixer suppliers should be consulted for guidance and selection of appropriate mixers. Static mixers may not be suitable for pipes with extremely high turndown ratios. The designer shall take this into consideration and may consider alternate mixing methodologies, parallel streams, or the use of carrier water.

Refer to *M-SPE-STD-001 General Mechanical* and *M-SPE-STD-013 Chemical Dosing Pipe Specification* for additional detail on fitting requirements for a static mixer system.

13.3.3 Recirculation / Jet Mixing

This mode of mixing relies on taking a small percentage of the plant flow and returning it to process stream at a defined point. This may be achieved in open channel processes by returning the flow via a pipe through an orifice and onto a plate in the mixing chamber or directing it against the feed flow to create turbulence.

Where a plate is used, the plate shall be removable for cleaning and maintenance.

Mixing may be achieved in a pipe by taking the upstream or downstream flow, dosing into the off-take line, and returning the off-take downstream or upstream, respectively, of the mixing pump into the process line.

Recycle ratios returning downstream flow usually fall somewhere in the vicinity of 2-8%. Literature identifies a range of figures, more typically 4-7%. If jet mixing is used in a channel, the jet should be sized using a momentum flux ratio of 0.5: 1 (ratio of the momentum flux of the channel / momentum flux of the jet).

The system including jet pump suction line and pump position shall be selected to avoid entrainment of air into the jet stream. Reinforcement at the point of jet injection (e.g., a steel plate) shall be provided if necessary, to prevent erosion of channels or pipes.

The mixing may be achieved by either gravity flow or pumping depending on site hydraulics.

If a pump is used, the jet mixing pump:

i. Shall be provided with duty/standby capability.
ii. Shall be controlled using a control valve, capable of isolating the pump suction side from the main process stream if mixing is not required.
iii. Shall include a non-return valve on the pump discharge.
iv. Shall be protected from low or no flow via a flow switch.
v. Shall be controllable via a variable speed drive for mixing optimisation over the full range of flow rates.
vi. May be submersible or above ground.

Static mixing is preferred over jet mixing where practicable due to the reduced maintenance and operational requirement of the pump.

13.3.4 Mechanical Mixing

Here mechanical mixing refers to a vertical type of mixer with motor, possibly a gearbox, shaft and propeller. Mechanical mixers shall not be used at Seqwater sites for limewater mixing into pipes.

Mixer requirements for mixing/batching tanks are included in Section 10.2.1.4.

13.4 Buried Pipes and Dose Pits

Considerations for below ground assets, including buried pipes and dose pits has been discussed in Section 11.4 and must be followed.

14 Acid Flushing System

This section describes the requirement for the design and construction of acid flushing and cleaning system and shall be read in conjunction with standard drawing *B-DWG-STD-026 Lime Storage, Mixing/Batching, and Dosing System – Sheet 6 of 6 (Acid Flushing System)* as referenced in Section 0.

Acid flushing system is required to clean lime scaling, calcium carbon scaling and other impurities deposition from dosing lines and valves. The system includes the storage of neat acid, batching of acid solution (where required), and acid recirculation/flushing system to remove lime and calcium carbonate scaling from the pipework and tanks.

Typically, at Seqwater sites, Hydrochloric Acid (HCl) at 32 % (w/w) is used as neat acid and diluted before using to clean the lime system. HCl is typically delivered to Seqwater sites with Intermediate Bulk Containers (IBCs) or in small drums (5-15 L) depending on the site's requirement. Where available in the market, diluted HCl at 10 % (w/w) should be sourced which will avoid the need of a separate acid dilution system.

Seqwater SPE-00464 *Chemical Quality Specification – Hydrochloric Acid 32% w/w [as HCl]* shall be referred for the product quality of hydrochloric acid.

Weak organic acid, Citric Acid, should be considered as an alternative to HCl due to its fuming characteristics for the acid cleaning system. However, it is advisable not to utilise powder as a source of acid as this may involve manual activities for batching. The effectiveness, site layout constraint, suitability of returning the washed solution to the process main, and other limiting factors shall be assessed prior to selecting acid types and its strength. Seqwater SPE-00468 *Chemical Quality Specification – Citric Acid 50% By Weight [as C6H8O7]* shall be referred for the product quality of citric acid.

The requirements of Australian Standard *AS 3780 The Storage and Handling of Corrosive Substance* shall be followed for the storage, handling and bunding arrangement for HCl and any acid that meet Class 8 classification criteria of Australian Dangerous Goods (ADG) code.

Neat acid needs to be diluted in the acid batching tank prior to use for cleaning/flushing. The diluted acid solution is circulated through the mixing/batching tanks and dosing lines. Either a dedicated acid recirculation pump or suitable process system pumps can be used to recirculate the acid. Appropriate pipework, isolation valves and interlocks shall be installed to facilitate acid cleaning.

Site based assessment needs to be conducted to determine if the resultant descaling solution can be returned into the process or discharged to the sludge/waste system. The system shall be designed so the acid solution is neutralised. Additional conditioning process may be required to adjust the pH before discharge or return to the system.

Where citric acid is used, the design shall prevent any entrance of flushing solution into the main as organic acids are strong precursors for the formation of chlorine disinfection by-products. If the flushing solution needs to be recirculated to the head of the treatment plant, a massive dilution is strongly recommended. For citric acid, the option of flushing to the sewer should be assessed at first.

Overall, the acid flushing system should be semi-automated initiated by the operator. The designer should consider the operational and safety benefits and the cost associated with the automation of the system. Acid batching system itself should be an automated system started by the operator. The selection of recirculation loops shall be available from SCADA or from a local panel installed for the acid flushing system. It shall be capable of automatically opening/closing specific isolation valves in sequence to isolate the process system and prepare a loop for acid recirculation. The start/stop operation of the recirculation pump should be done manually with a timer because it requires operational judgment to determine the completion of the descaling activity.

The main components of the acid flushing system should include the following:

- Acid Storage System.
- Acid Batching System.
- Acid Recirculation System.

14.1 Acid Storage System

The acid storage system generally should comprise of IBCs or drums to store either neat or diluted acid solution. If neat solution is stored in an IBC, it is required to transfer acid into the acid batching tank (or lime mixing tank) preferably by a transfer pump. Gravity transfer is generally not recommended as it may require an elevated support stand for the storage tank.

The acid storage system should include the following requirements:

i. A minimum site storage of two (2) IBCs with an appropriate size (generally 1000 L) for a larger site or a number of 5-15 L drums depending on the site requirement. Where IBCs are used, at a given time, only one IBC should be connected to the batching system.

ii. The total volume of the acid in the IBCs or drums shall provide a minimum capacity to hold 28 days of acid for flushing. The final storage size should be determined considering the available IBC or drum size in the market and supply chain risk for the site.

iii. A suitable support stand for the IBC tank shall be provided.

iv. The IBC shall include a tote scale to measure the weight of the acid content and should be the primary mode of monitoring and control parameter for the operation. It shall have the following requirements:

    a. Shall be mounted along with weighing modules, junction box and a transmitter to send the weight signal to PLC.

    b. Must be capable of reading the tank weight empty and full within ±0.1% accuracy.

    c. Electrostatic charges must be discharged to the ground without crossing the scales. Earthing shall be provided according to the requirements in *I-SPE-STD-015 Instrumentation.*

    d. It shall include a low weight setpoint and an alarm to notify operators and automatically trigger shutdown of the acid transfer pump when used.

    e. The IBC weight shall be on display as an electronic digital readout local to the IBC and viewable at ground level, local to the acid solution tank panel, and remotely at SCADA.

v. It shall include a transfer line to transfer the neat acid solution from the storage IBC tank to the batching tank. The transfer line shall:

    a. Be fitted a dry break coupling for connection the IBC to the transfer line.

    b. Be fitted with a manual isolation valve and a solenoid valve to open/close automatically when initiated the transfer.

    c. Be fitted with a drain line to enable complete and safe draining of transfer hose prior to decoupling.

    d. Be in a bunded area with the requirements include:

        i. Any spillage should be directed to the bund sump.

        ii. A level switch located in the bund sump to detect any leak.

   e. Be fitted with a vent/degassing line installed at the highest point to vent to atmosphere in a safe location. It shall include an isolation valve with a mechanism to lock open and be easily accessible.

   f. Be fitted with a non-return valve upstream of the acid batching tank to prevent back flow.

vi. A transfer pump shall be installed when gravity transfer is not practical with the following requirements:

   a. One (1) fixed speed drive transfer pump with the consideration of a spare pump in the workshop.

   b. Be designed to transfer the required volume of neat acid considering favourable mixing rate with water.

   c. Be an air driven diaphragm pump where compressed air supply is available however, other suitable pumps can also be used. When an air diaphragm pump is used the air inlet line shall:

      1. Be fitted with a solenoid valve to open/close the compressed air supply and a pump interlock from high air pressure.

      2. Be fitted with a pressure regulating valve to maintain the required air operating pressure for the pump and a manual isolation for positive isolation.

   d. Provide flanged connection at both inlet and discharge ends.

   e. Consider including a pressure transmitter at pump discharge with a high-pressure alarm for blockage indication and achieve pump interlock.

   f. Comply with standard requirement *M-SPE-STD-012 Chemical Dosing Pumps.*

14.2 Acid Batching Tank System

If neat acid solution is received, acid must be diluted prior to recirculation. Either a dedicated acid batch tank or the lime mixing/batching can be used for acid batching. It is preferable to use the lime mixing/batching tank; however, this may not be suitable to use for limewater dosing system flushing. In addition, this option may not be always practical and safe due to space or site layout constraint. If the lime mixing/batching system is located far away from the acid IBC tank or drum, transferring a neat acid solution possess a high safety risk, in this situation the acid solution should be prepared in an acid batching tank prior to transfer to the lime system.

The acid batching system should be an automatic process upon operator initiation. It shall be able to automatically transfer the dilution water and acid solution to prepare the required acid solution strength typically at 10% solution(w/w) when HCl is used.

The batching sequence always requires adding neat acid to water not the other way around. The dilution of HCl is an exothermic reaction (heat producing) and therefore the correct sequence of dilution is paramount to prevent rapid heat generation and splashing of the mixture. The installation of a temperature measurement device into the batching tank to trigger an alarm and interlock from high temperature should be considered for process and personnel safety.

When installed, the acid batching tank shall be above the ground, fixed, permanently positioned. The design of the acid batching tank should generally apply the requirements as provided in Section 10.2 for lime mixing/batching tank including the mixer, with some additional requirements as mentioned in this section. When a lime mixing/batching tank is used to batch the acid solution, the requirement in this section shall also be followed.

The acid batching tank shall:

i. Include a top manhole cover as the per tank design and construction standard, hinged manhole is not required.

ii. Have a fixed roof suitably designed as a working platform, but a flange or bolted roof is acceptable. However, if constructed using HDPE or FRP the roof shall not be used as a working platform then a suitable access to the top of the tank and working platform shall be provided.

iii. Have a vent which directs the acid fume to a safe location away from personnel working area.

iv. Include a temperature probe with local display to monitor acid solution temperature during batching.

v. Be fitted with an automated transfer system and shall include level control and protection as defined in Section 10.2.1.5 with exceptions for the transmitter setpoint:

   a. Batch Start (or Operational Low Level) – level that starts the batching sequence. It must have separate setpoints for dilution water and acid transfer system.

   b. Batch Stop (or Operational High Level) – level that stops the batching sequence.

vi. Be fitted with a dilution water, neat acid solution and acid recirculation line connection with design requirement as provided in Section 10.2.

vii. Be installed with a drain line to direct the recirculation solution into the bund sump with an option to collect the sample water for pH verification.

viii. Include dilution water system with design requirements as provided in Section 10.2.3.

ix. Be constructed, including all the tank fittings, from materials resistant to corrosion and substantially immune from attack by the neat and diluted acid solution. Refer to Section 7.5 for material guidance, however, if no guidance is provided the tank material shall be construction from HDPE.

x. Be mounted on a purpose designed concentre plinth in accordance to *AS 3600 Concrete Structure.*

14.2.1 Tank Number and Sizing

Generally, include one (1) acid batching tank.

When sizing the acid batching tank, the design shall consider the following:

i. The tank is sized based on the highest volumetric consumption of acid solution to clean particular recirculation loop(s) at a single time. The sizing design should consider providing the required volume to completely fill the dosing lines.

ii. The tank shall be provided with an ullage space to accommodate thermal expansion. Ullage shall be determined in accordance with the standards and specifications for the material, location, and contents of the tanks.

14.3 Acid Recirculation System

This section provides the design and construction guidelines of acid recirculation system and should be read in conjunction with standard P&ID drawings *B-DWG-STD-021 to B-DWG-STD-026* as referenced in Section 0.

The acid recirculation system is used to recirculate the dilute acid solution. Acid cleaning should be included for:

- Lime slurry dosing lines.
- Limewater dosing lines.
- Lime sludge recirculation pipework.
- Lime sludge removal pipework.
- Lime slurry mixing/batching and dosing tanks.

Acid cleaning of dosing lines should include both suction and discharge ends.

The system comprises of an acid recirculation pump, valves, pipework and controls for various loops to recirculate the acid solution.

The lime slurry, lime sludge and lime sludge recirculation pumps should be used to recirculate the acid solution provided that this has been considered in pump design and materials selection. Where the system pumps can be not used, a designated pump for acid recirculation shall be provided to recirculate the acid solution.

