# Uisce Éireann

# DESIGN SPECIFICATION: COAGULATION, FLOCCULATION & CLARIFICATION (CFC)

## TABLE OF CONTENTS

# 1 PURPOSE

Under the current European Union (Drinking Water) Regulations 2023 (S.I. No. 99 of 2023), Uisce Éireann has the responsibility to provide potable water to all public supply users in Ireland. The Regulations prescribe the quality standards to be applied, the relevant supervision required and the enforcement procedures in relation to the supply of drinking water, including sampling frequency requirements, methods of analysis, compliance monitoring points and the provision of information to consumers.

Drinking water treatment requirements are site specific, risk based and dependent on a number of factors, including source water quality, efficacy of water treatment technology and distribution system operational practices. While water clarification, filtration and disinfection are key process stages, they form only one part of a multi-barrier approach to providing safe drinking water. Effective management of microbiological, chemical and physical risks should also include measures to protect the water source and reduce distribution system risks in order to compliment the clarification and disinfection processes.

The World Health Organisation (WHO) has promoted a risk based approach based on Drinking Water Safety Plans (DWSP) as providing an integrated framework for operation and management of water supply systems. This approach involves an assessment of how particular risks can be managed by addressing the whole process of water supply from source to tap. As the first steps of a typical water treatment process, coagulation, flocculation and clarification (CFC) form a crucial part of the DWSP to achieve a process water of sufficient quality to advance to subsequent filtration and disinfection process stages.

As well as the issues highlighted above, this Specification intends to address the DWSP hazards listed in Table 1 below as a means of achieving desired target levels in the treated drinking water prior to filtration, disinfection and distribution. The hazards associated with CFC processes under Uisce Éireann's DWSP are as follows:

| Hazard Code | Hazard Description |
|---|---|
| **TC010** | Floc carryover due to inappropriate / inadequate dosing regime |
| **TC020** | Floc carryover due to overloading of the plant / surge flows |
| **TC030** | Floc carryover due to poor adjustment / maintenance / design of lamella plates |
| **TC040** | Floc carryover due to poor maintenance or flooding of settlement channels |
| **TC050** | Floc carryover due to variations in raw water characteristics |
| **TC060** | Flow carryover due to the effects of weather conditions |
| **TC070** | Floc carryover due to inadequate cleaning regime for clarifiers |
| **TC080** | Floc carryover due to poor settlement / unstable sludge blanket |
| **TC090** | Floc carryover due to sludge float / scraper not operating properly |
| **TC100** | Floc carryover due to sludge concentrators not operating properly |
| **TC110** | Floc carryover due to sludge bleeds not operating properly |
| **TC120** | Floc carryover due to insufficient sludge draw off |
| **TC130** | Inadequate cleaning regime of chemical mixing tank / contact tank causing contamination |
| **TC140** | Algal or plant growth in clarifiers causing poor water quality and clogged filters |
| **TC150** | Ingress into clarifier causing contamination |
| **TC160** | Malfunction / failure of chemical dosing point |
| **TC170** | Unapproved chemicals in used in clarification stage |

| | |
|---|---|
| **TC180** | Ineffective chemicals used in clarification stage |
| **TC190** | Chemicals delivered to incorrect storage vessel |
| **TC200** | Risk of running out of chemicals |
| **TC210** | Recycled sludge to head of works causing contamination |

**Table 1: Identified DWSP Hazards associated with coagulation, flocculation and clarification (CFC) process stages.**

This Specification will guide the Designer in establishing engineered solutions that deliver robust, reliable and repeatable performance that meet the coagulation, flocculation and clarification objectives for water produced by plants under Uisce Éireann's control, while also forming part of a series of standard specifications for use as 'building blocks' when compiling project designs. It should also be noted that the application of this, and every other specification within the 'building block' structure must also give due consideration to health & safety, operability, CAPEX and OPEX of each proposed design and installation.

The specification describes the suite of Uisce Éireann approved CFC processes, and outlines Uisce Éireann's policies towards design, control and automation techniques for each associated process element. In addition, the specification also incorporates information such as equipment specifications, critical alarms and critical control points which are to be applied throughout each installation. While the specification is provided as a template to describe Uisce Éireann's specific baseline requirements with regard to coagulation, flocculation and clarification, the appointed Contractor shall retain the role of detailed system Designer and each design will be carried out on a site specific basis, accounting for all constraints and restrictions therein.

Where appropriate, this Process Design Specification will make reference to the relevant Water Industry Mechanical and Electrical Specifications (WIMES) which have also been adopted by Uisce Éireann in a bid to ensure a baseline quality standard of system design and installation across all categories of water treatment plant. For the CFC Process Design Specification, the user should make reference to the following WIMES documents:

- WIMES 3.01 Low Voltage Switchgear and Control Assemblies
- WIMES 3.02 Low Voltage Electrical Installations
- WIMES 8.02 Chemical Dosing Equipment
- WIMES 8.02 (A) Sodium Hydroxide Dosing Equipment
- WIMES 8.02 (C) Sulphuric Acid Dosing Equipment
- WIMES 8.02 (D) Coagulant Dosing Equipment
- WIMES 8.02 (G) Polymer Dosing Equipment
- WIMES 8.06 Dissolved Air Flotation

The above documents shall form the basis of equipment selection, material selection, installation and testing for all CFC systems and, in tandem with this specification, should be used as a reference point by the Designer to ensure compliance with Uisce Éireann requirements. Where additional information is required, the Designer may also refer to Uisce Éireann's 'Water Treatment Strategy (Water Quality)' Document, which describes the strategies proposed to ensure safe and sustainable water supplies to all Uisce Éireann customers.

This Process Design Specification must be followed for both new and upgrade process works involving CFC process stages, across all Uisce Éireann plant classes (see Table 2 below for plant classification). If situations arise where compliance with this specification, WIMES, or Water Treatment Strategy documents is not possible and an alternative solution is proposed, then the Designer shall require prior approval from Uisce Éireann Asset Strategy (Water Treatment) before proceeding with detailed design and installation.

| Plant Class | MLD | m³/day |
|---|---|---|
| A | < 1 | < 1,000 |
| B | 1 – 5 | 1,000 – 5,000 |
| C | 5 – 10 | 5,000 – 10,000 |
| D | 10 – 20 | 10,000 – 20,000 |
| E | ≥ 20 | ≥ 20,000 |

**Table 2: Uisce Éireann plant classification by hydraulic capacity.**

## 1.1 DEROGATIONS FROM THE STANDARD/SPECIFICATION

Whilst the minimum requirements of this standard / specification shall be met (where applicable) this document is not intended to stifle innovation by the Contractor, or delay progress. Should the Contractor wish to apply for a derogation from any aspect of the document, they shall submit a derogation application to the Employer’s Representative in accordance with AD-EDS-SOP-005, in advance of any proposed departure from the requirements of the specification (the required form for the derogation application will be provided to the Contractor by the Employer’s Representative). Submission of the derogation application does not confer permission to proceed, and the application should be submitted allowing sufficient time for the Employer and the Employer’s Representative to evaluate. Works can only proceed on the basis of the derogation, after the Contractor has received written confirmation from the Employer’s Representative. The written confirmation of the derogation shall be treated as a change order/variation under the contract and its consequences shall be decided pursuant to the change/order variation mechanism of the contract.

The submission of a derogation application shall not impact on the programme of works for the specified project and shall be made at the risk and expense of the Contractor. Uisce Éireann or the Employer’s Representative shall retain the right to reject the derogation application in favour of compliance with this document.

For the avoidance of doubt, the derogation, where approved, shall only pertain to the specific circumstance for which the derogation is approved. An approved derogation shall not carry any precedent to another project/contract and shall not be used or applied on other similar projects/contracts or circumstances thereafter. The subject of a derogation can only be applied on another contract/project if it has been directly incorporated into the standards/specifications for the relevant contract/project.

# 2 OVERVIEW OF CFC PROCESS

The coagulation, flocculation and clarification (CFC) process in its simplest form is an attempt to agglomerate small organic, inorganic and biological contaminants, both dissolved and particulate, into larger particles (known as flocs) by the neutralisation of their repulsive electrical charges, and growth of the newly formed agglomerated flocs. The subsequent physical removal of the deliberately created flocs from the incoming raw water can then be achieved by utilising settlement or flotation mechanisms. This process train is generally employed upstream of a filtration system which offers enhanced physical separation of flocculated contaminants that may remain in the process water even after completion of the sedimentation or flotation clarification processes.

The entire coagulation, flocculation, clarification and filtration process stages are critical steps in ensuring that:

- The process water has been adequately prepared for disinfection.
- The levels of total organic carbon (TOC) in the raw water has been sufficiently reduced to minimise the disinfection by-product formation potential [i.e. the formation of Trihalomethanes (THMs)].

For disinfection by chlorination, this means the removal of organics, inorganics, metals and other contaminants in order to reduce competitive chlorine demand so that the disinfection chemical may specifically target pathogen removal. In the case of disinfection by UV irradiation, CFC and filtration processes are utilised in an attempt to remove particulates which may provide a microbial shield for pathogens, and to maximise the ultraviolet transmittance (UVT) of the clarified water by the reduction of both particulate organic carbon (POC) and dissolved organic carbon (DOC). The desired result is the subjection of residual biological pathogens to the full microbial inactivation potential of UV light, with minimal UV absorbance (UVA) caused by organic and inorganic contaminants, which are not the targets of disinfection practices.

There are a number of ways to implement a CFC process, and specific methods should be selected based on the type of source water that is to be treated – i.e. the amount of particulate material present in the raw water, the quantity and nature of the natural organic matter (NOM), and the bulk chemical and physical properties of the water. Consequently, the type of coagulant that is selected will also determine how the raw water has to be pre-conditioned to allow the optimal precipitate floc forming chemical reaction to take place. In this regard, the importance of raw water alkalinity and pH cannot be overstated. For example, the commonly used aluminium sulphate (alum) coagulant has a higher alkalinity demand than alternatives such as pre-hydrolysed poly-aluminium chlorides (PACl) and will therefore require a higher raw water alkalinity concentrations which may not be available in the source waters. The corollary of the above is that the buffering capacity of high alkalinity water to pH change may require the removal of some alkalinity to facilitate charge neutralisation of contaminants at lower pH levels.