The design requirements for the acid recirculation pump as provided in Section 14.1 for neat acid transfer pump shall apply, with the following exceptions:

i. Other types of pumps including centrifugal pump may be considered.
ii. The pump should be able to maintain velocity of at least 1 m/s in all lines designated for recirculation.
iii. The pump should be able to handle small amounts of suspended solids.

It is proposed to include four recirculation loops as a minimum for the proposed sample design for the P&IDs as referenced in Section 0. The proposed recirculation loops may include: -

i. Lime slurry dosing line. Note that if the dosing system is designed with eductors and motive water pumps then the system can be used as an alternative to the recirculation pump to recirculate acid solution.
ii. Lime slurry feed line, saturator feed line and the lime saturator sludge recirculation line within a one loop.
iii. Lime saturator sludge removal line.
iv. Limewater transfer and dosing lines.

In addition, separate acid recirculation loops may be needed for suction and discharge ends when a system pump cannot be used for acid recirculation.

Standard design P&IDs should be referred for valve arrangement examples to recirculate the acid solution.

Each recirculation loop pipework shall include the following:

i. Pipework to transfer acid solution to the process line and recirculation line at the end of the process line back to the acid batching tank. The recirculation pipework to be sized to ensure the line velocity of at least 1 m/s.
ii. Actuated isolation valves be installed in the process line and the recirculation line to isolate the process line automatically and allow acid recirculation.

iii. Be fitted with a non-return valve upstream of any acid inlet connection point to prevent backflow of lime solution to the acid system.

iv. Material of construction for the pipework and valves to be constructed suitable for concentrated acid and diluted acid solution. Any potential temperature rise from neutralization reaction shall also be considered in material selection.

v. The design shall assess the need of temperature monitoring in acid recirculation lines for any potential temperature rise from acid and base neutralization reaction.

vi. The recirculation line(s) shall be combined into a common header before returning back to the acid batching tank. A flow sensor or a clear section of pipe should be considered in the common header to identify the solution return to the tank. The header should have an appropriate connection to collect the sample for pH verification.

vii. The recirculation line(s) shall be double contained where not located in the bunded area.

viii. Acid recirculation pump shall be tripped from high pressure.

ix. Suitable interlocks with the process system shall be included to prevent any inadvertent process operation during acid cleaning. For example, during the lime mixing/batching tank cleaning, the screw feeder system should be prevented from operation by providing an interlock.

14.4 Water Flushing

In addition to acid cleaning, the design shall include automated flushing with water for lime slurry and limewater transfer and dosing lines before and after acid flushing. Each flushing system must have its own dedicated connection point and include actuated valves to automatically initiate the flushing upon the completion of chemical dosing/transfer. System pumps shall be used for water flushing.

The general design requirements for water flushing system have been provided in Section 13.2.11 and shall be followed.

15 Chemical Enclosures, Buildings, and Bunds

This section describes the requirement for enclosures, buildings and bunds for lime storage and dosing, and acid cleaning system.

The storage silo(s) and hopper(s), batching and dosing equipment shall be located inside preferably in one building. This would prevent moisture ingress that can disrupt the operation of silos and feeding equipment. In addition, process units located inside a building will reduce the impact to the environment from powder dust emission.

The lime saturator is to be installed outdoor under a shelter to protect equipment against weather. The acid cleaning system including the IBC tank, acid dilution tank, and acid recirculation pumps shall all be installed in a separate building or in a separate room of the lime building.

15.1 Lime Storage Building

As a minimum, the design and construction of the lime powder storage building should include the following:

i. Where required due to size, storage silo should be allowed to protrude through the roof / ceiling of the storage building. Appropriate sealing of the building shall be provided to ensure weather tightness. Soft seals (or similar) shall be provided to ensure vibration and movement of the silo or building does not induce vibration or movement in the other.

ii. Designer to consider most suitable location of the chemical building depending on the application and site layout (e.g. lime slurry system might be located near the source to avoid long distance piping).

iii. Where needed an intermediate platform shall be provided for easy access to lime silo equipment and instruments.

iv. Internal layout shall allow for:

   a. Sufficient access for maintenance and cleaning (typically minimum 1m between walls, equipment, panels, etc.). Equipment spacing and walkways must comply with the requirements of *M-SPE-STD-001 General Mechanical* and *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

   b. Separation between chemicals.

   c. Vehicle access for removal of equipment.

v. All trafficable areas shall include a non-slip (or slip resistant) finish.

vi. All surfaces that may come into contact with lime powder and slurry shall be chemically resistant to attack and degradation.

vii. The building should include a suitably designed bund (i.e. generally a concrete bund or an HDPE bund for a small system) where the mixing/batching and dosing tanks are located. The bund floor and similar surfaces shall be graded towards a drainage sump. The sump shall be sized suitably to accommodate sump pump and level indication device. Bund arrangement is discussed separately in Section 15.6 15.6.

viii. The room in which bulk lime is stored should be suitably humidity controlled and ventilated as recommended by the lime supplier, refer to Section 15.4 for further details on ventilation requirements.

ix. Where the building is in bushfire-prone areas, the requirements of *AS 3959 Construction of Buildings in Bushfire-prone Areas* shall be addressed.

x. Sufficient internal and external lighting to be provided and include the provision for easy access for lamp maintenance/replacement as according to *AS 1680 Interior and Workplace Lighting*.

xi. Safety showers, eye wash facility and hose reels complying with Section 7.14 of this standard shall be provided at all floors.

xii. Water hose reels shall be made available for lime wash down during spill, where appropriate.

xiii. Fire services which would include fire hose reels, sprinklers, alarming etc. to be installed in accordance with the Building Code of Australia and *AS 2118 Automatic Fire Sprinkler System*.

xiv. Building needs to be protected against lightning in accordance with the requirements of *E-SPE-STD-001 Electrical Design and Construction.*

15.2 Acid Storage Building

This section provides the following requirements for acid storage building in addition to the above requirements.

i. Materials of construction of the storage area shall be corrosion resistance to the acid being used.

ii. Building floor, when used for decanting shall be sealed and are drained to the bund sump.

iii. The IBC tank shall be positioned to prevent tank collapse spillage outside of the compound. The layout of the storage shall be designed to provide clear passage of personnel staff to locate/remove IBC tank using delivery vehicle and to permit full observation and cleaning of any spillage.

iv. To manage risk of corrosion of electrical equipment, wiring and lighting in the building, electrical equipment shall have the appropriate Ingress Protection (IP) rating in accordance with *AS 60529* and *E-SPE-STD-001 Electrical Design and Construction*.

v. The requirements for storage capacity, separation distance between chemicals and to protected places shall comply with requirements provided in *AS 3780 The Storage and Handling of Corrosive Substances*.

15.3 Access and Layout

The access and layout of the building shall include the following:

i. Access and layout (internal and external) of structures, including buildings and enclosures shall consider the requirements for maintenance and replacement of related assets, especially those which may have lifespans shorter than that of the structures. Designs shall clearly address such future requirements.

ii. All access doors shall open outward and be fitted with panic release bars.

iii. Access doors shall be designed sufficiently large to enable the installation, replacement, and maintenance of equipment.

iv. The distance between the top of any tanks and storage silo should be a minimum of 0.5m from the roof of any structures in all circumstances, except when top of the lime storage silo protrudes through the building. Notwithstanding the previous statement, there shall be sufficient space provided between the top of any tank or silo and the ceiling of any structures or buildings to allow ergonomic access for expected maintenance to take place.

v. If an access platform is required, a minimum clearance of 2m as per *AS 1657* shall apply between platforms and building ceilings.

vi. Provide at least two access doors to the acid building if the storage floor area is greater than $25m^2$.

15.4 Ventilation

Lime and acid storage and dosing area layout shall be designed using suitable natural or forced ventilation to:

i. Maintain exposure level to any vapour or fume or dust in the workspace below the recommended workplace exposure standard.
ii. Prevent the accumulation of lime powder.
iii. Prevent condensation build up.
iv. Ensure a safe operating atmosphere.

The exhaust from any mechanical ventilation shall be directed away from any sources of ignition and areas where people are likely to congregate.

Ventilation systems shall be designed in accordance with relevant Australian Building Codes, legislation, Industry Standards, Specifications, and *AS 1668 The Use of Ventilation and Air-conditioning in Buildings set*.

15.5 Compressed Air Room

Compressed air is required to operate air-driven instrumentation, lime powder aeration system, and operation of air driven diaphragm pumps (if used). The compressed air supply system should include air receivers and dryers. The air compressor/blower shall be fitted with a filter in the suction side to prevent dust to entrain into the system where applicable.

Depending on the site layout, the system may be housed in a separate room from the lime storage building or located sufficiently far from the storage building to avoid clogging and contamination.

Room design shall ensure a safe working atmosphere for personnel and mitigate the effects of pressure changes and noise level resulting from the compressor/blower operation and shall comply with requirements in *M-SPE-STD-001 General Mechanical*.

15.6 Bund Arrangement

Secondary containment shall be provided, in the form of a bund, for all mixing/batching, dosing tanks and the saturator. Each chemical shall be installed in a separate bund. The acid storage and batching, lime mixing/batching and dosing tanks bunds should adhere to the following requirements. Each bund

i. Shall preferably be a concrete bund, but a HDPE bund is acceptable for small tanks.
ii. Shall be sized to contain at least 110% of the largest dosing and mixing/batching tanks when located in the same bund.
iii. Shall be designed with bund walls and should generally be sized to include a freeboard of at least 100mm above the design fill volume.
iv. Shall be designed to prevent pooling of chemicals or water by providing a suitably finished surface with a minimum gradient toward the bund sump of 1: 75. Refer to Section 15.6.1 below for bund sump requirements.
v. Design should account for any liquid jetting / spraying that may arise because of a tank or nozzle failures. This may include increasing the distance of a tank from a bund wall or increasing the height of the bund wall. Splash screens may also be a viable alternative.
vi. Design should include open channel collection gutters with grating covers connected to the bund sump for the collection of wash down water, spills, overflow, and scours.
vii. Shall include chemically compatible wall and floor coatings in accordance with *M-SPE-STD-004 Protective Coatings*.

viii. Design shall comply with the requirements of *AS 3780* for acid storage and batching tanks.

15.6.1 Bund Sumps

A low point bund sump shall be provided in each bund to:

i. Provide means for detection of spills or mixing/batching/dosing tank overflows.
ii. Provide a point of collection or extraction of lime slurry/solution.

The bund sump should:

iii. Be sufficiently sized to accommodate two portable sump pumps and level instrumentation. A typical sump size of 1200mm (long) x 500mm (wide) x 500 mm (deep) may be considered for concrete bunds for the lime mixing/batching area.
iv. Include a chemical-compatible material grating sufficient to withstand any weight reasonably expected to be applied during construction, maintenance, and operations activities.
v. Provide a local and remote high-level alarm (LAH) from the level instrumentation to alert the operator of a high lime slurry or limewater solution or water level. The instrumentation shall include, as a minimum, a high-level switch (LSH).

The design shall take into consideration, and clearly define, how a filled bund or sump will be drained in the event of a spill, clean up or scouring activities. Depending on the site facilities, consideration should be given to include a drainage pipe to transfer wash down water or spill to the site waste handling facility or sludge treatment area or to a vacuum truck.

Where the vacuum truck option is selected, the drainage pipe would be expected to extend from the base of the sump to above the bund wall with a suitable mechanical coupling allowing connection.

Where drainage to site facility option is selected, the drainage pipework should include an isolation valve with limit switches with the following:

vi. The isolation valve shall be installed in a valve pit outside of the bund, manually actuated from a safe location and from above ground level. This is to provide operator-initiated release of lime slurry/solution to the designated location.
vii. The isolation valve limit switch shall provide an alarm to alert operators if the isolation valve is in the open position for a defined period.

In addition, the drainage pipework should have the option for flushing with water and acid solution.

15.6.2 Safety Showers and Eyewashes

Each chemical storage bund shall include a safety shower and eyewash station which complies with the requirements of Section 7.14 of this standard. Bunds shall be arranged to ensure a clear path, free of hazards, to the safety showers and eyewash station is provided.

16 Standard Designs

The standard designs or standard P&IDs as shown in Table 16-1 shall be used as the starting design concept for lime storage, lime mixing/batching, lime slurry and limewater dosing systems for all Seqwater works. The standard designs shall not be used for construction.

A project must develop new P&IDs based on the standard designs after incorporating the project specific requirements, and the outcome from design reviews and appropriate technical hazard studies.

Table 16-1 Standard P&IDs for lime storage, mixing/batching and dosing systems.

Chemical System	Standard Drawing	Description
Lime	B-DWG-STD-021	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 1 of 6 (Lime Storage and Mixing/Batching)
	B-DWG-STD-022	P&ID Standard – Lime Storage, Mixing/ Batching and Dosing System – Sheet 2 of 6 (Lime Saturator System)
	B-DWG-STD-023	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 3 of 6 (Limewater Dosing System)
	B-DEG-STD-024	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 4 of 6 (Lime Slurry Pumped Dosing System)
	B-DWG-STD-025	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 5 of 6 (Lime Slurry Eductor Dosing System)
	B-DWG-STD-026	P&ID Standard – Lime Storage, Mixing/Batching and Dosing System – Sheet 6 of 6 (Acid Flushing System)

Note that the standard design P&ID *B-DWG-STD-021 for Lime Storage and Mixing/Batching* as referenced above has been developed for bulk truck delivery. If a facility is designed with the large bag delivery system, the project will need to refer *B-DWG-STD-027 for Polymer, PAC, Pot Perm and Soda Ash Storage, Batching and Dosing System (Sheet 1 of 2)* for the starting design concept P&ID drawing.

The standard P&ID drawings as referenced in Table 16-1 have been developed following Seqwater P&ID Requirements Standard *B-SPE-STD-007,* P&ID Legend Sheet Drawings *B-DWG-STD-001 to B-DWG-STD-007* for Symbols, Instrumentation Valve and Motor Details and P&ID Drafting Procedure *B-PRO-STD-003*.

17 Process Control Requirements

This section provides Seqwater requirements on process control for lime storage, mixing/batching and dosing facilities. The section includes process control narratives on major sub-sections with operating and equipment control modes and dosing calculations.

Seqwater Standard *I-SPE-STD-013 Control Systems Design and Construction* provides the minimum technical requirements for the procurement, design, installation & construction of control systems inclusive of PLCs, SCADA, communications, and ancillary equipment.

A Functional Description for the lime chemical Unloading, Storage, Batching and Dosing System(s) shall be developed to cover control requirements in detail. Functional Descriptions shall use the following standards and templates as necessary:

- *B-SPE-STD-005: Functional Description Documentation*
- *I-TMP-STD-001: Functional Description Part A*
- *I-TMP-STD-005: Functional Description Part B*
- *I-SPE-STD-013: Control Systems Design and Construction*

17.1 Process Control Narratives

Lime has relatively a complex control system compared to other chemicals used in Seqwater. The control system can be divided into the following sub-system:

a. Lime powder bulk delivery/unloading system.
b. Lime powder transfer to silo/hopper from bags.
c. Lime slurry mixing and batching systems.
d. Lime slurry dosing system.
e. Lime saturator system.
f. Limewater dosing system.

For the saturator system, the control system essentially starts with the limewater dosing and cascades back to the lime slurry mixing/batching system. This can be described as:

- Limewater dosing is flow paced with the process main flow meter and operator dosing set point.
- Dilution water addition into the lime saturator is flow paced with the limewater flow rate with additional trim control from limewater dosing tank level.
- Lime slurry feed into the saturator operates at a fixed rate when screw feeder is operating with variable concentrations.
- Lime powder addition into lime mixing/batching tank is proportional to limewater dosing rate into the process main and controlled by a loss-in-weight feeder (if used).

Lime bulk delivery and lime powder transfer to storage silos/hoppers need initiation locally from the LCP.

Where a plant is designed for lime slurry dosing into the process main, the control starts with lime slurry dosing system and cascades back to the lime slurry mixing/batching system. If a plant needs both lime slurry and limewater dosing systems, separate control systems with separate mixing/batching system and screw feeder shall be required.

The rest of this section provides process control narratives for each sub-system for normal and abnormal operations. Specific start-up requirements and expected functionalities from any power failure for each sub-system are not covered in detail.

17.1.1 Delivery / Unloading System

17.1.1.1 Bulk Truck Unloading System

The following describes a typical operating and control philosophy for the lime powder bulk truck delivery, unloading, and storage system. This should also be read in conjunction with Section 8.2 of this document.

Normal Operation

Prior to starting the powder chemical unloading process, an operator may need to enable the LCP in the SCADA if this function is incorporated.

Once a delivery truck is in position, the delivery personnel connect the truck's delivery hose to the storage silo fill line through the camlock fitting. The delivery personnel shall then select the 'UNLOADING / FILLING' switch to initiate the LCP. Upon conformation from the delivery personnel that the unloading process is requested, an operator will need to initiate the silo filling procedure via SCADA (if included) and the control system will check that the following requirements are met:

- Silo load cells are healthy, and no alarm exists.
- Silo high-high level switch is healthy and not active.
- Fan extraction and dust collector system is healthy and starts to operate.
- Dehumidifier stops operating.
- Compressed air system is available.

Once all the above conditions are met, this will open the fill line actuated valve and enable "Ready" indicator in the LCP. This will also start the dust extractor fan and stop dehumidifier operation.

The delivery personnel shall then be able to start the unloading. The filling process shall then be initiated by starting the truck's blower, powered by the truck, to transfer the lime powder pneumatically into the storage silo. The delivery personnel and site operator shall monitor the silo weight continuously as displayed in the LCP during the filling process.

During the silo filling, an automatic pneumatic reverse pulse cleaning system will clean the filter at the pre-determined interval and end of fill cycle or when the differential pressure across the filter is high, by opening the compressed air solenoid valve.

The silo filling process will need to be stopped (delivery staff stopping the truck blower) if any of the following conditions are met:

- Silo weight reaches to the pre-determined level as displayed in the LCP.
- "Silo Fill Complete" indicator in the LCP is illuminated from the silo weight set point.
- Silo weight high or high-high level is detected.
- Fan extraction and dust collection system register fault signal or pressure differential across the filter is high.

Before stopping the truck blower, the delivery personnel shall purge the fill line to clear out any residual lime powder.

Upon confirmation from the delivery personnel that the filling process is finished, an operator will need to initiate the remaining shutdown sequence from the SCADA which includes the followings:

- Closing of the fill line actuated valve.
- Stopping the fan extractor and dust collection system. The system shall operate for a certain period after the fill line valve is closed. Any high pressure and vacuum scenarios should be assessed for this operation for a predefined period.
- Starting the dehumidifier operation 15 minutes after closure of the fill line actuated valve.

Abnormal Operation

In the event, where the silo weight reaches high-high or the silo high-high level switch or the filter high differential pressure alarm is activated, a visual and audible alarm is triggered in the LCP and signal to SCADA. The delivery personnel will be required to stop the lime transfer and purge the line clear before advising the control room to initiate the remaining shutdown process. If the fill line actuated valve left open for a predefined period, an alarm should be raised.

Alarm and control systems shall be fail-safe and fail to high-high alarm upon loss of echo or instrumentation failure.

17.1.1.2 Large Bag Unloading System

The following describes a typical operating and control philosophy for the lime powder large bag delivery and unloading system. This should also be read in conjunction with Section 8.3 of this document.

Normal Operation

The large bag unloading process is initiated locally by a site operator.

The site operator, using suitable lifting equipment, will transfer the lime powder bag from the storage area to the filling point. The lime powder bag is then unloaded to the transfer hopper using a remote-controlled gantry crane. The gantry crane can only be operated once the safety gate limit switch is in the closed position and the safety circuit is reset.

Once the bag is in position, the site operator will need to open the unloader safety door to access and seal the package bag discharge spout. The unloader door safety switch, when open, will start the dust extractor fan, open the dust extraction line valve and interlock the conveyor system. The motor operation is restarted once the safety door is closed and reset.

Prior to starting the powder chemical unloading process, the operator will select the 'ON/OFF' Unloading switch to initiate the LCP. This will trigger the control system to check the same requirements as detailed in Section 17.1.1.1 for silo filling procedure, with the additional requirements which include:

- Unloader safety door and hoist operation safety gate must be closed and reset.
- Motors associated with discharge hopper must not have fault signal.

Once all the above conditions are met, the "Ready" indicator will be enabled in the LCP. The operator should then be able to continue with the silo filling procedure.

The unloading process is initiated when an operator presses the “Unload Start” push button on the LCP. This sequence opens the dust extraction line solenoid valve, starts the dust extractor, transfer hopper vibrator, the unloader massager solenoid valves, and activates the conveyance system. Depending on the conveyance system used, the system will either initiate the screw conveyor for the mechanical conveyance system or otherwise initiate the blower or vacuum generator, hopper airlock rotary valve and opening the filling line actuated valve when pneumatic conveyance is used.

The filling process continues until any of the following process controls are triggered:

i. Transfer hopper reaches Low Level, and this triggers the unloading sequence to stop after a time delay to allow for complete transfer.

ii. Storage silo / hopper reaches Operational High Weight.

iii. Operator initiates manual stop by pressing down the “Unload Stop” button on the LCP.

Once the filling operation is completed, the operator must stop by pressing down the “Unload Stop” button in the LCP. But the system must be designed to allow the conveyor to be emptied into the silo after the operator stopped the process on the LCP (by incorporating a run-on timer).

The operation personnel must re-enter the safety door, detach the bag outlet spout from the clamping arrangement and exiting the safety door. The gantry crane is then used to maneuver the bag off the unloader and onto the floor where it can be removed.

The dust collector filter is automatically cleaned by the actuated reverse pulse air blast at the pre-determined interval and end of fill cycle or when the differential pressure across the filter is high. The dust collection system should run for a predefined period after finishing the silo filling process. If used, the dehumidifier operation should start at least 15 minutes after the silo filling process is stopped.

The same unloading procedure as described at the start of this section should be followed for the unloading of another bag.

Abnormal Operation

If the storage silo reaches High-High Weight / Level or the filter high differential pressure alarm is activated, a visual and audible alarm is triggered in the LCP and signal to SCADA. At this condition, the control will interlock the operation of screw conveyor or air blower to stop the unloading process.

The unloading stop sequence can also be triggered by an emergency stop button on the LCP.

Alarm and control systems shall be fail-safe and fail to High-High alarm upon loss of echo or instrumentation failure.

17.1.2 Powder Transfer to Intermediate Hopper

The following describes a typical operating and control philosophy for the lime powder transfer from the storage silo to the intermediate hopper. This should also be read in conjunction with Section 9.2 of this document.

Normal Operation

The lime powder transfer will start automatically when the intermediate hopper reaches the Operational Low Weight setpoint and the control system will check the following requirements before opening the rotary valve:

- Intermediate Hopper Fan extraction and dust collector system is healthy and starts to operate.
- Silo vibration and aeration systems are available and starts to operate.
- Intermediate hopper load cells are healthy, and no alarm exist.
- Silo Low-Low level switch is healthy and not active.
- Each intermediate hopper compartment low- and high-level switches are healthy.
- Compressed air system is available.

The intermediate hopper filling sequence includes starting of silo vibration system, silo aeration system, the intermediate hopper dust extraction fan and opening of the rotary valve.

The rotary valve will operate to refill the hopper until any of the following conditions are met:

- High level switch in any hopper compartment becomes active.
- Hopper weight high-high is detected.
- Fan extraction and dust collection system register fault signals.

During powder transfer, an automatic pneumatic reverse pulse cleaning system will clean the filter at the pre-determined interval or at the end of the transfer or when the differential pressure across the filter is high, by opening the compressed air solenoid valve.

Abnormal Operation

The operational and control philosophy for the intermediate hopper abnormal condition as provided in Section 17.1.1 shall apply, except that the control will interlock the rotary valve upon reaching High-High Weight / Level.

17.1.3 Lime Slurry Mixing System

The following describes a typical operating and control philosophy for the lime mixing system used either for lime slurry dosing into the main or feeding into the lime saturator. This is applicable for variable concentration eductor or pumped lime slurry dosing system, and lime saturator feed system. This should be read in conjunction with Section 10 of this document.

Normal Operation

The lime mixing system is a continuous process designed to prepare lime slurry at variable concentrations by adjusting the screw feeder speed from main/process flowmeter inputs and operator dosing set point.

The lime mixing system will start automatically whenever the plant is running, and the following conditions are met:

- Intermediate or transition hopper weight is higher than the low limit setpoint.
- No fault signals from the screw feeder, agitator, tank level instruments, mixer and mixing water supply line.
- For saturator system, limewater holding tank requires top up (i.e., not at high level - only applicable for lime saturator system)

Once all the above conditions are checked, it will trigger to open the mixing water solenoid valve. The float valve assists in preventing the tank to overflow. The system design will keep the tank at a constant level with equal inflows and outflows.

When the lime mixing tank has a pre-set liquid level, the powder feed system will initiate and trigger the operation of the hopper vibrator, hopper aeration, agitator operation and operate the screw feeder at the required speed determined by the process control. The tank mixer will start when the mixing tank reaches to a pre-set liquid level to avoid splashing and continue to run to keep slurry in suspension.

For lime slurry dosing, the controller will calculate the lime powder mass flowrate (in g/s) (setpoint) required based on the main/process flowrate (in L/s) and operator lime dose setpoint (in mg/L) in flow paced mode. This is used to calculate the feeder speed on a linear feeder speed / mass flow relationship for the volumetric feeder system. A calibration mode shall be provided for volumetric feeders to determine the calibration factor as used in the feeder speed calculation.

For the LIW screw feeder system, the controller output will be used to update the speed of the screw feeder to achieve the calculated lime powder mass flow rate setpoint. The transition hopper load cells will provide a weight loss feedback value (in g/s) (process variable) to the controller to adjust the screw feeder speed (controlled variable).

When a pH analyser trim is used with flow paced, the analyser control loop will be used to trim the chemical dose rate setpoint (mg/L) as described in Table 17-1. The pH controller shall be limited to a trim action only, changing the controller setpoint only +/-10% (operator adjustable) from the operator entered flow paced set point value (mg/L).

For lime slurry feeding to the saturator, the controller needs to consider additional parameters of limewater concentration, lime utilisation and lime impurities factor. The powder mass flowrate (g/s) for the saturator will be trimmed from the limewater tank set level.

Lime slurry dosing to the process main as described in Section 17.1.5 shall be followed. Lime slurry feeding to the lime saturator is described in Section 17.1.6.