This specification will describe the differing CFC methods that are acceptable to Uisce Éireann, and outline the processes which are most suited to differing raw water supplies. It will also describe how water is to be conditioned in advance of the selected CFC process and outline and emphasise the importance of pH and alkalinity control in order to facilitate optimum performance. The methods described in this document shall be the only processes acceptable to Uisce Éireann for CFC purposes, and shall be utilised by Designers for all future water treatment infrastructure upgrades, retrofits or new builds where CFC process stages are required. All alternative proposals shall require the prior approval of Asset Strategy (Water Treatment) and Uisce Éireann reserves the right to reject any alternative proposal which is not described within this specification. All such alternative proposals shall be made at the risk and expense of the Designer.

## 2.1 TARGET CONTAMINANTS

Contaminants may be present in all natural waters, regardless of whether the source is surface water (rivers and lakes), high risk ground water (surface influenced boreholes in karst limestone) or low risk ground waters from secured boreholes drilled to sand aquifers. The contaminants found in raw water sources may be of natural, anthropogenic (human) or microbiological origin, and may affect water quality to the point where it is unpalatable, aesthetically unappealing, or harmful to public health. While CFC and filtration processes are important to provide the consumer with a water that is of high visual, gustatory and olfactory quality, the primary purpose of clarification and filtration is to prepare the water for disinfection, as described on the previous page. In general, raw water contaminants can be classified into three main categories; organic, inorganic and biological, which are further described in Table 3 below.

| Contaminant | Description | Examples |
|---|---|---|
| **Organic** | Predominantly consists of natural organic matter (NOM), which is the result of the decomposition of plant and animal materials. May consist of both suspended particles and dissolved molecules. Typically measured in mg/L of Total Organic Carbon (TOC), which may be subdivided into Particulate Organic Carbon (POC) and Dissolved Organic Carbon (DOC). | Fulvic Acids, Humic Acids, Colloidal & Suspended Solids |
| **Inorganic** | Predominantly consists of mineral particles such as silts, clays or sands which are naturally present in lake/river beds, or which have accumulated due to catchment run off and erosion. As with NOM, inorganic materials may be present in particulate or dissolved forms (the latter commonly referred to as dissolved inorganic compounds). Dissolved minerals such as ferric (iron) oxide and manganese oxide also constitute inorganic contaminants. | Gravel, Silt, Clays, Sands, iron oxides, manganese oxides, aluminium oxides, calcites, dissolved inorganic compounds |
| **Biological** | Biological contaminants generally enter the water source via direct discharge of wastewater, waste from wild animals or livestock, or surface run off from the fertilization of agricultural lands. Biological contaminants may often attach to organic or inorganic suspended matter, thereby increasing the importance of their removal. Living species such as algae may also be considered biological contamination. | Bacteria (*E.coli*, *Salmonella*), Viruses (*Adenovirus*, *Poliovirus*),Protozoa (*Cryptosporidium*, *Giardia*), Algae |

**Table 3: Classification of Organic, Inorganic and Biological contaminants typically found in raw water sources.**

As stated in the previous section, the purpose of coagulation and flocculation is to neutralise the mutually repulsive negative charge on particles and agglomerate these small organic, inorganic and biological contaminants into larger particles so that the effectiveness of physical separation by downstream clarification and filtration processes is maximised. While sand and silt constituents of inorganic contaminants will generally be large enough to settle out of the raw water flow by gravity, and some inorganic dissolved metals will require dedicated oxidation and filtration processes to achieve removal (see Uisce Éireann Specification TEC-900-04), the majority of remaining contaminants will be organic in nature, i.e. natural organic matter (NOM) consisting predominantly of total organic carbon (TOC) which can be further subdivided into particulate organic carbon (POC) and dissolved organic carbon (DOC).

## 2.2 COAGULATION AND FLOCCULATION

While the words coagulation and flocculation are often used interchangeably, they are in fact two distinct processes that are used in conjunction with each other on many water treatment applications.

**Coagulation** refers to the process in which negatively charged natural organic matter (NOM - made up of both DOC, POC), colloidal particles, very fine suspended solids and small amounts of inorganic contaminants are charge neutralised (or destabilised) so that their repulsive forces are removed and they can begin to agglomerate. The charge neutralisation, or destabilisation, is achieved by the addition of a positively charged coagulant chemical, and the subsequent vigorous agitation (flash mixing) of the dosed raw water. The flash mixing stage fulfils two purposes; it ensures that the coagulant is adequately mixed with the flow, and it also promotes collisions between the now neutrally charged particles, allowing them to bind together to form larger conglomerates.

**Flocculation** refers to the process by which the particles that have been charge neutralised or destabilised by the coagulation process actually conglomerate into larger aggregates known as flocs, so that they can be physically separated from the raw water. Flocculation begins at the flash mixing stage of the coagulation process, where the initial collisions between charge neutralised particles are promoted. Floc growth is then continued by the subsequent gentle stirring of the water to promote further collisions between suspended particles, so that they conglomerate even further. The physical size of the required floc will be determined by the proposed downstream physical separation process, which may require a large, heavy and dense floc for settlement, or a small light floc for attachment to microbubbles generated in the flotation process. A number of flocculation mechanisms may be utilised, such as chemical bridging, or sweep flocculation, depending on the extent of floc growth required. These mechanisms are further discussed in Section 2.3 below. Effective coagulation and flocculation is dependent on a number factors, including:

- the nature of the particulate contaminant (i.e. size, surface electrical charge, hydrophilic / hydrophobic nature of NOM)
- the type of coagulant employed (organic polyelectrolytes or inorganic salts)
- the dose rate of the coagulant (initiation of sweep flocculation)
- the speed / vigorousness of the flash and flocculation mixing

As the cost of organic coagulants makes them prohibitive for use as charge neutralisers, inorganic trivalent salt chemicals (i.e. aluminium sulphate, poly-aluminium chloride) are more commonly employed to initiate charge neutralisation and particle destabilisation, making the management of raw water pH and alkalinity the most critical factor for achieving successful coagulation and flocculation. The reasons for this are described in more detail in Sections 2.6 and 4.0 of this document.

## 2.3 COAGULATION & FLOCCULATION MECHANISMS

While coagulation is achieved by the charge neutralisation of organic matter, colloidal particles and very fine suspended solids, flocculation may be implemented by a number of mechanisms, as outlined in Table 4 below. While coagulation by charge neutralisation may be implemented as the only method of agglomeration on raw water sources where TOC levels are consistently less than 2.00mg/L, none of the flocculation mechanisms described in Table 4 are possible without first achieving adequate charge neutralisation.

For surface water sources (lakes in particular), or surface influenced high risk ground water sources, where TOC concentrations will consistently be in excess of 2.00mg/L, additional mechanisms consisting of slow speed mixing, sweep flocculation and/or chemical bridging shall always be required in tandem with charge neutralisation. As stated in Section 2.2 above, the extent of required floc growth during the coagulation and flocculation process will be determined by the proposed downstream physical separation process, which may require a large heavy floc (if settlement is proposed) or a small light floc (if flotation is proposed).

| Process | Mechanism | Description |
|---|---|---|
| Coagulation | Charge Neutralisation | The charge neutralisation of negatively charged colloidal particle surfaces resulting in the destabilisation of their repulsive charges and thereby allowing particles to agglomerate together. May be implemented by the addition of positively charged organic or inorganic coagulants, followed by vigorous flash mixing, and can be used without further flocculation as the only coagulation mechanism on low TOC (< 2.00mg/L) raw waters. |
| Flocculation | Basic Flocculation | Encouragement of further floc growth by the gentle stirring of process water in a dedicated flocculation tank after charge neutralisation has been achieved. May be completed mechanically or hydraulically, and is often used in conjunction with the chemical bridging mechanism to facilitate the growth of large, heavy flocs. |
| | Tapered Flocculation | Encouragement of further floc growth by the sequential stirring of process water in dedicated flocculation tanks after charge neutralisation has been achieved. Typically implemented as a three stage mix of decreasing intensity, with the first stage being the most vigorous mix (yet still significantly less vigorous than flash mixing), and the last stage the least. Tapered flocculation may be used in conjunction with chemical bridging to facilitate the growth of large, heavy flocs. |
| | Chemical Bridging | NOM, colloidal solids and metal hydroxide flocs are bound together to long chain polymers by the addition of organic coagulants that improve settlement and filtration. The organic coagulant is typically added during one of the flocculation mixes and may be used in conjunction with slow mixing, tapered flocculation or sweep flocculation in order to promote growth of a heavy floc which is suitable for downstream settlement. |
| | Sweep Flocculation by Adsorption | Natural organic matter (NOM) is adsorbed onto the surface of the floc particle created by previous charge neutralisation. Implemented by the addition of larger amounts of inorganic coagulants which react with raw water alkalinity to form a larger metal hydroxide floc. Adsorption works in tandem with enmeshment and is typically used on raw waters with higher TOC concentrations (> 2.00 mg/L). |
| | Sweep Flocculation By Enmeshment | Colloidal solids are enmeshed in the floc particle created by charge neutralisation. Implemented by the addition of larger amounts of inorganic coagulants which react with the raw water alkalinity to form a larger metal hydroxide floc. Enmeshment works in tandem with adsorption and is typically used on raw waters with higher TOC concentrations (> 2.00 mg/L). |

**Table 4: Coagulation and flocculation mechanisms. Note that charge neutralisation must always be achieved before flocculation or sweep flocculation can take place.**

## 2.4 ENHANCED COAGULATION

As the majority of inorganic contaminants will be large enough to either settle out by gravity, be captured in the 1st stage filters, or be removed by dedicated oxidation and filtration processes (iron, manganese, etc.), the remaining contaminants found in raw water from surface sources are typically organic in nature. Enhanced coagulation may therefore be defined as the specific and deliberate targeting of DOC for removal (instead of targeting turbidity), which in turn will create the conditions required for subsequent agglomeration of larger colloids, turbidity and biological contaminants via basic, tapered or sweep flocculation mechanisms, as well as chemical bridging processes. As DOC and colloidal solids are typically the smallest and lightest of the constituent contaminants which make up NOM, targeting these will also inadvertently result in the agglomeration and subsequent removal of larger organic particulates.