Abnormal Operation

The lime slurry mixing tank system will stop and raise alarms in SCADA to alert the operator when any of the following conditions are met.

i. Intermediate or transition hopper reaches to Low-Low Weight / Level.

ii. Mixer stops or register fault signal or shows high or low current.

iii. Mixing tank reaches Low-Low Level or High-High Level.

iv. The flow meters for the mixing water do not register healthy flows for a pre-set time when their respective solenoid valves are open.

17.1.4 Lime Slurry Batching System

The following describes a typical philosophy for the lime powder batching for a fixed concentration and variable flow rates system. This should also be read in conjunction with Section 10 and Section 0 of this document.

An operator can vary the batching concentration set point in the SCADA and the PLC will then calculate the required feeder run time from the screw feeder calibration curve for volumetric feeders or provide the required lime powder in weight taking feedback from transition hopper load cells for LIW feeders.

Normal Operation

A batching sequence will start automatically when the batching tank reaches the "batch start" level and the following conditions are met:

- The batching tank actuated outlet valve is closed (applicable for gravity transfer).
- No fault signals from the screw feeder, agitator, tank level instruments, mixer and water supply line.
- Intermediate or transition hopper weight is higher than the low limit setpoint.

Upon chemical batching initiation, the batching water solenoid valve will open and starting of the booster pump, when applicable, start filling the batching tank. When the batching tank reaches a pre-set level, the lime powder feed system will initiate and trigger the operation of the bin activator or vibrator and hopper aeration (where applicable), agitator and starting the screw feeder at the designed speed and duration.

The controller will calculate the feeder runtime (in seconds) required to achieve the operator input batch strength concentration at a set speed for volumetric feeder or the required lime powder weight for the batch strength for LIW feeders. The screw feeder will deliver a fixed volume of powder into the batching tank and stop once the calculated feeder run time is reached for volumetric feeder. For the LIW feeder system, the screw feeder will stop from the feedback signal from the transition hopper load cell signal.

The batching water system will continue to flow and the solenoid valve will close once the batching tank reaches the "Stop Batch" level. The mixer will start when the batching tank reaches a pre-set level to avoid splashing and continues to run until batching transfer occurs.

For the volumetric screw feeder calibration, the operator will be able to measure the flow rate and enter the measured flow rate in SCADA under calibration mode. This is to accommodate probable derating of the screw feeder as lime powder may clump up in the feeder.

Abnormal Operation

The lime batching sequence will stop by interlocking the operation of screw feeder and water system and raise an alarm in SCADA for the same conditions as specified in Section 17.1.3 under abnormal operation.

17.1.5 Lime Slurry Dosing System

The following describes a typical operating and control philosophy for lime slurry dosing system using eductors and pumps. This should be read in conjunction with Section 10 and Section 0 of this document.

17.1.5.1 Eductor system

Normal Operation

The lime slurry dosing system will start automatically when the plant is running (indicated from the process main water flowmeter) and the following conditions are met:

- Level in the mixing/batching tank is above the Operational Low Level.
- Mixing/batching tank eductor upstream actuated outlet valve (where used) is available and ready to open.
- Motive water supply system components including solenoid valve, booster pump, pressure transmitter, and flow transmitter are available.

Once all the above conditions are met, this will trigger to open the motive water solenoid valve and start the booster pump allowing motive water to flow through the eductor. This will also open the eductor upstream actuated isolation valve and draw the lime slurry from the mixing/batching tank to the dosing point.

Upon treatment plant shutdown, eductor upstream isolation valve will close (where available), the motive water flow will be maintained for a certain period to provide flushing water to the eductor and pipework to the injection point before stopping.

Abnormal Operation

Motive water flowrate and pressure to the eductor is monitored. If high/low pressure is observed in the dosing line, it will trip the pump. High/low flow will raise alarms to notify Operator(s).

If the lime mixing/batching tank level goes below the operational low level an alarm will be triggered and an interlock to stop the motive water pump at Low-Low tank level.

17.1.5.2 Pumped Dosing System

A. Variable Concentration and Fixed Flow System

Normal Operation

Lime slurry dosing system will start automatically whenever the lime screw feeder is called to run as described in Section 17.1.3. When called to start, the lime slurry dosing pump will check the following requirement:

- Slurry level in the mixing tank is above the Operational Low Level.
- Open position feedback from actuated valves located in suction and discharge lines.

Once the conditions are met, the lime mixing tank outlet actuated valve will open and the pump will start to dose lime slurry into the main. The dosing pump will operate at a fixed speed as set by the operator to achieve a constant flowrate.

Upon normal shutdown of the slurry system, a flushing cycle will purge the mixing tank and dosing line. This stops the screw feeder and allows the concentration to decrease in the tank and through the lines.

Abnormal Operation

If the duty mixing tank reaches Low-Low Level, its respective outlet valve will be isolated and dosing pump will be stopped. The system shall allow dosing using other mixing tanks, if available.

If the duty dosing line discharge pressure reaches high pressure or flow detected in the pressure relief valve relief line (where flow switch used) or high liquid level detected in pump casing, the duty dosing pump shall be stopped or tripped. The system shall still allow dosing using other dosing pump and dosing line.

The flow meter in the dosing line will identify flow deviations from the set flowrate, initiating low and high flow alarms in the SCADA.

In the event of a trip, the pump will stop operating and the pump suction side isolation valve may be required to close depending on the trip conditions.

B. Fixed Concentration and Variable Flow System

Normal Operation

Upon initiation of the dosing system, the duty lime slurry dosing tank actuated isolation valve any discharge line actuated valve will open. When called to start, the controller will calculate the required flowrate (in L/h) required to meet the dosing rate setpoint (entered in mg/L by the operator), based on flow-pacing to the main / process water flowmeter, and accounting for batch concentration. It will then output a pump speed by the particular dosing control mode selected (see

Table 17-5 for details on dosing control modes). The controller will continuously update the calculated values or the required pump speed in order to achieve the calculated values as process parameter changes.

For flow paced with chemical flowmeter feedback system, the dosing skid (or dosing line) flowmeter will typically provide a flow feedback value (process variable, PV, in L/h) to the controller to adjust the pump speed.

When a pH analyser trim is used, the analyser control loop will be used to trim the chemical dose rate setpoint (mg/L) as described in

Table 17-5. The pH controller shall be limited to a trim action only, changing the controller setpoint only +/-10% (operator adjustable) from the operator entered flow paced set point value (mg/L).

Abnormal Operation

The dosing pump will stop when discharge pressure is high, or dosing tank reaches Low-Low level or flow detected in pressure relief valve discharge lines or high liquid level detected in pump casing. This will raise an alarm in SCADA similar to conditions as specified above under abnormal operation for a variable concentration and fixed flow system. The system shall still allow dosing using other dosing pump and dosing line.

The flow meter in the dosing line will identify flow deviations, initiating an alarm in the SCADA if a deviation condition is met. If the chemical flow fails to achieve ±10% of the required flow within a defined period upon triggering a pump speed change, an alarm will be triggered.

17.1.5.3 Batching Transfer System

The following describes a typical philosophy for the lime powder batching transfer system. This should be read in conjunction with Section 11.2.3 of this document.

Normal Operation

Lime slurry transfer from the batching tank is initiated when a batching sequence is completed, and the dosing tank level reaches operational low level setpoint.

The level transmitter in the dosing tank will confirm the tank has sufficient capacity to accept a batch and that will not trigger a high level in the dosing tank. Once confirmed, the system will open the transfer line actuated valve for gravity system. For the pumped system, the pump will start to transfer the lime slurry. It will operate until the dosing tank transfer stop level is reached, or the batching tank low level is reached. Once one of these events is triggered, the actuated valve will close for a gravity system and the transfer pump will stop for a pumped system.

Abnormal Operation

After transfer initiation, if there is no change of level detected in the dosing tank within a pre-set time period, an alarm will be raised and the transfer system shutdown.

Low-low level in the batching tank and high-high level in the dosing tank or high liquid level in pump casing will also trigger the pump shutdown or close the transfer line actuated valve for gravity transfer system.

17.1.6 Lime Saturator System

The following describes a typical operating and control philosophy for the lime saturator system. This should be read in conjunction with Section 0 of this document.

Normal Operation

Lime saturator system will start automatically whenever the lime screw feeder is called to run. The lime saturator system triggers the operation of the following systems simultaneously when called to run:

- Lime slurry feed pump,
- Dilution water pump,
- Polymer dosing pump and batching system,
- Limewater transfer line actuated valve.

- Lime sludge removal system.

Lime slurry feed pump

When called to start, the lime slurry feed pump will check the following requirements:

- Slurry level in the mixing/batching tank is above the Operational Low Level.
- Limewater tank level is not high.

Once these conditions are met, the lime mixing/batching tank outlet actuated valve will open and the pump will start to feed the lime slurry into the dilution water line. The fixed speed motor pump will deliver lime slurry at a constant flowrate regardless of limewater demand.

Dilution water pump

When called to start, the dilution water line solenoid valve will open, and the dilution water pump will start. The controller will calculate the required dilution water flowrate (in L/h) using the lime powder mass flowrate (in g/s) and limewater concentration (in g/L). The lime slurry and polymer dosing flowrates will be deducted from the calculated flow rate and the flowrate will be trimmed from the limewater set tank level. It will then use the flowrate measured by the dilution line flowmeter as a feedback value and adjust the pump speed accordingly. Lime sludge removal flowrate may need to be added to the required dilution water flowrate depending on the system design.

Polymer dosing and batching system

The polymer dosing control provided in *B-SPE-STD-011 Polymer, PAC, Pot Perm, and Soda Ash Systems* shall be followed. For lime saturator system, the polymer flowrate setpoint (in L/h) is calculated based on the lime powder mass flowrate (in g/s), polymer batch concentration setpoint (in %) and the polymer dose rate setpoint (in g polymer/kg of lime). The output of the controller will adjust the polymer dosing pump speed to reach the setpoint with feedback from the polymer dosing line flowmeter (where available).

Saturator rake mechanism

The saturator rake should be kept running all time to prevent the settling of lime sludge even when the operation of the saturator is terminated. Uninterruptible Power Supply (UPS) is required for the rake operation when there is a power outage. Operators can adjust the rake speed from SCADA.

Lime sludge recirculation pump

The recirculation pump should be running all time when the saturator is operating and is above the low-low level setpoint and is not disabled. The recirculation sludge pump speed is manually set by the site operator from SCADA.

Limewater transfer line actuated valve

The saturated limewater from the saturator will overflow through the launders. When the saturator is in operation, the duty limewater transfer line actuated valve will open to allow limewater overflows through lime saturator overflow weir drain via gravity into the limewater holding tank.

The lime saturator system continues to operate until any of the following process controls are triggered:

- Limewater holding/dosing tank reaches High-High level setpoint.
- Screw feeder stops due to fault or for other interlocks.

- Plant shutdown

After each shutdown, the system will initiate an automatic water flushing to flush the lime slurry line. This is to remove retained lime slurry from the line, prevent lime scaling and keep the system ready for next time usage.

The duty/standby pumps will have a switch to alternate between pumps at every start up to ensure even operation and wear.

Lime Sludge Removal

The lime sludge pump will start at a pre-set time interval and will de-sludge for a specific period irrespective of the sludge bed level in the saturator. The automated de-sludging valve will open prior to the start of the pump, and will be an interlock with the pump. An operator can adjust the timing interval for de-sludging and duration of de-sludging from PLC to achieve the optimum result.

At the end of each de-sludging, the system will initiate an automatic water flushing to remove lime sludge from the line. Depending on the site-specific sludge handling facility arrangement, there could be an interlock from the sludge receiving end to stop the de-sludging pump.

Abnormal Operation

The turbidity and conductivity meter installed on the limewater transfer lines will raise alarms to notify the Operator(s) if the limewater turbidity exceeds the turbidity set point or the conductivity falls below the low conductivity setpoint.

When dilution water flowmeter reads High or Low flows, it will trigger alarms to notify the Operators and will trigger shutdown of the lime saturator process with some time delay.

Lime sludge bed level instrument will raise alarms to notify the operators if the sludge bed level is detected outside the operational range for a certain time.

17.1.7 Limewater Dosing System

This section describes the typical operation and control philosophy of the lime dosing system, its alarms, and interlocks. This should be read in conjunction with Section 0 of this document.

Normal Operation

Upon initiation of the dosing system using positive displacement pump, the duty suction isolation valve and duty dosing line isolation valve will open.

When called to start, the controller will first calculate the flowrate set point (in L/h) required to meet the lime dosing rate setpoint (entered in mg/L) based on flow-pacing to the main water flowmeter and limewater concentration input. It will then output a pump speed by the particular dosing control mode selected (see

Table 17-5 for details on dosing control modes), with the control continuing to update the required dosing pump speed (controlled variable, CV) in order to achieve the calculated set point of chemical flowrate (setpoint, SP).

When using diaphragm pumps, the calibrated flow curve and pump speed calculation may need to accommodate stroke length adjustment, as mentioned in

Table 17-5.

For flow paced with chemical flowmeter feedback system, the dosing skid (or dosing line) flowmeter will typically provide a flow feedback value (process variable, PV, in L/h) to the controller to adjust the pump speed. For pH analyzer trim feedback system, the controller will trim the limewater dosing flow rate within a range of the defined limit.

Abnormal Operation

If the duty limewater dosing tank reaches Low-Low Level, its respective outlet valve shall be isolated and the duty dosing pump will be stopped, however the system shall still allow dosing using other dosing tanks, if available.