To effectively implement an enhanced coagulation system for both sedimentation and flotation clarification processes, the Contractor shall ensure the following critical parameters are implemented for each installation:

- Accurate management of raw water pH to create the conditions for charge neutralisation to occur
- Accurate management of raw water alkalinity to facilitate the required buffer to pH change (if alkalinity is too high, pH will be difficult to adjust, whereas if alkalinity is too low, pH levels will vary uncontrollably by the addition of coagulant chemical). Alkalinity levels must be maintained throughout the treatment process to ensure stability of pH.
- Accurate management of raw water alkalinity to facilitate the reaction required to form the metal hydroxide precipitate when attempting to create sweep flocculation conditions (sufficient alkalinity must be available to allow this reaction to occur).
- Accurate management of coagulant dosing based on fully automated feedback control from analytical instruments dedicated to monitoring the efficacy of coagulation performance.
- Appropriate mixing intensity and retention times for effective charge neutralisation.
- The implementation of flocculation mechanisms appropriate to the downstream clarification process (basic flocculation, tapered flocculation, sweep flocculation, chemical bridging).

The mechanisms at work in the enhanced coagulation process mean that it is also an effective tool for the removal of biological pathogens, viruses in particular, which may attach themselves to organic or inorganic contaminants. Without enhanced coagulation, TOC (predominantly made up of DOC) and the lighter colloidal solids will not be removed by settlement, flotation or subsequent filtration processes, resulting in a final water which is difficult to disinfect, has an increased THM formation potential, a lower UVT percentage and an increased risk of breakthrough by various pathogens. In addition, if granular activated carbon (GAC) is employed within the treatment stream for polishing, taste or odour removal purposes, TOC that has not been removed by the CFC process will compete with other compounds for pore space within the GAC, resulting in the premature exhaustion of the media and its prevention in achieving its targeted treatment objective.

While all schemes that abstract from a surface water, or high risk groundwater source shall incorporate a coagulation system, it is Uisce Éireann policy to implement enhanced coagulation for all plants with a raw water TOC concentration in excess of 2.00 mg/L in order adequately prepare the process water for disinfection, regardless of the source.

## 2.5 TYPES OF COAGULANTS

Chemical coagulants can be subdivided into two categories; inorganic and organic.

### a) *Inorganic Coagulants*

Inorganic coagulants are cost-effective chemicals, which make them applicable for a broad range of raw water conditions. They are typically trivalent metal salt solutions, which may be used for both charge neutralisation and sweep flocculation purposes. Once added in the required quantity to raw water with an appropriate pH and sufficient alkalinity, inorganic coagulant can neutralise negatively charged colloidal particles, as well as react with the raw water alkalinity and hydrate to form metal (aluminium or iron) hydroxide precipitates, which allows sweep flocculation to progress. This process facilitates the removal of many difficult-to-treat colloidal suspensions and DOC. Common types of inorganic coagulants include:

| | |
|---|---|
| - Aluminium sulphate (alum) | $Al_2(SO_4)_3$ |
| - Poly-aluminium Chloride (PACl) | $Al_2(OH)_3Cl_3$ |
| - Aluminium chlorohydrate (ACH) | $Al_2(OH)_5Cl$ |
| - Ferric sulphate | $Fe_2(SO_4)_3$ |

Whereas the effectiveness of organic coagulants is not dependant on pH, pH and alkalinity management is critical when using inorganic coagulants, especially aluminium sulphate and ferric sulphate, where optimal coagulation is highly dependent on maintaining an optimum pH level in the raw water. In addition, in order to facilitate enhanced coagulation mechanisms, a sufficient quantity of alkalinity must be present within the raw water to allow the reaction that creates the metal hydroxide precipitate to occur.

PACl and ACH are pre-hydrolysed compounds which reduces their alkalinity demand when creating the metal hydroxide floc precipitate. While they are not as dependant on pH their use will still require pH and alkalinity management in order to ensure optimum enhanced coagulation. Table 5 overleaf outlines the different forms of organic and inorganic coagulants that may be used as part of the water treatment process.

### b) *Organic Coagulants*

Organic coagulants are typically long chain polymers which may be used for charge neutralisation (cationic poly), or as coagulation / flocculation aids (anionic and cationic) which bind flocs together by means of chemical bridging. Cationic polys are more effective than inorganic coagulants at accomplishing charge neutralisation, and when used as a primary coagulant, the required dose can be less than 10% of the inorganic dose required to achieve equivalent results. In contrast to inorganic coagulants, the effectiveness of charge neutralisation is also not dependant on pH, and there is no alkalinity demand. Organic coagulants also produce a large, strong floc which is easily settled and has the ability to bridge between similarly charged particles.

However organic coagulants are expensive and are therefore not generally used for charge neutralisation purposes. Instead, polymers are typically deployed as part of an enhanced coagulation sedimentation process by providing a chemical bridging which aids the growth of flocculated agglomerations by bonding them together within a polymeric chain.

Table 5 below outlines the different forms of organic and inorganic coagulants that may be used as part of the water treatment process. The most common chemicals used for coagulation as part of an enhanced coagulation process are aluminium sulphate and poly-aluminium chloride.

| Organic / Inorganic | Chemical | Typically Used for |
|---|---|---|
| **Organic** | Anionic Polymer | Flocculation Aid |
| | Cationic Polymer | Charge Neutralisation, Flocculation Aid |
| **Inorganic** | Ferric Sulphate | Charge Neutralisation, Sweep Flocculation |
| | Aluminium Sulphate (Alum) | Charge Neutralisation, Sweep Flocculation |
| | Poly-aluminium Chloride (PACl) | Charge Neutralisation, Sweep Flocculation |
| | Aluminium Chlorohydrate (ACH) | Charge Neutralisation, Sweep Flocculation |

Table 5: Organic and inorganic chemicals typically used as part of the enhanced coagulation process.

## 2.6 IMPORTANCE OF PH AND ALKALINITY

The predominant use of inorganic coagulants for charge neutralisation and enhanced coagulation processes makes pH and alkalinity control a critical factor in achieving effective system performance, as highlighted in Sections 2.2, 2.4 and 2.5 of this document. Depending on the type of inorganic coagulant used, the pH at which charge neutralisation occurs has a significant effect on the surface charge of colloidal particles, the charge of the NOM, the charge of the dissolved phase coagulant species, the surface charge of formed floc particles and the solubility of coagulant in the water.

The metal based inorganic coagulants typically used for charge neutralisation purposes are highly acidic. Therefore the addition of this type of chemical to the raw water depresses the pH, which in turn may greatly affect the charges of the colloidal solids, NOM, etc. as outlined above, and consequently prevent effective destabilisation. The extent of which the pH is depressed by the addition of an acidic coagulant salt is governed by the alkalinity of the raw water, which is a critical parameter to be considered when designing a coagulation system.

Alkalinity is a quantitative measurement of a waters acid neutralising capabilities. While pH measures the intensity of the $H^+$ ion in the water, alkalinity measures the capacity of the water to neutralise the $H^+$ ion. The capacity to neutralise the $H^+$ ion is related to the concentrations of carbonates, bicarbonates, and hydroxides present in the water. When using inorganic chemicals for charge neutralisation and enhanced coagulation, raw water alkalinity needs to be controlled for two reasons;

- ***pH buffering*** - If the raw water alkalinity is too low, the addition of an acidic inorganic coagulant will depress the raw water pH to such an extent that the precipitate metal hydroxides (aluminium or iron) cannot form. Conversely, if the raw water alkalinity is too high, then the raw water pH will most likely be raised and offer resistance to pH change when coagulant is added. While higher dosages of the acidic coagulant will eventually reduce the alkalinity, and subsequently the pH, to the required levels to allow the aluminium or iron species to exist, as well as the creation of metal hydroxide precipitates, such high dosing is not a cost effective use of the inorganic coagulation chemical, and it also multiplies the risk of residual metal (aluminium or iron) exceedances in the final treated water. Alkalinity should therefore be adjusted in a separate process upstream of the coagulation system.

- ***Creation of Metal Hydroxides*** - Metal hydroxide precipitates are created when the inorganic coagulant reacts with the alkalinity in the raw water, and are the chemical species which facilitate the sweep flocculation mechanisms of enmeshment and adsorption. Therefore if there is insufficient alkalinity, then the hydroxide ions will not be produced.

The levels of background raw water pH and alkalinity required will be dependent on the proposed inorganic coagulant. For example, the addition of aluminium sulphate at a raw water pH of between 6.2 (@ 20°C) and 6.5 (@ 5°C) will create the optimum conditions for the charge neutralising aluminium cations and hydroxides to exist. Alum also consumes the raw water alkalinity at a rate of 0.49mg/L as $CaCO_3$ per mg/L of alum added. In contrast to this, the addition of various grades of pre-hydrolysed poly-aluminium chlorides at a raw water pH of between 5.50 (@ 20°C) and 7.00 (@ 5°C) will create the optimum conditions for the aluminium cations and hydroxides to exist, while consuming much less alkalinity than alum, thereby making PACl very useful when treating low alkalinity waters.

The importance of pH and alkalinity to the coagulation process means it is critical to employ an appropriate alkalinity boosting or acid dosing system upstream of the addition of inorganic coagulants. pH and alkalinity boosting / suppression is therefore typically the first element of many water treatment processes. However in order to determine the type of system that is required, and the extent to which the pH / alkalinity must be adjusted, the most appropriate method of coagulation must first be selected. The selection of the most appropriate coagulation chemical and associated enabling pre-treatment dosing systems shall be determined by the Designer following the completion of a suite of jar tests. These tests will establish the optimum coagulant to be used in relation to the chemistry of the raw water and its' constituent source contaminants. The Designer shall disclose full details of the suite of jar tests that were completed, the results obtained and the justification for selecting the proposed coagulant and pre-treatment systems. These disclosures shall be made in a Jar Testing Report that will be submitted to Uisce Éireann during the design stages for all new, upgrade or retrofit works taking place on coagulation, flocculation and clarification treatment processes.

# 3 SELECTION OF APPROPRIATE COAGULANT

As outlined in Section 2.5 of this specification, coagulant chemicals are available in organic or inorganic forms. The range of coagulation chemicals that are permitted for use on Uisce Éireann sites are listed in Table 6 below.

| Organic / Inorganic | Chemical | Charge | Chemical Formula | Commonly Called | Uisce Éireann Approved Use |
|---|---|---|---|---|---|
| Inorganic | Ferric Sulphate | Positive | $Fe_2(SO_4)_3$ | Ferric | Charge Neutralisation, Sweep Flocculation |
| | Aluminium Sulphate | Positive | $Al_2(SO_4)_3$ | Alum | Charge Neutralisation, Sweep Flocculation |
| | Poly-aluminium Chloride (50% pre-hydrolysed) | Positive | $Al_2(OH)_3Cl_3$ | PACl | Charge Neutralisation, Sweep Flocculation |
| | Poly-aluminium Chloride (83% pre-hydrolysed) | Positive | $Al_2(OH)_5Cl$ | PACl, ACH | Charge Neutralisation, Sweep Flocculation |
| Organic | Anionic Polymer | Negative | - | Polyelectrolyte, Poly | Flocculation Aid |
| | Cationic Polymer | Positive | - | Polyelectrolyte, Poly | Flocculation Aid |

Table 6: Organic and inorganic chemicals permissible for use on Uisce Éireann CFC applications.

Of all the chemicals listed above, by far the most commonly used on Uisce Éireann treatment processes is aluminium sulphate, which can facilitate both charge neutralisation coagulation and sweep flocculation mechanisms. For sedimentation processes, this is typically followed by the addition of an organic polymer during the slow mix flocculation stage in order to promote the growth of a heavy floc that can be easily settled.

The widespread use of aluminium sulphate in Ireland has primarily been due to its suitability for both charge neutralisation and sweep flocculation mechanisms, but also for commercial reasons, with alum and ferric being the least expensive of all the chemicals listed above. While it can be very effective on highly alkaline waters where its alkalinity demand can be satisfied while leaving sufficient residual alkalinity to allow the aluminium hydroxide species to be created, it is not always the most optimum solution.

The use of 50% pre-hydrolysed PACl or 83% pre-hydrolysed ACH may often present a more effective and cost efficient means of facilitating charge neutralisation and sweep flocculation mechanisms, particularly on low TOC waters, due to;

- their lower alkalinity demand (resulting in a reduced requirement for alkalinity boosting)
- their higher percentage aluminium oxide [$Al_2O_3$] content which can result in large reductions in chemical consumption.

Regardless of the type of coagulant chosen, the objective shall remain the same - charge neutralisation of the organic material, followed by basic, tapered or sweep flocculation depending on the target contaminants and the downstream clarification methods, to such an extent that their collective charge is slightly negative. Depending on the downstream process, the addition of a cationic (positively charged) polymer will chemically bridge the negatively charged flocs. If the collective charge is slightly positive, then an anionic (negatively charged) polymer may be added to chemically bridge the flocs, however this is not the optimum solution, and may be a sign that the inorganic coagulant is being overdosed.

## 3.1 ATTRIBUTES OF VARIOUS INORGANIC COAGULANTS

While aluminium sulphate has historically been the most common of the four inorganic coagulants listed in Table 6, each of the chemicals have differing properties which make them more suitable for particular raw water conditions, and less suitable for others. In addition, the choice of coagulant may not only come down to which chemical is the most suitable for the raw water, but may also be dictated by the particular requirements of industrial consumers within the area of supply. In any case, there is no ‘one size fits all’ solution, and the advantageous attributes of using one type of coagulant on a particular water, may pose problematic when utilised on a different raw water. Each coagulation system must therefore be selected on the site specific characteristics of the raw water and the area of supply distribution. Typical attributes of permissible inorganic coagulants are listed in Table 7 below.

| Inorganic Coagulant | Attributes |
|---|---|
| **Ferric Sulphate** | ▪ Cost effective and works over a wide pH range (4.0 – 11.0)<br>▪ Only effective for sweep flocculation (i.e. creation of iron-oxide hydroxide precipitate) in a narrow raw water pH band of 7.50 – 8.0, however this may be useful for use on high alkalinity waters<br>▪ High alkalinity demand (0.53mg/L of alkalinity for every 1.00mg/L of ferric added) and severe depression of pH on low alkalinity waters<br>▪ Produces a fluffy floc which may be difficult to settle<br>▪ Risk of production of corrosive water due to excessive iron concentrations<br>▪ May be used in place of aluminium based coagulants for supplies to industrial processes sensitive to aluminium residuals<br>▪ Higher levels of sludge production than aluminium based coagulants<br>▪ Reddish brown liquid which stains heavily |
| **Aluminium Sulphate** | ▪ Cost effective<br>▪ Most effective for sweep flocculation (i.e. creation of aluminium hydroxide precipitate) in a narrow raw water pH band of 6.20 – 6.50<br>▪ Most effective for charge neutralisation at a pH of between 5.00 – 5.50 but should be maintained at approximately 6.2 to balance the risk of soluble aluminium at lower pH<br>▪ High alkalinity demand (0.49mg/L of alkalinity for every 1.00mg/L of alum added) which may result in severe depression of pH on low alkalinity waters<br>▪ Risk of aluminium residuals (regulated to < 0.2mg/L) in treated water if overdosed<br>▪ Available in liquid or pelletized form, and is a clean, translucent chemical |
| **Poly-aluminium Chloride (PACl)**<br>**(50% pre-hydrolysed)** | ▪ 2 – 3 times the cost of aluminium sulphate or ferric sulphate<br>▪ Higher percentage alumina content than alum, requiring approximately 55% less dose<br>▪ May be used over a wide pH range (5.50 – 8.00) but most effective for charge neutralisation between 6.1 - 7.00 where fraction of highly charged soluble pH species is highest<br>▪ 50% basicity (pre-hydrolysed) results in lower alkalinity demand and pH suppression compared to alum - PACl useful for low pH / alkalinity waters<br>▪ More effective charge neutralisation than aluminium sulphate in colder water |
| **Poly-aluminium Chloride (Aluminium Chloro-hydrate) (ACH)**<br>**(83% pre-hydrolysed)** | ▪ Highly positively charged so very effective for charge neutralisation,<br>▪ Higher percentage alumina content than alum requiring approximately 75% less dose<br>▪ 83% basicity (pre-hydrolysed) results in minimal alkalinity demand and pH suppression compared to alum - ACH useful for low pH / alkalinity waters<br>▪ May be used over a wide pH range (5.50 – 8.00) but most effective between 6.00 – 7.00 where fraction of highly charged soluble pH species is highest<br>▪ Other attributes as per 50% Pre-Hydrolysed PACl above. |

Table 7: Attributes of inorganic chemicals permissible for use on Uisce Éireann CFC applications.

## 3.2 JAR TESTING

The inorganic coagulants listed in Table 7 can be categorised into classifications that are most suitable to a particular kind of water; i.e. alum or ferric to be used for raw waters with high turbidity, TOC or alkalinity; or PACl or ACH to be used for raw waters with low turbidity and alkalinity, but moderate to high levels of TOC, etc. While this may be considered as a very general rule of thumb, the reality is that there are many more factors to be considered, such as the type of contaminants to be removed, the amount of particulate matter in the raw water, the quantity and nature of the NOM, and the bulk chemical and physical properties of the water, including background alkalinity and pH.

The selection of the coagulation method and associated enabling pre-treatment dosing shall be therefore determined by the Contractor following the completion of a Report which shall be submitted to Uisce Éireann following detailed jar testing, appropriate to the chemistry of the raw and its constituent source contaminants. Table 8 below outlines the focus of the required tests to be carried out on the coagulated waters from different types of sources to determine if the targets for effective coagulation have been achieved:

| Source Type | Residual Alkalinity | Turbidity | UVA | Streaming Current |
|---|---|---|---|---|
| **River** | ü | ü | - | ü |
| **Lake** | ü | - | ü | ü |
| **Low Quality Groundwater** | ü | - | ü | ü |
| **High Quality Groundwater** | n/a | n/a | n/a | n/a |

**Table 8: Methods of ascertaining if effective coagulation has been achieved, depending on raw water source.**

The Designer shall test the effectiveness of each of the inorganic coagulants listed in Table 7 by accurately simulating the proposed pre-treatment conditioning, coagulation, flocculation and clarification process, using a series of jar tests which are to be completed in accordance with the American Water Works Association (AWWA) Manual M37 "*Operational Control of Coagulation and Filtration Processes*". When completing jar testing, the source waters will dictate the methods used to ascertain whether the process simulation has been successfully replicated in the test.

Comprehensive details of each jar test completed, as well as their results shall be submitted with the Designer's proposals. These submissions shall include detailed raw water analysis of the test samples used, a full description of the measures taken to pre-condition the raw water for coagulation (i.e. pH and alkalinity adjustment), details of how each test was carried out and the conditions therein (water temperature), the results of each test, and the reasons why the proposed pre-treatment and inorganic coagulant was selected on the basis of the jar test findings and other considered factors (see Section 5.0)

The design of the proposed process solution shall only proceed following consideration of the Jar Testing Report by Uisce Éireann or their representatives, and their agreement as to the appropriateness of the process solution proposed by the Contractor.

# 4 CHEMICAL DOSING INSTALLATIONS – COMMON REQUIREMENTS

The following section details the requirements for all liquid chemical dosing installations on the UE asset base. Sections 5 and 6 detail further specific requirements based on the specific chemical selected for raw water treatment prior to clarification. Where a requirement stated below is contradicted by chemical specific information provide in sections 5 or 6, the information from the sections 5 or 6 shall be adhered to

## 4.1 GENERAL DESIGN

The volume of chemical storage on-site shall be determined by the Designer in accordance with chemical demands as estimated by the completion of the jar tests. Bulk storage tanks design shall comply with the requirements outlined in TEC-600-06-01. Note that IBCs will not be permitted for use as permanent storage tanks.

With the exception of the bulk storage tanks, the Designer shall at a minimum allow for all equipment as shown in the relevant diagrams from sections 5 or 6. Ultrasonic level sensors (LI001 & LI002) will be installed on each bulk tank to monitor chemical stock levels, initiate changeover of source tank and issue alarms in the event of low stocks or overfilling. Leak detection level indicators (LI003) shall be provided in all bunds and shall be of probe type instruments (conductivity probes, capacitance probes, etc.). Ultrasonic level sensors will not be permitted for use as leak detection as they may return a loss of echo signal during normal operation.

## 4.2 INSTALLATION AND GENERAL LAYOUTS

All liquid chemical dosing installations shall be completed in accordance with TEC-600-06-01, with features specific to the chemical dosed, as described in the following sections of this standard.