If the duty dosing line discharge pressure reaches high pressure, the duty dosing pump shall be stopped. The system shall still allow dosing using other dosing pump and dosing line.

The flow meter in the dosing line will identify flow deviations, initiating an alarm in the SCADA if a deviation condition is met. If the chemical flow fails to achieve ±10% of the required flow within a defined period upon triggering a pump speed change, an alarm will be triggered.

In the event of a trip, the pump will stop operating and the dosing line isolation valve will close (if available and needed) to prevent any additional chemical dosing as a result of siphoning. The pump suction side isolation valve may be required to close depending on the trip condition.

17.1.8 Acid Batching and Flushing System

The following describes a typical operating and control philosophy for the acid flushing system. This should be read in conjunction with section 0 of this document.

Normal Operation

The acid batching is an automated process initiated by the operator. When acid batching is required, operator will ensure the neat acid IBC tank is connected to the transfer line via the flexible hose and dry break coupling connection. Once confirmed or connected, the operator will initiate the "Acid Batching" switch located in the LCP. This will trigger the acid batching procedure and the control system will check the following requirements:

- Acid solution tank level is at the operational low level / batch start level setpoint.
- Acid solution tank outlet solenoid valve is closed.
- No fault signals from the tank level instruments, mixer, and water supply line.
- Acid transfer pump and the compressed air system are available (or otherwise control valve when gravity transfer is used).

Once all the above conditions are met, the "Ready" indicator will be enabled in the LCP. The operator should then be able to continue with the acid batching procedure by pressing the "Start" button in the LCP.

The service water inlet valve will open to allow dilution water to fill the batching tank up to a pre-set level before closing. The acid transfer pump will start to fill the tank with acid to a level to make the required acid solution concentration before stopping.

The tank mixer will start when the batching tank reaches a pre-set level to avoid splashing and continue to run until a pre-set timer has lapsed.

The acid flushing system is a semi-automated process initiated by the operator. The operator shall need to select a particular "Acid Recirculation Loop" switch from the LCP. This will trigger a particular acid recirculation flushing procedure and the control system will open/close the appropriate valves to create the required recirculation loop and isolate duty process line. Once all the required valve settings are prepared, the "Ready" indicator will be enabled in the LCP.

The operator is then able to start the acid recirculating pump (or other recirculation device including the eductor system in the lime slurry dosing line) to allow acid solution to be drawn out and recirculate back to the tank. The recirculation pump will run for a pre-set period or the operator can stop the pump anytime from the LCP. The operator shall need to confirm the recirculation water pH before stopping the pump.

When the acid recirculation process is complete, the operator needs to deselect the particular "Acid Recirculation Loop" switch in the LCP. The control system will trigger the closing/opening of the appropriate valves to allow the system to be ready for operation.

The same acid flushing procedure as described at the start of this section needs to be followed for acid flushing of another recirculation loop.

Once acid flushing is complete, the operator will drain the content from the acid solution tank opening the drain valve. This will direct the solution into the sludge system or recycling back to the process plant depending on the design and site process capability.

Abnormal Operation

If any of acid transfer line reaches High Pressure, the duty transfer pump(s) or recirculation pump will be stopped automatically from high pressure interlock function.

If the acid batching tank reaches Low Level, it will trigger an alarm to notify the Operator(s) and stop the acid recirculation pump from tank low level interlock function.

If the acid batching tank reaches High level, it will trigger an alarm to notify the Operator(s) for an imminent overflow and will stop the acid transfer pump and isolate dilution water supply line if opened.

17.2 Control Modes

Equipment Control Modes, Process Permissive, Trip Interlocks, and Hardwired Interlocks as discussed below are defined in I-SPE-STD-013. The control system shall support three distinct control modes for plant, processes, and equipment as outlined below:

I. Local – plant may only be operated in the field independent of the control system. In this mode, only hardwired interlocks remain active.

II. Remote Manual Mode – plant may only be operated manually remotely under the control of the control system. In this mode, hardwired and trip interlocks remain active.

III. Remote Automatic Mode – plant is controlled by the control system. In this mode, all interlocks (i.e., hardware/hardwired, trip), process and start permissives remain active.

The standard lime slurry mixing system (for variable concentration) with Proportional–Integral-Derivative (PID) control shall include the following:

i. Fixed Speed - Operator inputs the screw feeder speed to a percentage output of the maximum speed.

ii. Fixed Flow – Operator inputs mass flow in g/s – the controller output as feeder speed for calibrated volumetric feeder.

iii. Flow Paced – Operator inputs chemical dose rate in mg/L. The controller first calculates the set point of lime powder mass flowrate (in g/s) based on the main/process flowrate (in L/s) and operator lime dose setpoint (in mg/L). This mass flowrate set point is then used to set up the volumetric feeder speed with the following options:

a. Flow paced without any feedback.
b. Flow paced with load cell feedback (LIW feeders).
c. Flow paced with pH analyser trim feedback.
d. Flow paced with load cell and pH analyser trim feedback (LIW feeders).

There is no standard batching system control mode with PID control except load cell feedback for LIW feeders. For the batching system, the controller calculates the feeder run time based on the batching concentration and feeder mass flow rate.

The standard lime slurry and limewater dosing mode (where dosing pumps used) with PID control shall include the following:

1. Fixed Speed - Operator inputs the pump speed to a percentage output of the maximum pump speed.

2. Fixed Flow – Operator inputs chemical flow in L/h. This mode can have the following options:

   a. Fixed flow without any feedback – the controller output as pump flow for calibrated pumps.

   b. Fixed flow with chemical flowmeter feedback – the controller output as pump speed for non-calibrated equipment with chemical flowmeter feedback.

3. Flow Paced – Operator inputs chemical dose rate in mg/L (for variable flow rates). The controller first calculates the set point of chemical flowrate (in L/h) based on the dose rate set point, operator input batching or chemical solution concentration, and main process/water flowmeter. This chemical flowrate set point is then used to set up the pump speed with the following options:

   a. Flow paced without any feedback.
   b. Flow paced with chemical flowmeter feedback.
   c. Flow paced with pH analyser trim feedback.
   d. Flow paced with chemical flowmeter and pH analyser trim feedback.

4. Ratio Control - Operator inputs the mass ratio of the chemical to be dosed to another chemical already dosed. The controller receives the dose rate (mg/L) of the reference chemical and first calculates the setpoint for the chemical to be dosed in mg/L. It then calculates a flow rate in (L/h) using the main process/water flowmeter. This chemical flow is then used to set the pump speed as per above Flow Paced control modes.

The table in the following section summarises the different Control Modes for lime mixing/batching and dosing systems. Automatic Dosing Control Modes as summarised in the tables will only be available when all equipment is in Remote Automatic Equipment Control Mode. In Local/Remote Manual Modes, the pump and/or feeder speed is set manually / locally.

Equipment and devices shall be programmed to include Disable and Maintenance Functions as described in *I-SPE-STD-013*. All instruments shall be programmed to include Instrument Calibration Functions as described in *I-SPE-STD-013*.

17.2.1 Lime Slurry Mixing System

Table 17-1 summarises the Equipment and Group Control Modes suitable for lime slurry mixing system (variable concentration).

Table 17-1 Typical lime slurry (variable concentration) preparation system operating and control modes.

Equipment Control Mode	Group Control Mode	Description
Local	N/A	Operator enters feeder speed in the field. Feeder operates at the designated Fixed Speed. This mode only allows hardware/hardwired interlocks to be active and is beneficial for pump testing.
Remote Manual	N/A	Operator enters feeder speed remotely from SCADA. Feeder operates at the designated Fixed Speed. This mode allows hardware/hardwired and trip interlocks to be active and is beneficial for pump testing and commissioning.
Remote Automatic	Fixed Speed	Operator inputs the feeder speed to a percentage output of the maximum feeder speed. When this mode is selected, it is recommended a timer is incorporated to trigger an operator alert upon timeout to manage the risk of indefinite operation in this mode. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Fixed Flow	Operator inputs feeder mass flow rate in g/s. The controller output as feeder speed following the linear feeder speed / mass flow relationship curve is set as described before. This selection allows all interlocks (i.e. hardwired, trip), process and start permissives to be active.
	Flow Paced without any feedback	Operator inputs Lime Dose Rate (mg/L). The controller calculates the set point of feeder mass flowrate (g/s) from the main/process water flow rate (L/h) and input dose rate. It then calculates the feeder speed from the linear calibrated feeder speed/mass flow relationship curve. Additional parameters need to be included in the calculation for the saturator system as mentioned in Section 17.1.3. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Flow Paced with Load Cell Feedback (LIW feeder)	Operator inputs Lime Dose Rate (mg/L). The controller calculates the set point of feeder mass flowrate (g/s) from the input dose rate and main process/water flowrate (L/h). It then modulates the feeder speed from the load cell data (using loss of powder weight in transition hopper) to maintain the set point of feeder mass flowrate. Additional parameters need to be included in the calculation for the saturator system as mentioned in Section 17.1.3. This selection allows all interlocks (i.e., hardware/ hardwired, trip), process and start permissives to be active.
		Operator inputs Lime Dose Rate (mg/L). Operator also inputs target pH from downstream analyser. The controller operates a control loop targeting the pH. The output of this control loop

Equipment Control Mode	Group Control Mode	Description
	Flow Paced with pH Analyser Trim Feedback	is limited (or trimmed) to a percentage of the feeder mass flowrate from operator lime dose rate. The controller then calculates the set point of feeder mass flowrate (g/s) from the main/process water flow rate (L/h), the pH analyser control loop output and input dose rate. It then calculates the feeder speed from the linear calibrated feeder speed/mass flow relationship curve. If using this mode, the trimmed output from the analyser feedback should be limited to ±10% (operator adjustable) of operator lime dose rate-based output. This is limited since the long-time reliability of an online analyser is low in a continuous system. Additional parameters need to be included in the calculation for the saturator system as mentioned in Section 17.1.3. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Flow Paced with Load Cell and pH Analyser Trim Feedback (LIW Feeders)	This mode combines the requirements of the following control modes: • Flow Paced with Load Cell Feedback • Flow Paced with pH Analyser Trim Feedback Operator inputs Lime Dose Rate (mg/L). Operator also inputs target pH from downstream analyser. The controller operates a control loop targeting the pH. The output of this control loop is limited (or trimmed) to a percentage of the feeder mass flowrate from operator lime dose rate. The controller then calculates the set point of feeder mass flowrate (g/s) from the main/process water flow rate (L/h), the pH analyser control loop output and input dose rate. It then modulates the feeder speed from the load cell data (using loss of powder weight in transition hopper) to maintain the set point of feeder mass flowrate. If using this mode, the trimmed output from the analyser feedback should be limited to ±10% (operator adjustable) of operator lime dose rate-based output. This is limited since the long-time reliability of an online analyser is low in a continuous system. Additional parameters need to be included in the calculation for the saturator system as mentioned in Section 17.1.3. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.

17.2.2 Lime Slurry Batching System

Table 17-2 summarises the Equipment and Group Control Modes suitable for lime slurry batching system (fixed concentration).

Table 17-2 Typical lime slurry (fixed concentration) preparation system operating and control modes.

Equipment Control Mode	Mixing/Batching Control Mode	Description
Local	N/A	Operator able to manually trigger and prepare the lime slurry locally. The operator starts/stops the screw feeder, service water pump, tank mixer, and other lime slurry preparation related equipment as required locally. This mode only allows hardware/hardwired interlocks to be active. This mode is beneficial for equipment testing.
Remote Manual	N/A	Operator able to manually trigger and prepare the lime slurry remotely. The operator starts/stops the screw feeder, service water pump, tank mixer, and other lime slurry preparation related equipment as required remotely. This mode only allows hardware/hardwired and trip interlocks to be active. This mode is beneficial for equipment testing and commissioning.
Remote Automatic	Automatic	The screw feeder, agitator, hopper vibrator, hopper aeration, service water pump, tank mixer and other lime slurry related equipment will operate automatically based on batching concentration input from operators when a lime slurry preparation system is called by the control system. For the fixed concentration system, this call will be triggered when plant is running, and batch start level is attained in the batching tank. For LIW feeders, a PID loop will utilise weight loss feedback from the transition hopper load cell to control the feeder run time and achieve the setpoint of powder weight based on operator input of batching concentration. Upon treatment plant shutdown, the screw feeder, agitator, hopper vibrator, hopper aeration will stop, actuated isolation valve(s) will close and will result stopping the lime slurry batching system. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.

17.2.3 Lime Slurry Dosing System (fixed flow)

Table 17-3 summarises the Equipment and Group control modes suitable for lime slurry dosing system for a variable concentrations and fixed flow system with the eductor or pumped system.

For a fixed concentration and variable flow rates system, the dosing system control modes as described in Section 17.2.5 should be followed.