## 4.3 PLC & HMI FUNCTIONALITY

The Designer shall provide PLC & HMI functionality for the installed dosing system in line with the requirements stated in the Control System Interface section of TEC-600-06-01.

## 4.4 SECURITY OF SYSTEM CONTROL

See TEC-600-06-01 for the requirements around security of system control for this type of installation.

## 4.5 AUTOMATIC CHANGEOVER OF DOSING PUMPS

The PLC shall be capable of initiating an automatic rotation policy between the duty and standby dosing pumps as well as an automatic changeover in the event of pump or process failure. The rotation policy shall ensure that the pumping workload is distributed over both pumps, and each of the pumps should be capable of operating as the duty or standby unit. Changeover shall take place when one of the following applies;

- On a scheduled time basis (in auto mode) with 24 hour rotation (operator adjustable on the HMI)

- If a fault signal is registered on the duty pump, the standby unit will start and act as a replacement for the failed pump, operating on the same flow proportional to pH target set-point control ratio
- No flow signal generated from one of the chemical flowmeters (if corresponding pump is running)

## 4.6 EQUIPMENT SPECIFICATION

As stated in Section 1 of this document, the Water Industry Mechanical and Electrical Specifications (WIMES) shall form the basis of equipment selection, material selection, installation and testing for all liquid chemical dosing systems and, in tandem with this document, should be used as a reference point by Designers to ensure compliance with Uisce Éireann requirements. The particular WIMES documents relevant to liquid chemical dosing systems are as follows:

- WIMES 8.02 Chemical Dosing Equipment (General Requirements)
- WIMES 3.01 Low Voltage Switchgear and Controlgear Assemblies

In addition to the particulars outlined in the WIMES documents, Uisce Éireann has a range of specific requirements for each piece of equipment, which are outlined in the following sections. Note that where an Uisce Éireann requirement contradicts a WIMES clause, the Uisce Éireann requirement shall take precedence.

### 4.6.1 BULK STORAGE TANKS

All bulk storage tanks shall be designed in accordance with TEC-600-06 Chemical Storage Systems and referenced documentation outlined therein. Sections 5 and 6 detail further specific requirements based on the specific chemical selected for raw water treatment prior to clarification. Where a requirement stated in TEC-600-06 is contradicted by chemical specific information provide in sections 5 or 6, the information from the sections 5 or 6 shall be adhered to

### 4.6.2 DAY TANKS

All day tanks and non-concrete bunds shall be designed in accordance with TEC-600-06 Chemical Storage Systems and referenced documentation outlined therein. Sections 5 and 6 detail further specific requirements based on the specific chemical selected for raw water treatment prior to clarification. Where a requirement stated in TEC-600-06 is contradicted by chemical specific information provide in sections 5 or 6, the information from the sections 5 or 6 shall be adhered to

### 4.6.3 DOSING & TRANSFER PUMPS

For all chemical dosing installations, two dosing pumps will be provided which will operate in a duty/standby configuration, with dose control to be facilitated as described in relevant sub-section from sections 5 and 6. Where a day tank is deemed a requirement, a single transfer pump shall also be provided to maintain stock within the day tank. Each dosing and transfer pump proposed should comply with the relevant WIMES documents referenced in the specific sub-sections from sections 5 and 6, with the exception of Uisce Éireann's specific dosing pump requirements, which are outlined in Table 23 below.

| Description | Criteria | Notes |
|---|---|---|
| **Pump Type** | Variable speed – servomotor driven, stepper motor driven, solenoid driven, air diaphragm driven | Required for precision flow proportional and target set point trim dosing at low flows |
| **Pump Turn Down Ratio** | Minimum of 1:800 | Required for precision flow proportional and/or target set point trim dosing at low flows at < 1MLD locations |
| **Dosing Control** | mg/l, flow pulse or 4..20mA | Input from treated water flowmeter or treated water pH analyser |
| **Fault Detection** | Over/under pressure protection, no flow, trip | Built in digital I/O for fault signal generation to PLC. |
| **User Display** | mg/l, ppm, l/h, totaliser, fault | |
| **PLC / SCADA Interface** | Fieldbus | |

Table 23: Specific requirements for sodium hydroxide dosing pumps. All additional requirements as per the relevant WIMES document.

All parts (dosing head, suction/pressure connectors, ball seats, seals, etc.) in contact with transfer medium are to be of materials suitable for use with the selected chemical in line with the requirements in TEC-60-06-01. For further guidance on this, consult the relevant WIMES documents referenced in from sections 5 and 6. Each pump is to be suitable for use with a 220V or 400V, 50 Hz, single or three phase power supply and shall remain operational within permissible ambient temperatures of -10˚C to +45˚C. Each proposed pump shall also have an ingress protection rating of IP65, and an insulation class F. When installed, the suction line for each pump shall incorporate a strainer and a foot valve in order to keep each pump primed and prevent air-locking throughout the duty cycle of the make-up tank (i.e. varying chemical levels within the tank).

### 4.6.4 PIPEWORK, VALVES, FITTINGS & ACCESSORIES

All necessary hoses, pipework, fittings and control valves shall be of materials which have a high resistance to degradation to the chemical dosed and in line with the material requirements stated in TEC-600-06-01. If proposed as part of the installation, all of the following peripherals associated with the liquid chemical dosing system shall be manufactured from materials in accordance with the relevant WIMES documents from sections 5 and 6.

- Suction & Delivery Pipework
- Isolation & Non Return Valves
- Carrier Water Injection Point Pipework
- Pressure Relief Valves
- Degassing Valves
- Loading Valves
- Foot Valves
- Weights
- Calibration Vessels
- Filling Lines
- Suction Strainers
- Pulsation Dampers
- Pressure Gauges
- Injection Fittings
- Static Mixers

### 4.6.5 CONTROL PANEL, HMI AND PLC

For chemical dosing installations that are part of the design of an entirely new treatment facility, or that are being completed in conjunction with a major upgrade of a treatment plants entire control system, the control equipment may be incorporated into a centralised panel which may be installed in a dedicated control room, in a location remote from the chemical dosing room. The pH / alkalinity suppression dosing panel shall take the form of the panel into which it is being incorporated (Form 2, Form 4, etc.)

However, if the liquid chemical dosing system is proposed as a stand-alone installation, the control panel shall be installed as shown in Section 4.2.3 of this document. Control panels that are installed as part of a stand-alone system shall be of Form 2 construction and be as per the general arrangement layouts shown in Diagrams 2 and 3. Panels for this type of installation shall be wall mounted and shall incorporate both power distribution and signal terminations for all items of plant and instrumentation, as well as all necessary breakers, transformers, starters and ancillary equipment required for a fully functional control system. The panel should be constructed of 1.5mm thick high grade sheet steel and have a powdered and baked enamel finish to RAL7032, 50µm in depth. Cable entry may be top or bottom, whichever best suits the individual installation. The door to each panel should be hinge mounted and when shut shall provide an ingress protection rating of IP65.

As well as all required control panel functions, it shall also incorporate 2 No. 220 volt domestic outlets, accessible by opening the panel door. The panel shall be constructed in accordance with WIMES 3.01 – Low Voltage Switchgear and Controlgear Assemblies and shall incorporate lightning protection systems and uninterruptible power supplies (UPS) in order to protect and maintain all instruments in the event of power surges or losses.

The PLC provided shall have sufficient digital and analogue I/O to accommodate all functionalities required by the pH / alkalinity suppression system as described in this document, and also be capable of expansion should additional I/O signals need to be incorporated. The unit shall also incorporate an SD card port to allow logging, backup and cloning of the PLC code. An Ethernet port shall be provided on the PLC and to enable connection to an external GPRS device to issue and receive signals by radio transmission. All information shall be made available via Modbus/TCP for relay to the plant telemetry system. The HMI screen shall have a minimum diagonal dimension of 175mm and shall have full ‘touch screen’ capability, allowing all control functions as described in Section 5.5 of this document. Touch properties should be capable of being applied to all text and graphical on-screen elements and a HMI troubleshooting function should be available to eradicate the requirement for an onsite PC. Combined PLC and HMI units are acceptable to Uisce Éireann.

The control system should also incorporate a dial out facility which is capable of issuing text message alarms to plant operators, with a function on the HMI screen that will enable a range of mobile phone numbers to be inputted on the touch screen. A hierarchy of contacts shall also be programmable via the HMI, with text based alarms being sent to the primary contact number. The dial out should wait for an acknowledgement response for a pre-set adjustable period of time until the text alarm is then issued to the secondary contact number. Once a text acknowledgement is received by the dial out, the text alarm shall no longer be sent, however visual alarms shall remain displayed on the HMI and, if applicable, SCADA screen.

### 4.7 CHEMICAL DELIVERY

Chemicals that are delivered to site must comply with the relevant up to date European Standard (currently IS EN 901 2013), and manufacturers / suppliers of the product shall provide a copy of the certificate and testing report from approved certification bodies.

The chemical shall be delivered in bulk liquid form and pumped directly to the bulk storage tank(s). For single tank installations, replenishment may take place via the top of the bulk tank, however for all other installations chemical replenishment will be completed via fill lines constructed from an appropriately chemically resistant material. A standard operating procedure and MSDS for bulk chemical shall be provided and posted in a protective shop envelope on the wall of the dosing room for use by the operating personnel. A chemical inventory shall be maintained to monitor the stock levels stored on site. In order to ensure the health and safety of all staff and on-site personnel, handling of chemicals shall only be carried out by suitably trained operators. This shall also minimise the risk of chemical delivery to incorrect storage vessels.

## 5 PRE-CONDITIONING OF RAW WATER

The selection of the coagulant by completion of the jar testing procedures as outlined in the previous section will also determine the extent to which the raw water will have to be pre-conditioned, if at all. As described in previous sections of this document, the importance of pH and alkalinity cannot be overstated when it comes to optimisation of the coagulation process; the raw water must be at the correct pH in order for the charge neutralisation to occur, and if sweep flocculation is required, sufficient alkalinity must be maintained within the raw water to allow the creation of the metal hydroxide precipitates which will instigate the enmeshment and adsorption mechanisms. In addition, the alkalinity will have a significant bearing on how difficult it will be to achieve the right levels of pH in the raw water to allow any of the above to occur, as alkalinity acts as a buffer to pH change (i.e. easy to change pH of low alkalinity water, difficult to change pH of high alkalinity water).

### 5.1 REQUIRED PH ON THE BASIS OF COAGULANT SELECTION

Once the inorganic coagulant has been selected, the Designer shall allow for the implementation of a chemical dosing system in order to achieve the optimum raw water pH levels as determined from the results of the completed jar tests. In doing so, the system shall also ensure that sufficient alkalinity is maintained within the raw water to facilitate the creation of the metal hydroxide precipitate (if required), and that an appropriate level of alkalinity (minimum of 40 mg/L as $CaCO_3$) is maintained in the post coagulation process water to buffer against pH change which may occur during subsequent treatment processes (i.e. oxidation, disinfection, etc.). Typical pH ranges for differing coagulants and differing mechanisms are outlined in Table 9 below.

| **pH & Alkalinity Requirements for Various Coagulants** | **Ferric Sulphate** | **Aluminium Sulphate** | **Poly-aluminium Chloride (50% Pre-Hydrolysed)** | **Poly-aluminium Chloride (86% Pre-Hydrolysed)** |
|---|---|---|---|---|
| **Optimum pH range required for Charge Neutralisation (C.N.)** | < 4.20 | 5.50 – 6.00 | 6.00 – 7.00 | 6.00 – 7.00 |
| **Optimum pH range required for Sweep Flocculation (S.F.)** | 4.50 – 8.00 | 6.20 – 6.50 | 6.50 – 7.00 | 6.50 – 7.00 |
| **Alkalinity consumption (per 1.00mg/L of added chemical)** | 0.53 mg/L as $CaCO_3$ | 0.49 mg/L as $CaCO_3$ | 0.25 mg/L as $CaCO_3$ | 0.09 mg/L as $CaCO_3$ |
| **Minimum raw water alkalinity to be maintained post Coagulation** | 40 mg/L as $CaCO_3$ | 40 mg/L as $CaCO_3$ | 40 mg/L as $CaCO_3$ | 40 mg/L as $CaCO_3$ |

**Table 9: Raw water pH ranges required to achieve desired coagulation mechanism for particular inorganic coagulants. Note that precise pH targets shall be established on the basis of jar testing in accordance with Section 3.2.**

As pH and alkalinity are closely related to each other, the same process may be employed to adjust both parameters, i.e. suppression of the alkalinity by dosing with an acid will also have the ultimate effect of reducing the pH. Conversely, boosting of the alkalinity with a base chemical will also increase the pH (the lower the raw water alkalinity the less base chemical required for this to occur). The Designer shall determine whether the raw water alkalinity will need to be suppressed so as to facilitate pH adjustment, or whether it will need to be boosted to prevent erratic pH change and allow creation of the metal hydroxide precipitates required for sweep flocculation. The raw water analysis and type of inorganic coagulant selected on the basis of the jar tests will determine the extent to which alkalinity must be adjusted and the optimum pH required to achieve the target flocculation mechanism.

## 5.2 RAW WATER PH / ALKALINITY SUPPRESSION USING SULPHURIC ACID

The suppression of raw water pH and alkalinity to the appropriate levels as required by the selected coagulant shall be facilitated by the addition of sulphuric acid ($H_2SO_4$) to the process flow. Concentrated sulphuric acid reacts violently when added suddenly or in large quantities to water, in an exothermic reaction, and releases large quantities of corrosive sulphuric acid fumes. It can cause severe acid burns when in contact with human tissue, and inhalation of sulphuric acid fumes may cause severe irritation of the lungs and throat. Sulphuric acid therefore constitutes one of the major health and safety hazards at a water treatment plant site. As such, design of sulphuric acid dosing and storage systems shall only be completed by suitably qualified and competent staff. Similarly, handling of sulphuric acid onsite (i.e. chemical replenishment, disconnection of dosing or storage equipment, etc.) shall only be carried out by competent staff that have received specific training in how to handle sulphuric acid, and the dangers / safety precautions to be taken when working with the chemical.

Designers shall ensure that sulphuric acid installations are implemented with operator safety as the primary design goal. All indoor sulphuric acid installations shall be adequately force ventilated to ensure that mist concentrations are kept below 0.3mg/m$^3$, and at a minimum shall facilitate ten air changes per hour. All spillages / leaks from storage tanks, valve connections and dosing pumps shall be contained within bunded areas. Carrier water shall also be used for all sulphuric acid installations to minimise the risk of dosing pipework failure outside of the bunded area. Hastelloy Steel or PVDF/fusion bonded epoxy lined steel pipework shall be provided for a distance of 30 diameters upstream and downstream of the point where the acid is dosed into the carrier water.

While sulphuric acid is a highly corrosive chemical, it is the most effective substance to facilitate pH and alkalinity suppression, and is therefore typically utilised on water treatment plants which abstract from high alkalinity raw water sources. As the behavioural properties of sulphuric acid varies considerably at different concentrations, 96% and 50% shall be the only concentrations of $H_2SO_4$ permitted on Uisce Éireann sites. Note that 50% shall only be considered if the Contractor can demonstrate a TOTEX benefit against the use of 96% - see TEC-600-06 Chemical Storage Systems for further details. The results of the jar tests as described in Section 3.2 shall establish a number of parameters for the raw water pH / alkalinity suppression system:

- The determination of the proportionality relationship between process flow and the sulphuric acid dose rate, and consequently, the duty range of the dosing pumps, the capacity of the bulk storage tanks, and the required flow rates and pressures for carrier water.
- Establishment of the pH target set point to achieve optimum charge neutralisation and creation of metal hydroxide precipitate flocs.
- Establishment of the target alkalinity range to achieve optimum creation of floc precipitates and to ensure stability of pH throughout the subsequent treatment processes.

The dosing system will be a fully automated process and will be accurately controlled on a flow proportional basis, with fine adjustment of dosages based on feedback control from a pH monitor located downstream of the injection point. Sulphuric acid pH / alkalinity suppression systems shall be acceptable across all Uisce Éireann plant categories (Class A to E). The following sections outline Uisce Éireann's requirements for all future raw water pH / alkalinity suppression systems, and the Designer shall ensure that each installation is completed in strict accordance with the details outlined herein.

### 5.2.1 GENERAL DESIGN

Each sulphuric acid pH / alkalinity suppression system installed at new treatment plants, or retrofitted at existing facilities, shall be as outlined in the Diagram 1.

With the exception of the bulk storage tanks (2 No. shown in Diagram 1 as an indicative example only) the Designer shall at a minimum allow for all equipment as shown, as well as that outlined in subsequent sections of this specification, and in addition to any other plant or instrumentation required for a complete pH / alkalinity suppression package.

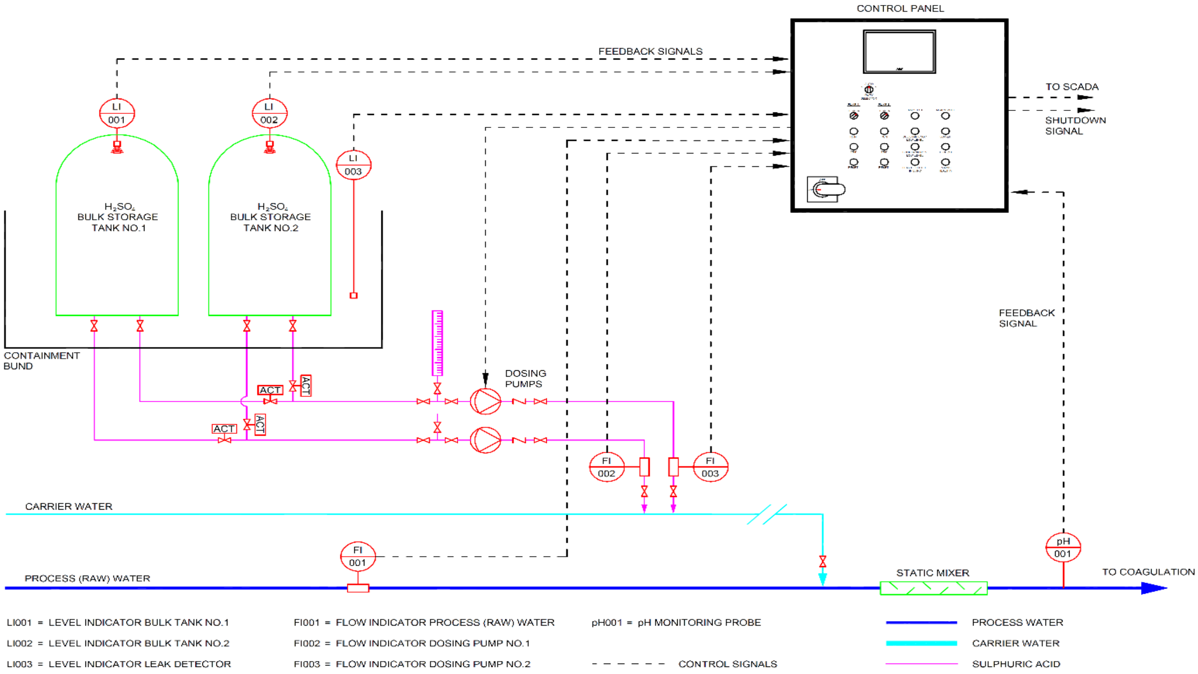


**Diagram 1: General Design for sulphuric acid storage, administration, monitoring and control system**

Sulphuric acid shall always be dosed into a carrier water in order to minimise the risk and impact of chemical leakage, and to mitigate against conduit corrosion. The pH monitor (pH001), or the pH sampling line connection, shall be installed downstream of the point where the carrier water is injected to the process flow, at a minimum distance of 40 times the process flow pipe diameter, in order to allow sufficient mixing of the chemical with the process water. If sufficient space is not available on the site to achieve this, the Designer shall allow for the inclusion of a stainless steel static mixer, which will allow the pH probe, or the sample line connection, to be installed immediately after.

Note that all tanks, pumps, instruments and accessories shall be suitable for use with 96% sulphuric acid and be in accordance with WIMES 8.02 (C) *Sulphuric Acid Dosing Equipment*. The Designer shall also ensure that all pumping systems shall incorporate high quality non-return valves and injection nozzles on the sulphuric acid delivery lines to prevent the backflow of carrier water to the suction side of the dosing pump. High quality non-return valves shall also be included on the suction side of the dosing pumps, as an added measure against process water backflow to the bulk storage tank. This is critical to mitigate against the risk of exothermic reactions, and consequent tank corrosion occurring by the sudden addition of water to the acid in storage.