Table 17-3 Typical lime slurry dosing system operating and control modes (fixed flow)

Equipment Control Mode	Group Control Mode	Description
Local	N/A	Operator able to manually trigger dosing operation locally. The operator may open/close the duty eductor upstream actuated valve (if available) and starts/stop and control the speed of the motive water booster pump locally. This mode only allows hardware/hardwired interlocks to be active. This mode is beneficial for equipment testing.
Remote Manual	N/A	Operator able to manually trigger dosing operation remotely. The operator may open/close the duty educator upstream actuated valve (if available) and start/stop and control the speed of the motive water booster pump remotely. This mode only allows hardware/hardwired and trips interlocks to be active. This mode is beneficial for equipment testing and commissioning.
Remote Automatic	Automatic	For eductor system, the eductor upstream actuated valve (if available) and motive water booster pump operates automatically when lime slurry dosing process is called by the control system. This will draw lime slurry from the tank and will dose into the process main. For pumped system, the dosing pump suction and discharge line actuated valves and dosing pump operates automatically at a fixed speed when lime slurry dosing process is called by the control system. This call will be triggered by signal from the main water flowmeter. When the main water flowmeter indicates no flow, it will stop the lime slurry dosing system. This selection allows all interlocks (i.e. hardware/hardwired, trip), process and start permissives to be active.

17.2.4 Lime Saturator

Lime saturator is a large system which includes several sub-systems as described in Section 17.1.6. Each sub-system is not separately described here, only a summary discussion is included in Table 17-4 for Equipment and Group control modes.

Table 17-4 Typical lime saturator system operating and control modes.

Equipment Control Mode	Group Control Mode	Description
Local	N/A	The operator manually starts/stops lime slurry transfer pump, dilution water pump, polymer dosing pump, sludge recirculation pump and lime sludge removal pump as required at the pump location. This mode only allows hardware/hardwired interlocks to be active. This mode is only beneficial for equipment testing.
Remote Manual	N/A	The operator manually starts/stops lime slurry transfer pump, dilution water pump, polymer dosing pump, sludge recirculation pump, lime sludge removal pump as required remotely via SCADA. The operator also opens/closes actuated valves remotely. This mode only allows hardware/hardwired and trips interlocks to be active. This mode is beneficial for testing and commissioning.
Remote Automatic	Automatic	The lime slurry feed pump, dilution water pump, lime recirculation pump, polymer dosing pump, lime sludge removal pump and actuated valves operate automatically as programmed when lime saturation process is called by the control system. This call will be triggered/stop when the screw feeder is called to stop or when limewater dosing tank reaches to high-high level. This is the preferred control strategy, and this selection allows all interlocks (i.e. hardware/hardwired, trip), process and start permissives to be active.

17.2.5 Limewater and Lime Slurry Dosing System (variable flows)

Table 17-5 summarises the equipment and group control modes suitable for lime water and lime slurry dosing system with variable flows.

For lime slurry batching system, an additional step is required to transfer lime slurry from a batching tank to a dosing tank either by gravity or by pumps. For simplicity, the operating and control modes for this transfer are not included here.

Table 17-5 Typical limewater and lime slurry dosing system operating and control modes (variable flows).

Equipment Control Mode	Group Control Mode	Description
Local	N/A	Operator enters pump speed in the field. Pump operates at the designated Fixed Speed. This mode only allows hardware/hardwired interlocks to be active and is beneficial for pump testing.
Remote Manual	N/A	Operator enters pump speed remotely from SCADA. Pump operates at the designated Fixed Speed. This mode allows hardware/hardwired and trip interlocks to be active and is beneficial for pump testing and commissioning.
Remote Automatic	Fixed Speed	Operator inputs the pump speed to a percentage output of the maximum pump speed. When this mode is selected, it is recommended a timer is incorporated to trigger an operator alert upon timeout to manage the risk of indefinite operation in this mode. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Fixed Flow	Operator inputs limewater or lime slurry flow in L/h. The controller output as pump flow or pump speed is set as described above. This selection allows all interlocks (i.e. hardwired, trip), process and start permissives to be active.
	Flow Paced without any feedback	Operator inputs Lime Dose Rate (mg/L). The controller calculates the set point of limewater or lime slurry flow (L/h) from the input dose rate, limewater or lime slurry concentration and main process/water flow meter. It then calculates the pump speed from calibrated pump curves. Where applicable, the pump curve needs to be updated for any changes in stroke length. Seqwater favors *Flow Paced with Chemical Flow Feedback* (see below) over this mode where analyser trim is not required. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active
	Flow Paced with Chemical Flowmeter Feedback	Operator inputs Lime Dose Rate (mg/L). The controller calculates the set point of limewater or lime slurry flow (L/h) from the input dose rate, limewater or lime slurry concentration and main process/water flow meter. It then uses the flowrate measured by the chemical line flowmeter and the calibrated pump curves (where available) to achieve the pump speed for the set point flowrate and adjust the pump speed as required. This is Seqwater's preferred dosing control mode where analyser trim is not required. The chemical flow meter on the dosing line can also be used to raise flow deviation alarms from the set point if the expected flow is not achieved in a pre-set time period.

Equipment Control Mode	Group Control Mode	Description
		This selection allows all interlocks (i.e., hardware/ hardwired, trip), process and start permissives to be active.
	Flow Paced with pH Analyser Trim Feedback	Operator inputs Lime Dose Rate in mg/L. Operator also inputs target pH from downstream analyser. The controller operates a control loop targeting the pH. The output of this control loop is limited (or trimmed) to a percentage of the flow rate from operator lime dose rate. The controller then calculates the set point of limewater or lime slurry flow (L/h) based on the dose setpoint, limewater or lime slurry concentration, the analyser control loop output and main process/water flowmeter. This chemical flow is then used to set the pump flow/speed from calibrated pump curves. If using this mode, the trimmed output from the analyser feedback should be limited to ±10% of operator lime dose rate-based output. This is limited since the long-time reliability of an online analyser is low in a continuous system. Where applicable, for this mode, the pump curve needs to be updated for any changes in stroke length. Seqwater prefers the use of *Flow Paced with Chemical Flow Feedback and Analyser Trim* (see below) dosing control mode. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Flow Paced with Chemical Flowmeter and Analyser Trim Feedback	This mode combines the requirements of the following control modes: • Flow Paced with Chemical Flowmeter Feedback • Flow Paced with Analyser Trim Feedback Operator inputs Lime Dose Rate in mg/L. Operator also inputs target pH from downstream analyser. The controller operates a control loop targeting the analyser pH setpoint. The output of this control loop is limited (or trimmed) to a percentage of the operator dose rate-based pump output. The controller then calculates the set point of limewater or lime slurry flow (L/h) based on the dose setpoint, the analyser control loop output, limewater or lime slurry concentration and main process/water flowmeter. This limewater or lime slurry flow is then used to set the pump flow/speed with the chemical flow meter and analyser feedback. If using this mode, the trimmed output from the analyser feedback should be limited to ±10% of operator lime dose rate-based output. This is limited since the long-time reliability of an online analyser is low in a continuous system. This is Seqwater's preferred dosing control mode where analyser trim is used. This selection allows all interlocks (i.e., hardware/hardwired, trip), process and start permissives to be active.
	Ratio Control	Refer Section 17.2 for the description of Ratio Control mode.

Equipment Control Mode	Group Control Mode	Description
		This mode may be combined with chemical flow meter and analyser trim feedback as described above. This selection allows all interlocks (i.e., hardware/hardwired, trip) and process permissive to be active.

17.2.6 Actuated Isolation Valves

Table 17-6 summarises the Equipment and Group Control Modes suitable for isolation valves.

Table 17-6 Typical Isolation Valve Operating and Control Modes

Equipment Control Mode	Description
Remote Manual	The operator will be able to modulate the isolation valve between open and close to isolate systems or tanks.
Remote Automatic	Isolation valves will open and closed based on system demands, faults/alarms, and interlocks.

17.3 Batching and Dosing Calculations

17.3.1 Lime Slurry Dosing

This section provides the calculation for control systems for lime feeder discharge rate to prepare lime slurry for dosing into the main.

Variable Concentration and Fixed Rate System:

The lime screw feeder (in g/s) is calculated based on lime dose rate setpoint (in mg/L) and flow paced to the main flowmeter (in L/s) as follow:

$$Lime\ Feeder\ \ (g/s) = \frac{Lime\ dose\ rate\ \left(\frac{mg}{L}\right)*Main\ flow\ rate\ \left(\frac{L}{s}\right)}{Lime\ powder\ purity\ (\%)*1000} \qquad (1)$$

The above equation is based on the fixed make-up flow rate in the mixing/batching tank.

Fixed Concentration and Variable Flow Rates System:

The dry powder feeder running time is calculated as follows:

$$Feeder\ run\ time\ \ (s) = \frac{Batch\ concentration\ set\ point(\%)*10\left(\frac{g}{L}\right)*Batch\ tank\ working\ volume\ (L)*60\left(\frac{s}{min}\right)}{Lime\ powder\ purity\ (\%)*\ Feeder\ rate\ \left(\frac{kg}{min}\right)*1000\left(\frac{g}{kg}\right)} \qquad (2)$$

In the above equation, 1% (w/v) batching concentration is equivalent to 10 g/L. Batching tank working volume is the volume associated with the batch start and batch stop tank level. For the above equation, a fixed volume of water is added for each batch.

The lime slurry flow rate is calculated as follows:

$$Lime\ slurry\ \ flow\ rate\ \left(\frac{L}{h}\right) = \frac{Process\ water\ flow\ rate\left(\frac{L}{s}\right)*dose\ rate\ \left(\frac{mg}{L}\right)*3600\left(\frac{s}{h}\right)}{Batch\ concentration\ (\%)*\ 10,000\ \left(\frac{mg}{L}\right)} \qquad (3)$$

17.3.2 Saturator and Limewater Dosing System

This section provides the calculation for control system for the screw feeder discharge rate, saturator make-up water flowrate, polymer dosing flowrate, limewater flow rate for the lime saturator system.

Screw Feeder Discharge rate

The screw feeder discharge rate (in g/s) is calculated based on the limewater flowrate (in L/h) and limewater concentration (in g/L) as follow:

$$Feeder\ discharge\ \ (g/s) = \frac{Limewater\ flowrate\ \left(\frac{L}{h}\right) * Limewater\ concentration\ \left(\frac{g}{L}\right) * \frac{1}{3600}\left(\frac{h}{s}\right)}{Lime\ Utilisation\ Factor\ (\%) * Lime\ Impurities\ (\%)} \quad (4)$$

The screw feeder rate calculated above needs to be adjusted or trimmed from the limewater dosing tank level.

Saturator Dilution Water Flowrate

The dilution water flowrate (in L/h) to the saturator is calculated as follows:

$$Dilution\ water\ flowrate\left(\frac{L}{h}\right) = Limewater\ flow\ rate\ \left(\frac{L}{h}\right) - Lime\ Slurry\ Transfer\ rate\ \left(\frac{L}{h}\right) - Polymer\ solution\ flowrate\left(\frac{L}{h}\right) \quad (5)$$

The dilution water flowrate calculated above needs to be adjusted or trimmed from the limewater dosing tank level. Lime sludge removal flowrates may also need to be adjusted depending on the design.

Limewater Dosing Flowrate

The control system calculates the necessary limewater flowrate (in L/h) based on the lime dose rate setpoint (in mg/L) and flow paced to the main water flowrate.

$$Limewater\ flowrate\ \left(\frac{L}{h}\right) = \frac{Main\ water\ flowrate\left(\frac{L}{s}\right) * lime\ dose\ rate\ \left(\frac{mg}{L}\right) * 3600\left(\frac{s}{h}\right)}{Limewater\ concentration\ \left(\frac{g}{L}\right) * 1000\ \left(\frac{mg}{g}\right)} \quad (6)$$

The limewater dose rate calculated above may need to be adjusted or trimmed from the process main pH meter feedback.

Polymer Dosing Flowrate

The polymer dosing based on the lime feeder discharge rate (g/s). The polymer flowrate setpoint (in L/h) based on plant dose rate setpoint (in kg polymer/ ton of lime) is calculated as follow:

$$Polymer\ flow\ rate\ \left(\frac{L}{h}\right) = \frac{Lime\ Feeder\ discharge\ \left(\frac{g}{s}\right) * dose\ rate\ \left(\frac{g\ of\ poly}{kg\ of\ lime}\right) * \left(\frac{1}{1000}\right)\left(\frac{kg}{g}\right) * \ 3600\left(\frac{s}{h}\right)}{Polymer\ \ concentration\ (\%w/v)} \quad (7)$$

In the above equation, use 1% (w/v) batching concentration is equivalent to 10 g/L.

Polymer solution will require carrier water, polymer solution flowrate will need to consider the carrier water flowrate.

$$Polymer\ solution\ flowrate\left(\frac{L}{h}\right) = Polymer\ flowrate\ \left(\frac{L}{h}\right) + Carrier\ water\ flowrate\left(\frac{L}{h}\right) \quad (8)$$

Pump Speed

Once the required chemical flowrates are calculated from the above equations, the pump speed is then calculated with the following equation for a particular stroke length:

$$Pump\ speed\ (\%) = \frac{Required\ flowrate\ (\frac{L}{h})}{Pump\ capacity\ (\frac{L}{h})}\ X\ 100 \qquad (9)$$

17.4 Alarms

Refer to Seqwater Standard Specifications *I-SPE-STD-013 Control System Design & Construction* and *I-SPE-STD-006 Monitoring and Control System Alarm Strategy* which outlines the philosophy that should be applied to the assessment of alarm priority and entered into the Master Alarms Database as prepared using the *I-TMP-SPE-008 Master Alarm Template.*

An assessment and validation-based approach shall be applied in determining plant alarms. The requirements for critical control points (CCPs) are described in *SPE-00320 WTP and Supply System Process Validation* and the above referenced documents.