### 5.2.2 PROCESS CONTROL OF CHEMICAL ADMINISTRATION

Each sulphuric acid dosing system shall have the capacity to be controlled on a combination of flow proportionality and pH feedback, with analogue signals from FI001 and pH001 both issued to a 'Chemtrim' type control system. During process commissioning, the Designer's commissioning staff shall set the most appropriate pH Target Set Point, based on the results of the completed jar tests and the selection of the inorganic coagulant. The 'Chemtrim' system shall use a pre-programmed algorithm to generate a refined analogue signal that will control the sulphuric acid pump in order to administer an accurate chemical dose that can finely trim the pH of the raw water to achieve the pH Target Set Point.

The dominant control signal (flow from FI001, or pH from pH001) will be determined by the consistency of flow through the plant. For example, if the plant throughput is at a constant flow rate for 24 hours per day, the pH meter reading will be the dominant signal. Conversely, if the flow varies considerably during the day, the flow meter reading will be the dominant signal, and the pH probe will influence fine trimming. The ratio of control influence exerted by the 'Chemtrim' system (e.g. 70% flow readings, 30% pH feedback readings) will be determined during process commissioning, and shall be selected so that the most effective means of accurately achieving and maintaining the pH Target Set Point is implemented.

Note that the pH probe shall be installed at a distance of 40 times the diameter of the process water pipework downstream of the carrier water injection point, or immediately downstream of a static mixer if space is limited. This is to ensure that the sulphuric acid has sufficiently mixed with the process flow before the pH is measured. The carrier water will also be injected into the raw water flow at a fixed rate, and pH trimming will be facilitated by altering the concentration of sulphuric acid in the carrier water flow by increasing or decreasing the rate of the sulphuric acid dosing pumps.

| Control Parameter | Limits |
|---|---|
| **pH Target Set-Point** | To be set during process commissioning to permit optimum performance of the selected inorganic coagulant. |
| **Plant Operator Adjustability** | Increments of 0.1 up to a maximum of ± 0.5 from the target set point |
| **System Accuracy** | ± 0.1 pH Unit for 99% of time |
| **Maximum Allowable Variability** | ± 0.5 pH Units from the pH Target Set-Point |
| **Level 2 Alarm Generated** | ± 0.2 pH Units from the pH Target Set-Point |
| **Level 1 Alarm Generated** | ± 0.5 pH Units from the pH Target Set-Point |
| **Automatic System Shutdown** | At a measured pH of ± 0.5 pH Units from the pH Target Set-Point.<br>No flow detected. |

Table 10: Control Parameters for pH / alkalinity suppression system.

The control system shall allow the plant operator the flexibility to change the pH Target Set Point, albeit within the limitations as outlined in Table 10 on the previous page. Similarly, the operator shall have the ability to change the control ratio as dictated by the 'Chemtrim' system, but again in a limited capacity. The facility to adjust both parameters shall be available via the system HMI, and the system Designer shall set the upper and lower restrictions on pH Target Set Point and control ratio changes during process commissioning. The ability to change these limitations shall be available via a password protected page on the HMI screen.

**Note that all chemical dosing shall cease if the flowrate detected by FI001 is zero, regardless of the control ratio imposed**. This is in order to prevent the creation of a high pH 'slug' within the process water pipeline during interruptions to the raw water supply.

### 5.2.3 INSTALLATION AND GENERAL LAYOUTS

All sulphuric acid based pH / alkalinity boosting installations shall be completed in accordance with TEC-600-06-01, with features specific to sulphuric acid added, as described in the following sections

### 5.2.4 CONTROL PANEL LAYOUT

The minimum control panel layout requirements for the sulphuric acid dosing system *General Design* are shown in Diagram 2 and Diagram 3 below. For other chemical dosing control panel requirements, refer to TEC-600-06-01.

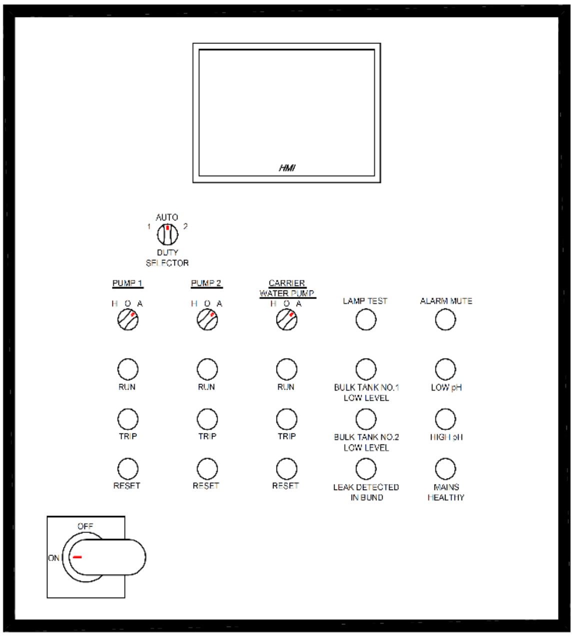


**Diagram 2: MCC for $H_2SO_4$ General Layout No.1 & No.2**

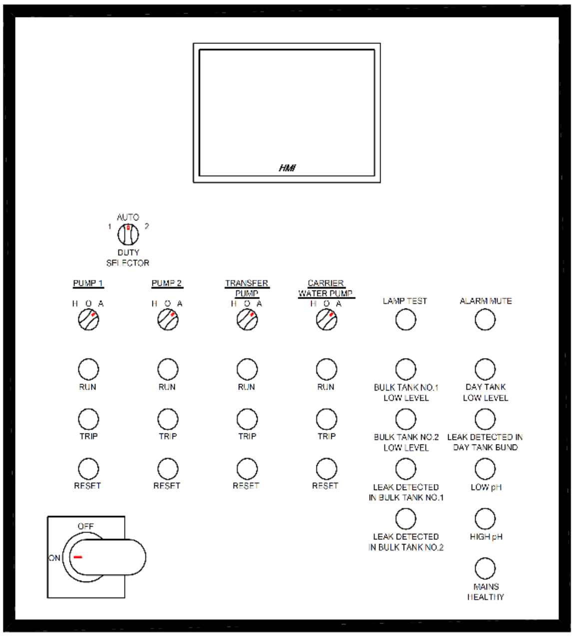


**Diagram 3: MCC for $H_2SO_4$ General Layout No.3**

### 5.2.5 AUTOMATIC CHANGEOVER OF DOSING PUMPS

In addition to the criteria set in section 4.5, changeover shall take place when one of the following applies;

- If the pH of the raw water measured by pH001 moves ± 0.3 pH units beyond the target pH set point

Once the standby pump is activated it will automatically operate on the flow proportional to target pH set point control ratio (70/30, 80/20, etc.) that has been selected by the plant operator.

If automatic changeover has been initiated by a high or low pH reading from pH001 caused by the failure of the duty pump, the PLC will not attempt to changeover again if the high/low pH level and the (now) standby pump fault signal persists. If the high/low pH fault clears, the next changeover will occur on the next scheduled time basis, provided the pump fault which caused the changeover has been eradicated.

## 5.2.6 EQUIPMENT SPECIFICATION

In addition to the criteria specified in section 4.6, the following criteria shall apply to equipment specification for sulphuric acid installations. WIMES 8.02 (C) Sulphuric Acid Dosing Equipment should also be consulted in the design or refurbishment of any new installation. Note that where an Uisce Éireann requirement contradicts a WIMES clause, the Uisce Éireann requirement shall take precedence.

### 5.2.6.1 BULK STORAGE TANKS

All filling lines and associated valves shall be of appropriate grade stainless steel, PTFE or PVDF construction, in accordance with TEC-600-06-01. Note that mild steel is not suitable for filling lines as the passivating layer is eroded by the high fluid velocities (> 2.0 m/s) generated during acid delivery. All other pipework proposed shall be of appropriate grade stainless steel, PTFE or PVDF construction. Moisture traps shall be fitted to prevent moisture ingress into venting / overflow pipework. This is to prevent the reduction of the acid concentration within the bulk storage tank, which may alter the corrosivity of the sulphuric acid solution, thereby rendering the tank unsuitable for use.

### 5.2.6.2 DAY TANKS

Day tanks are not permitted as part of any sulphuric acid installation within the UE asset base.

### 5.2.6.3 INSTRUMENTATION

The table below outlines the instrumentation required to provide a fully automated and reliable sulphuric acid pH / alkalinity suppression system. Also contained in the table is the type of I/O signal [analogue (A) and Digital (D)] required from each instrument, the instrument's function, and the data logs to be generated. All instruments shall be in accordance with WIMES 8.02 (C), Section 6.10.3 and associated guidance text.

| Description | Instrument Type | I/O Type | Function | Data Log |
|---|---|---|---|---|
| **Bulk Tank Level** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Remaining Volume |
| **Day Tank Level** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Trend |
| **Leak Detection** | Point Level | D | Alarm | Trend |
| **Process Water Flowmeter** | Flowmeter | A & D | Alarm, auto shut down, dose control | Trend |
| **Chemical Flowmeter** | Flowmeter | A & D | Stock level management & flow profile trend. Dosing pipework leakage alarm. | Trend |
| **pH Analyser** | Monitor | A | Alarm, target pH set point dose control | Trend |

Table 12: Instrumentation requirements for sodium hydroxide based pH / alkalinity adjustment systems.

Ultrasonic Level Indicators

All ultrasonic level sensors used in this installation shall be suitable for use with a sulphuric acid at 96%, and be capable of issuing two 4..20mA analogue signals to within ±1% accuracy of range and a minimum of 3 relay signals.

Sensors and controllers shall be rated to IP68 and shall have a measurement range of 0.3 to 6.0 metres. Controllers shall be wall mounted and installed adjacent to the pH / alkalinity adjustment control panel, or within the instrumentation / control room if the control panel has been incorporated into a centralised MCC.

Point Level Indicator (Leak Detection)

All point level indicators used in this installation shall be suitable for use with sulphuric acid and be capable of issuing a digital signal to the system PLC. Point level indicators may only be used as leak detection instruments and are not permitted for installation as stock level management instruments.