17.5 Interlocks and Trips

All interlocks shall be defined in the Functional Description, and appropriate CCP protection measures defined in the Hazard Analysis and Critical Control Points (HACCP) Plan.

Refer to *I-SPE-STD-013 Control System Design and Construction* for additional information on the application and structure of interlocks.

The plant (or parts of the plant) shall only be available in Automatic where all plant dosing systems critical to safety/environmental and maintenance of correct treated water quality are also available.

Conditions and failures in each chemical system (or interfacing systems) shall trigger appropriate responses in all affected systems including control systems of other plant areas, overarching control systems, and external control systems.

Additional interlocks should be determined based on chemical, plant and process function and criticality, in accordance with *I-SPE-STD-013* requirements.

Plant trips shall also be determined on a case-by-case basis factoring chemical, plant and process functions and criticality. Before a system is tripped as an action, the following should be considered:

- Can the plant operate without lime for a period?
- Are there alternate control parameters that can be applied?
- Can the last known operating parameter be held safely?
- Can the plant shut down to a safe state immediately, or is a ramp down necessary?
- Are there other safety mechanisms in place that may be preferable to trigger in lieu of a plant trip?
- Could an alternate design prevent the need for a trip in the first place?

Appendix B summarizes typical process permissives, trip and hardware/hardwired interlocks to be considered for Seqwater Lime storage, mixing/batching and dosing systems. Trips and interlocks specified in Appendix B must be modified in accordance with project design requirements, and additional trips and interlocks may be necessary depending on the specific application and design. These should be outlined in key control system documents of *I-TMP-*

STD-001 Functional Description Part A, *I-TMP-STD-013 Cause and Effect Matrix* and *I-TMP-STD-005 Functional Description Part B*.

18 Testing and Commissioning

All systems shall be tested and commissioned in accordance with the requirements of

i. *B-SPE-STD-003 Commissioning Requirements*
ii. *E-SPE-STD-001 Electrical Design and Construction*
iii. *M-SPE-STD-001 General Mechanical Specification.*
iv. *I-SPE-STD-011 Control System Testing*

Testing shall, as a minimum, include:

i. Storage silos and hopper:
    a. Pressure and static load testing.
    b. Flow obstruction test due to ratholing or an arching issue.
ii. Bin vibrator:
    a. Operation sequence – Bin vibrator shall operate to the specified operational methodology to prevent mechanical damage to the silo.
iii. Tanks shall be:
    a. Hydrostatically tested using water, to an appropriate hydrostatic test method by the supplier/manufacturer prior to installation. Test report shall be made available to Seqwater.
    b. Leak tested using water to full volume, on-site, following installation and prior to commissioning any ancillary systems. This test should be held and successfully demonstrated over a minimum of 24 hours.
iv. Tank Liners:
    a. Shall be tested using an approved non-destructive method.
v. Pipework:
    a. Shall be tested in accordance with the relevant material standards and codes.
    b. Shall be hydrostatically leak tested as per *M-SPE-STD-013 Chemical Dosing Piping.*
vi. Dosing systems:
    a. All dosing systems shall be tested and proved first with water prior to the introduction of lime slurry or limewater:
        i. Across the design dosing range
        ii. Applying all Equipment and Dosing Control Modes.

19 Performance Testing

As part of performance testing, the contractor shall demonstrate, as a minimum, compliance of the lime system with design intent for the following:

i. Lime screw feeder – able to achieve the specified accuracy for all feed rates range from the maximum to the minimum dose rate

ii. Lime slurry concentration – able to achieve the range of specified, lime slurry concentration.

iii. Lime slurry mixing/batching tank sequencing and timing.

iv. Silo dehumidifier – able to achieve the specified relative humidity.

v. Lime saturator

   a. Hydraulic loading rate – able to achieve the target water quality parameter within the and maximum and minimum specified hydraulic loading rates.

   b. Solid loading rate – able to achieve the target water quality parameter within the maximum and minimum specified solid loading rates.

   c. Lime water turbidity – able to achieve the desired turbidity range of less than <15 NTU under the maximum and minimum hydraulic and solid loading rates.

   d. Lime water conductivity – able to achieve the required lime water concentration at the tested water temperature.

   e. Lime utilisation – able to achieve the specified lime utilisation of minimum 85% for all lime products and with minimum 93% of total calcium hydroxide.

vi. Service water delivery pressure and flow rate (if required).:

vii. Lime dosing:

   a. Desired dose concentration across the specified range can be achieved.

   b. Required dose rate (L/h) can be achieved across the plant flowrates.

20 Changes from previous version

This Engineering Standard will be regularly reviewed and updated, including the consideration of requested alterations, in accordance with Seqwater Procedure X-PRO-STD-004 Development and Review of Asset Standards. Changes made from the previous version are detailed below (Table 20-1):

Table 20-1 Changes from Previous Version

Section Number	Change
Not Applicable	Not Applicable (Original Version)

21 Verification

Compliance with this document may be verified by internal audit.

22 Further Information

For further information please contact the owner of this document.

Appendix A Lime Powder Information and Sample Calculations

The following appendix contains summary data, key information for lime and descaling acid used in water treatment at Seqwater Sites and flow rate calculations. This section should be read in conjunction with *PRO-00008 WHS Hazardous Chemicals Procedure* and appropriate chemical safety data sheets.

The following types of chemicals shall not be allowed to come into contact under any circumstance:

- Lime shall not come into contact with acid.
- Acid shall not come into contact with sodium hypochlorite.

An appropriate safety data sheet shall be used to provide guidance on toxicity and safe handling of all chemicals.

A.1. Hydrated Lime

Synonym: Calcium Hydroxide

Chemical Formula: $Ca(OH)_2$

Molecular Weight: 74.09 g/mol

Specific Gravity: 2.1 – 2.3

pH: 13

Bulk Density: 450 – 500 kg/m^3

Classification: Not Classified as Dangerous Goods according to ADG Code

Hydrated ;lime specification details should be obtained from Seqwater SPE-00469 *Chemical Quality Specification – Hydrated Lime*.

Sample Calculations:

Lime feeder discharge rate calculation for lime slurry dosing (variable concentration system):

Lime dose rate = 15 mg/L as $Ca(OH)_2$ (assumption)

Process water flow rate = 1000 L/sec (assumption)

Lime Impurities = 95% or 0.95 (assumption, this is a constant, in build to the PLC or operator adjustable setpoint)

$$Feeder\ discharge\ rate\ (\frac{g}{s}) = Lime\ Dose\ rate\left(\frac{mg}{L}\right) * Process\ water\ flowrate\left(\frac{L}{s}\right) * \frac{1}{Lime\ impurities} * \frac{1}{1000}$$

$$Feeder\ discharge\ rate\ = 15\ \left(\frac{mg}{L}\right) * 1000\left(\frac{L}{s}\right) * \frac{1}{0.95} * \frac{1}{1000}$$

$$Feeder\ discharge\ rate\ = 15.8\ \left(\frac{g}{s}\right)$$

Lime feeder run time calculation for lime slurry dosing (fixed concentration system):

Batch Concentration = 2.5% (w/v) = 2.5*10 g/L = 25 g/L (assumption, based on operator input setpoint)

Batching tank working volume = 1500 L (assumption)

Chemical powder purity = 95% (assumption, based on product specification)

Feeder rate = 6 kg/minute (assumption, determined through drop test)

$$Feeder\ run\ time\ \ (s) = \frac{Batch\ concentration\ set\ point(\%) * 10\left(\frac{g}{L}\right) * Batch\ tank\ working\ volume\ (L) * 60\left(\frac{s}{min}\right)}{Lime\ powder\ purity\ (\%) *\ Feeder\ rate\ \left(\frac{kg}{min}\right) * 1000\left(\frac{g}{kg}\right)}$$

$$Feeder\ run\ time\ \ (s) = \frac{2.5 * 10\left(\frac{g}{L}\right) * 1500\ (L) * 60\left(\frac{s}{min}\right)}{0.95\ *\ 6\ \left(\frac{kg}{min}\right) * 1000\left(\frac{g}{kg}\right)}$$

$$Feeder\ run\ time\ \ (s) = 395\ s \approx 6.5\ min$$

Lime slurry dosing flowrate calculation (fixed concentration system):

Process water flowrate = 1000 L/sec (assumption)

Lime dose rate = 15 mg/L as $Ca(OH)_2$ (assumption)

Batch Concentration = 2.5 % (w/v) (assumption)

$$Lime\ slurry\ flow\ rate\ \left(\frac{L}{h}\right) = \frac{Process\ water\ flow\ rate\left(\frac{L}{s}\right)*dose\ rate\ \left(\frac{mg}{L}\right)*3600\ \left(\frac{s}{h}\right)}{Batch\ concentration\ (\%)*\ 10{,}000\ \left(\frac{mg}{L}\right)}$$

$$Lime\ slurry\ flow\ rate\ \left(\frac{L}{h}\right) = \frac{1000\left(\frac{L}{s}\right)*15\ \left(\frac{mg}{L}\right)*3600\ \left(\frac{s}{h}\right)}{2.5\ *10{,}000\ \left(\frac{mg}{L}\right)}$$

$$Lime\ slurry\ flow\ rate\ \ = 2160\frac{L}{h}$$

Limewater flowrate and screw feeder discharge rate calculation (saturator system):

Lime dose rate = 15 mg/L as $Ca(OH)_2$ (assumption)

Process water flow rate = 1000 L/sec (assumption)

Saturated limewater concentration = 1.4 g/L as $Ca(OH)_2$ (a constant, operator adjustable)

Lime Utilisation Factor = 0.85 (a constant, operator adjustable)

Lime Impurities = 0.95 (a constant, operator adjustable)

Limewater flowrate calculation:

$$Limewater\ flowrate\ \left(\frac{L}{h}\right) = \frac{Main\ water\ flowrate\left(\frac{L}{s}\right) * lime\ dose\ rate\ \left(\frac{mg}{L}\right) * 3600(\frac{s}{h})}{Limewater\ concentration\ \left(\frac{g}{L}\right) * 1000\ (\frac{mg}{g})}$$

$$Limewater\ \ flowrate\ (\frac{L}{h}))\ \ = 1000\ \left(\frac{L}{s}\right) * 15\left(\frac{mg}{L}\right) * 3600\ (\frac{s}{h}) *\ \ \frac{1}{1.40}\left(\frac{L}{g}\right) * \frac{1}{1000}\left(\frac{mg}{g}\right)$$

$$Limewater\ flowrate\ \ = 38{,}571\ \left(\frac{L}{h}\right)\ or\ 10.7\ \left(\frac{L}{s}\right)$$

Screw feeder discharge rate calculation:

$$Feeder\ discharge\ \ (g/s) = \frac{Limewater\ flowrate\ \left(\frac{L}{h}\right) *\ Limewater\ concentration\ \left(\frac{g}{L}\right) * \frac{1}{3600}\left(\frac{h}{s}\right)}{Lime\ Utilisation\ Factor\ (\%) * Lime\ Impurities\ (\%)}$$

$$Feeder\ discharge\ rate\ \left(\frac{g}{s}\right) = 38{,}571\left(\frac{L}{h}\right) * 1.4\ \left(\frac{g}{L}\right) * \frac{1}{3600}\ (\frac{h}{s}) * \frac{1}{0.85} * \frac{1}{0.95}$$

$$Feeder\ discharge\ rate\ \ = 18.57\left(\frac{g}{s}\right)$$

Polymer dose rate calculation:

Polymer batch concentration = 0.2% (w/v) (assumption)

Polymer dose rate = 3 gm of poly/kg of lime (assumption)

Lime feeder discharge rate = 18.5 (g/s) (assumption)

The polymer dosing and flowrate required is calculated as follow.

$$Polymer\ flowrate\ \left(\frac{L}{h}\right) = \frac{Lime\ Feeder\ discharge\ \left(\frac{g}{s}\right) * dose\ rate\ \left(\frac{g\ of\ poly}{kg\ of\ lime}\right) * \left(\frac{1}{1000}\right)\left(\frac{kg}{g}\right) * 3600\left(\frac{s}{h}\right)}{Polymer\ concentration\ (\%w/v)}$$

$$Polymer\ flowrate\ \left(\frac{L}{h}\right) = \frac{18.5\ \left(\frac{g}{s}\right) * 3\ \left(\frac{g\ of\ poly}{kg\ of\ lime}\right) * \left(\frac{1}{1000}\right)\left(\frac{kg}{g}\right) * 3600\left(\frac{s}{h}\right)}{0.2 * 10\ (\frac{g\ of\ polymer}{L\ of\ water})}$$

$$Polymer\ flow\ rate = 100\frac{L}{h}$$

Polymer solution flowrate with carrier water, assuming dilution factor of 10

$$Polymer\ solution\ flow\ rate = 100\left(\frac{L}{h}\right) + (10 * 100)(\frac{L}{h})$$

$$Polymer\ solution\ flow\ rate = 1100\ (\frac{L}{h})$$

Saturator dilution water flowrate calculation:

Lime slurry flowrate = 2500 L/h or 0.7 L/s (assumption)

$$Dilution\ water\ flowrate\ (\frac{L}{h}) = Limewater\ flowrate\ \left(\frac{L}{h}\right) - Lime\ slurry\ flowrate\ \left(\frac{L}{h}\right) - Polymer\ solution\ flowrate(\frac{L}{h})$$

$$Dilution\ water\ flowrate\ = 38571\left(\frac{L}{h}\right) - 2500\ \left(\frac{L}{h}\right) - 1100\ (\frac{L}{h})$$

$$Dilution\ water\ flowrate = 34971\ \left(\frac{L}{h}\right) or\ 9.7\ (\frac{L}{s})$$

A.2. Hydrochloric Acid

Chemical Formula:	HCl
Atomic Mass:	36.5 g/mol
Chemical Concentration:	Typically delivered as 32% w/w as HCl
Density:	1.16 g/cm^3 at 20^{o}C
pH:	<1
Classification:	Dangerous Goods Class 8 (Corrosive), Packing Group II
UN Number:	1789

Hydrochloric acid specification details shall be obtained from Seqwater Specification *SPE-00464 Chemical Quality Specification – Hydrochloric Acid 32% w/w [as HCl].*

Appendix B Typical Trips and Interlocks for Lime System

Table B-1 Lime Powder Unloading and Storage Trips and Interlocks

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
Storage silo weight transmitter for load cells	Fault Power Loss High-High Weight	Interlock silo filling sequence. Bulk delivery: Not to open (if closed) fill line actuated valve. Bag unloading: Stop conveyance system		Y	
	Low-Low Weight	Interlock opening rotary valve or close rotary valve if open.		Y	
Storage silo High-High Level Switch	Fault Power Loss High-High Level	Interlock silo filling sequence. Bulk delivery: Not to open (if closed) fill line valve. Bag unloading: - Stop conveyance system		Y	
Storage silo Low-Low Level Switch	Fault Power Loss Low-Low Level	Interlock not to open rotary valve or close rotary valve if open.		Y	
Storage Silo High-High Pressure Switch	Fault Power Loss High-High Pressure	Interlock silo filling sequence. Bag unloading: Stop conveyance system		Y	
Dust Filter Differential Pressure Transmitter	Fault Power Loss High-High Differential Pressure	Interlock silo filling sequence. Bulk delivery: Not to open (if closed) fill line valve. Bag unloading: - Stop conveyance system		Y	
Storage Silo dust extraction fan	Fault Power Loss	Interlock filling sequence. Bulk delivery: Not to open (if closed) fill line valve (bulk delivery)		Y	

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
		Bag unloading: Stop conveyance system			
Storage silo vibrator	Fault Power Loss	Interlock not to transfer powder		Y	
Storage silo knife gate isolation valve	Fail close during powder transfer	Interlock not to transfer powder		Y	
Storage silo rotary valve	Fault Power Loss Fail to open during transfer	Interlock not to transfer powder		Y	
Intermediate hopper manhole access position switch	Open during powder transfer	Stop powder transfer sequence		Y	
Intermediate hopper weight transmitter for load cells	Fault Power Loss	Close silo rotary valve and stop screw feeder		Y	
	High-High Weight	Close silo rotary valve		Y	
	Low-Low Weight	Stop screw feeder and mixing operation or close hopper rotary valve		Y	
Intermediate hopper compartment Low-Low Level Switch	Fault Power Loss Low-Low Level	Stop screw feeder and mixing operation or close hopper rotary valve		Y	
Intermediate hopper compartment High-High Level Switch	Fault Power Loss High-High Level	Close silo rotary valve		Y	
Intermediate Hopper Dust Filter Differential Pressure Transmitter	Fault Power Loss High-High differential pressure	Interlock not to transfer powder and close silo rotary valve		Y	
	Fault			Y	

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
Intermediate hopper dust extraction fan	Power Loss	Interlock not to transfer powder and close silo rotary valve			
Intermediate hopper knife gate isolation valve	Fail close during powder transfer	Close rotary valve		Y	
Transition hopper weight transmitter for load cells	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
	Low-Low Weight				
	High-High Weight	Close intermediate hopper or silo rotary valve		Y	
Transition hopper Low Level Switch	Fault	Stop screw feeder and mixing/batching operation		Y	
	Power Loss				
Transition hopper High Level Switch	Fault	Close intermediate hopper or silo rotary valve		Y	
	Power Loss				
Transition or Intermediate hopper agitator	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
Large Bag unloading safety gate position switch	Open	Interlock to inhibit bag unloading sequence. Stop conveyance system		Y	
Lage Bag unloading discharge hopper safety door position switch	Open	Interlock to inhibit bag unloading sequence. Stop conveyance system		Y	
Large Bag unloading dust extraction line solenoid valve	Close	Interlock to inhibit bag unloading sequence. Stop conveyance system		Y	

Table B-2 Lime Slurry Mixing/Batching Tank System Trips and Interlocks

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
Screw feeder	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
	High Motor Current				
	Low Motor Current				
Mixing/batching tank Level Transmitter	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
	High-High Level	Stop screw feeder and isolation mixing water supply		Y	
	Low-Low Level	Stop lime slurry pump or motive water pump for eductor		Y	
Mixing/batching tank Level Transmitter *(batching for fixed concentration and variable flowrates system)*	Fault	Stop batching sequence and transfer system		Y	
	Power Loss				
	Batch Start Level	Start batching sequence	Y		
	Batch Stop Level	Stop batching transfer	Y		
Mixing/batching tank High-High Level Switch	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
	High-High Level				
Mixing/batching Tank Low-Low Level Switch	Fault	Stop lime slurry feed pump or motive water for eductor		Y	
	Power Loss				
	Low-Low Level				
	Fault			Y	

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
Mixing Tank Mixer	Power Loss	Stop screw feeder, mixing and transfer operation			
	High Motor Current				
	Low Motor Current				
Mixing water solenoid valve	Fault	Stop screw feeder and mixing operation		Y	
	Power Loss				
	Not open				

Table B-3 Lime Slurry Dosing System Trips and Interlocks (Eductor System)

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
Motive water Flow Transmitter	Fault	Stop motive water pump, screw feeder and mixing operation		Y	
	Power Loss				
Motive Water Pressure Transmitter	Fault	Stop motive water pump, screw feeder and mixing operation		Y	
	Power Loss				
	High High Pressure				
Motive water pump	Fault	Switch over to standby pump or stop screw feeder, mixing operation		Y	
	Power Loss				
	Stopped				
Actuated isolation valve (upstream of eductor)	Fault	Switch over to standby line or stop motive water pump		Y	
	Power Loss				
	Not opened within time	Do not start relevant motive water pump	Y		
	Fail Open during flushing	Stop motive water pump		Y	
Actuated isolation valve (for acid cleaning or water flushing)	Fault	Switch over to standby line or stop slurry dosing pump		Y	
	Power Loss				
	Fail to open within time	Do not start relevant dosing pump	Y		

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware / Hardwired Interlocks
	Do not open or close as needed	Stop dosing pump or acid recirculation pump as appropriate		Y	

Table B-4 Lime Slurry Dosing System Trips and Interlocks (Pumped – variable concentration and fixed flowrate System)

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware /Hardwired Interlocks
Slurry Dosing Line Pressure Transmitter	Fault Power Loss High-High Pressure	Stop dosing pump, screw feeder and mixing operation		Y	
Slurry Dosing Line Flow Transmitter	Fault Power Loss High-High Flow Low-Low Flow	Stop dosing pump, screw feeder and mixing operation		Y	
Pressure relief valve relief line flow switch	Fault Power Loss	Stop dosing pump, screw feeder and mixing operation		Y	
	Flow Detection	Stop dosing pump, screw feeder and mixing operation			Y
Slurry Dosing Pump	Fault Power Loss Stopped	Switch over to standby pump or stop screw feeder, mixing operation		Y	
	High liquid level in pump casing (from level switch)	Stop relevant pump and switch over to standby pump		Y	
Actuated isolation valve (for acid cleaning) or water flushing))	Fault Power Loss	Switch over to standby line or stop slurry dosing pump		Y	
	Fail to open within time	Do not start relevant dosing pump	Y		

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware /Hardwired Interlocks
	Do not open or close as needed	Stop dosing pump or acid recirculation pump as appropriate		Y	

Table B-5 Lime Slurry Dosing System Trips and Interlocks (Pumped – fixed concentration and variable flowrates System).

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware /Hardwired Interlocks
Lime slurry dosing tank Level Transmitter	Fault	Stop dosing and transfer pumps or close transfer line actuated valve		Y	
	Power Loss				
	Batch Transfer Start	Start transfer pump or open transfer line actuated valve	Y		
	Batch Transfer Stop	Stop transfer pump or close transfer line actuated valve	Y	Y	
	Low-Low Level	Stop slurry dosing pump (s)		Y	
Dosing Tank High-High Level Switch	Fault	Stop transfer pump or close transfer line actuated valve		Y	
	Power Loss				
	High-High Level				
Dosing Tank Low-Low Level Switch	Fault	Stop relevant slurry dosing pump(s), close tank outlet valve		Y	
	Power Loss				
	Low-Low Level				
Dosing Tank Mixer	Fault	If standby dosing tank is not available, stop all dosing pumps.		Y	
	Power Loss				
	Low Motor Current				
	High Motor Current				
Slurry Dosing Line Pressure Transmitter	Fault	Stop the relevant pump and changeover to standby dosing line and pump		Y	
	Power Loss				
	High-High Pressure	Stop relevant pump, close actuated valve and changeover to		Y	

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardware /Hardwired Interlocks
		standby dosing line and pump			
Slurry Dosing Line Flow Transmitter	Fault	Stop relevant dosing pump		Y	
	Power Loss				
Pressure relief valve relief line flow switch	Fault	Stop relevant slurry dosing pumps		Y	
	Power Loss				
	Flow Detection	Stop relevant slurry dosing pumps			Y
Slurry Dosing Pump	Fault	Close relevant dosing line actuated valve. Start other dosing pump Switch over to standby pump		Y	
	Power Loss				
	Stop	Close relevant dosing line actuated valve		Y	
	High liquid level in pump casing (from level switch)	Stop relevant pump and switch over to stand by pump		Y	
Actuated isolation valve (for acid cleaning or water flushing)	Fault	Switch over to standby line or stop slurry dosing pump		Y	
	Power Loss				
	Fail to open within time	Do not start relevant pump	Y		
	Do not open or close as needed	Stop dosing pump or acid recirculation pump as appropriate		Y	

Table B-6 Lime Saturator System Trips and Interlocks

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardwire /Hardwired Interlocks
Lime slurry feed line Flow Transmitter	Fault	Switch over to standby pump, if cause to persist then stop screw feeder, lime mixing operation and saturation system		Y	
	Power Loss				
	Low Flow				
	High Flow				
	Fault	Stop lime slurry feed pump, screw		Y	
	Power Loss				

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardwire /Hardwired Interlocks
Lime slurry feed line pressure transmitter	High Pressure	feeder, mixing and saturator system			
Lime slurry feed pump or dilution water pump	Fault	Switch over to standby pump operation or Stop saturation process, screw feeder and mixing operation		Y	
	Power Loss				
	Stopped				
	Power Loss				
	High Pressure				
	High liquid level in slurry feed pump casing (form level switch)	Stop relevant pump and switch over to standby pump		Y	
Lime de-sludge line Pressure Transmitter	Fault	Stop de-sludge pump		Y	
	Power Loss				
	High Pressure				
Saturator Liquid Level Transmitter	Fault	Stop saturator system and screw feeder		Y	
	Power Loss				
Actuated isolation valves in lime slurry line or dilution water line or lime recirculation or de-sludge line	Fault	Stop respective pump and close valve		Y	
	Power Loss				
	Not Open within time	Do not start respective line pump	Y		
	Fail Close	Stop respective pump		Y	
Saturator rake motor	Fault	Stop saturator system and screw feeder		Y	
	Power Loss				
	Not Running				

Table B-7 Limewater Dosing System Trips and Interlocks

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardwire / Hardwired Interlocks
Limewater holding/dosing tank Level Transmitter	Fault	Stop saturator system and screw feeder		Y	
	Power Loss				
	Trim control set level	Trim saturator dilution water flow rate and screw feeder rate	Y		

Device / Instrument	Cause	Action	Process Permissive	Trip Interlocks	Hardwire / Hardwired Interlocks
	Low-Low Level	Stop limewater dosing pump (s)		Y	
Dosing Tank High-High Level Switch	Fault	Close transfer line actuated valve and stop saturator system and screw feeder		Y	
	Power Loss				
	High-High Level				
Dosing Tank Low-Low Level Switch	Fault	Stop limewater dosing pump(s), close tank outlet valve		Y	
	Power Loss				
	Low-Low Level	Stop limewater dosing pump(s), close tank outlet valve		Y	
Dosing Flowmeter	Fault	Stop relevant dosing pump		Y	
	Power Loss				
Discharge Pressure Transmitter	Fault	Stop the relevant pump and changeover to standby dosing line and pump		Y	
	Power Loss				
	High Pressure	Stop relevant pump, close actuated valve and changeover to standby dosing line and pump		Y	
Limewater Dosing Pump	Fault	Close relevant dosing line actuated valve. Start other dosing pump		Y	
	Power Loss				
	Stop	Close relevant dosing line actuated valve		Y	
Dosing Line Flow Switch (if available)	Fault	Stop relevant dosing pump and isolate relevant dosing line		Y	
	Power Loss				
	No flow but pumps operating				
Actuated Isolation Valve (for acid cleaning or water flushing)	Fault	Stop relevant dosing or acid recirculation pump, close valve		Y	
	Power Loss				
	Not Open within time	Do not start relevant pump	Y		
	Do not open or close as needed	Stop dosing pump or acid recirculation pump as appropriate		Y	

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