Process Water Flowmeters

Process water flow measurement is to be achieved by the use of electromagnetic flowmeters, lined internally with EPDM NBR hard rubber Ebonite. The external casing of the flow meter shall be epoxy coated carbon steel and rated for a pressure of up to 16 bar, with PN16 oriented flanges. Flow meter controllers shall be wall mounted and capable of issuing a 4..20mA analogue (live measurement) and a digital signal (bulk measurement) to the control PLC to within 1% accuracy of range, with a minimum flow velocity of 5 metres/second.

Chemical Flowmeters

Chemical flow measurement is to be achieved by the use of wall mounted ultrasonic flowmeters, to best accommodate pulsing flows generated by diaphragm or stepper motor driven metering pumps. All internal or wetted parts are to be resistance to corrosion by contact with sulphuric acid, using chemically resistant parts manufactured from PVDF/PTFE or similar. The chemical flowmeter should be capable of issuing a 4-20mA output signal and generate a flow measurement of < 2% accuracy of range. Connections should be available to accommodate a range of hose sizes and the instrument should be rated for a maximum operating pressure of 16 bar.

pH Monitors

All pH monitors shall be capable of immersion type installation, which shall be mounted in a sampling bath which is continuously supplied from the process water rising main. The Designer shall ensure that sufficient contact time has been allowed for the pH / alkalinity adjustment chemical to mix with the process water before the point of sample take off (i.e. a distance of 40 times the process water carrier pipe diameter, or immediately downstream of a static mixer). The pH probe itself shall be suitable for the continuous measurement of pH in aqueous solutions and shall utilise a differential electrode measurement technique. The probe shall be of robust construction, suitable for use in an industrial application and shall have a pH measurement range from 0 – 14, at a sensitivity of 0.01 pH units. It shall be capable of a pH stability of 0.03 pH units per 24 hours, non-cumulative. The probe shall be provided with an approved controller, which shall be capable of issuing a 4-20mA signal to the main system PLC, which represents the pH measurement of the final process water. The probe and immersion bath shall be installed indoors, and shall have an operating range of -5°C to 25°C. The velocity of the sample turnover shall not exceed 3m/s.

### 5.2.7 CHEMICAL DELIVERY

Delivery and storage of sulphuric acid chemical stocks shall be in accordance with the details outlined in Table 13

| Description | Criteria | Notes |
|---|---|---|
| **Allowable Concentrations** | 96% | - |
| **Minimum / Maximum Storage Temperature** | Min 10°C, Max 20°C | Extract fans & heaters to be installed in chemical storage room. External tanks to be heated to maintain sulphuric acid temperature > 5°C |
| **Minimum Liquid Temperature** | 5°C | Outdoor Storage Tanks to incorporate automated heating system to maintain acid temperature above 5°C |
| **Delivery Method** | Bulk liquid | Pumped to bulk storage from delivery tanker |
| **Bulk Storage Volume** | As per TEC-600-06-01 | Bulk tank volume to be selected to achieve this target |
| **Bulk / Day Tank Bund Volume** | As per TEC-600-06-01 | - |
| **Dosing Room Ventilation** | Forced Ventilation. Directly to atmosphere external to building | Required to prevent build-up of sulphuric acid gases within dosing rooms. Minimum of 10 air changes per hour. |

Table 13: Delivery and storage requirements for $H_2SO_4$

### 5.2.8 PROCESS ALARMS AND AUTOMATIC SHUTDOWN

The Designer shall ensure that the pH / alkalinity suppression system has the capability to generate alarms in the event of an out of specification pH detected in the raw water. Alarms associated with an increase or decrease in pH levels of acid corrected raw water should take the form of text messages to plant operators, audible alarms on site, flashing beacons on the external wall of the dosing buildings and flashing messages or mimics on HMI/SCADA screens. Tables 14 and 15 (below) outline the Alarm Generation and Plant Shutdown criteria for pH / alkalinity suppression systems, and specifies the type of alarm that each occurrence should generate. Please note that alarms or plant shutdowns shall not be initiated until 3 consecutive 'out of specification' readings are detected, or upon detection of a sustained reading lasting more than 3 minutes.

| Alarm & Automatic Shutdown Criteria | Minimum Target Criteria (Alarm) | Critical Control Points (Dosing System Shutdown) |
|---|---|---|
| **pH Ranges** | ± 0.2 pH units from pH Target Set Point | ± 0.5 pH units from pH Target Set Point |
| **Low Sulphuric Acid Stock** | ≤ 10% of total bulk storage capacity or | - |
| **Leak Detection** | Positive level in bund | - |
| **Pump Fault / Trip** | 1 No. Chemical Dosing Pump Trips | - |

| | | |
|---|---|---|
| **Chemical Flowmeter (while positive flow from process water flowmeter)** | No flow signal from 1 No. chemical flow meter (if associated pump is running) | - |
| **Process Water Flowmeter (while positive flow from chemical flowmeter)** | No flow signal from process water flowmeter while chemical pumps are running | **Inhibit all dosing pumps**<br>(Prevent creation of pH ‘slug’) |

Table 14: Alarm and shutdown criteria for pH / alkalinity adjustment systems.

Any occurrence of a Critical Control Point shown in the right hand column of the above table will result in the immediate shutdown of the dosing system. The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. The level of alarms are described in the below table:

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | ▪ Flashing Mimic<br>▪ Text Message<br>▪ Flashing Beacon<br>▪ Audible Alarm | ▪ Dosing system shutdown for any reason<br>▪ Positive level in bund (chemical spill or leak) |
| **Level 2** | ▪ Flashing Mimic<br>▪ Text Message | ▪ pH ± 0.2 from Target Set Point<br>▪ 1 No. dosing pump trips<br>▪ Transfer pump trips<br>▪ Any other equipment trip<br>▪ No flow signal from 1 No. chemical flow meter when associated pump is operating |
| **Level 3** | ▪ Flashing Mimic | ▪ Low sulphuric acid stock (≤ 10% capacity) |

Table 15: Alarm grades and methods of alerting supervisory staff

## 5.3 RAW WATER PH / ALKALINITY BOOSTING USING SODIUM CARBONATE

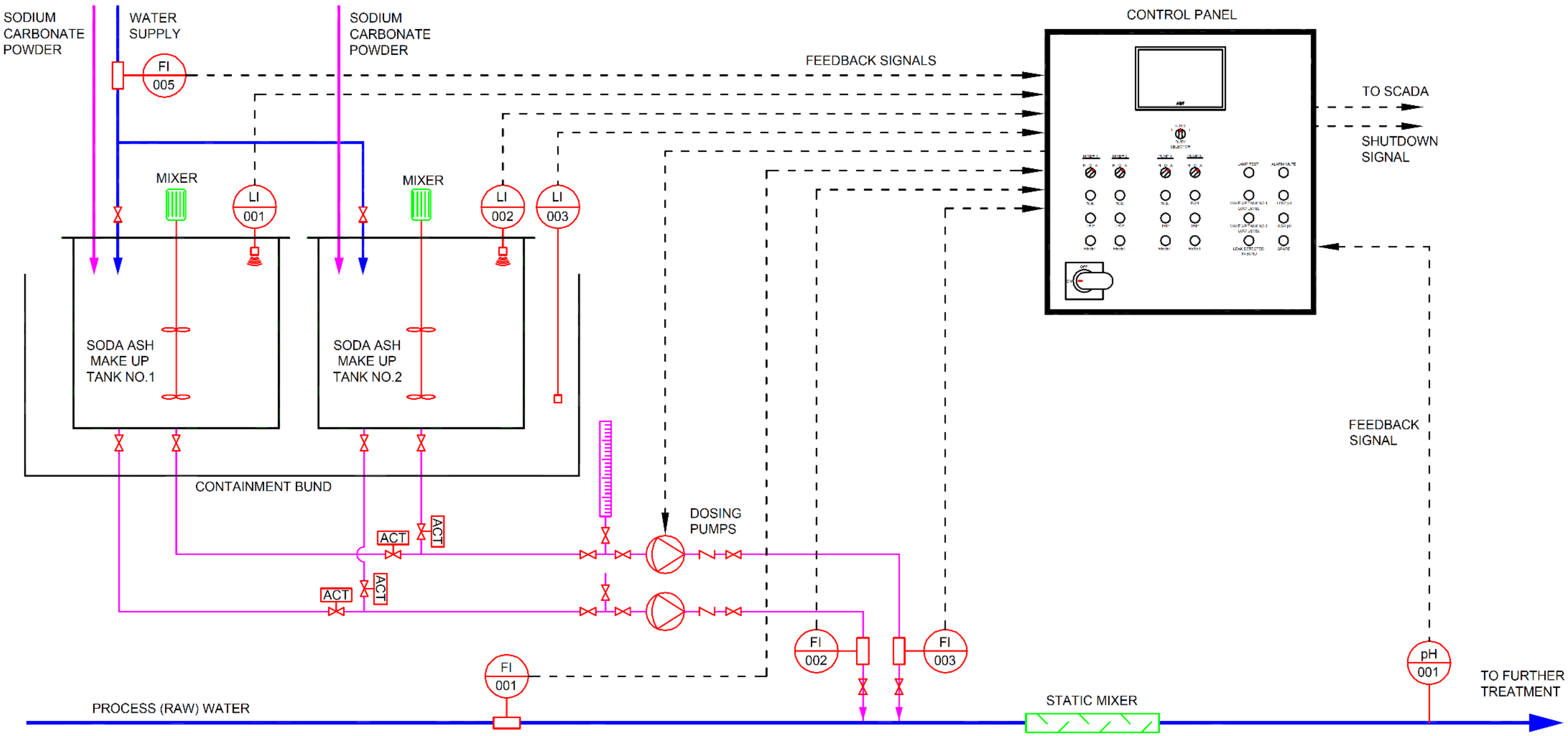
As well as pH and alkalinity correction of final water, Sodium Carbonate ($Na_2CO_3$), commonly referred to as Soda Ash, may also be used to boost the pH and alkalinity levels of raw water to sufficient levels to allow effective coagulation to take place. Sodium Carbonate is typically delivered and stored onsite in powdered form in 50kg bags, and made up in situ to the desired concentration by mixing a known weight of powder with a known weight of water (e.g. 80kg of powder + 920kg of water for an 8% w/w solution). Whilst the capital cost of a soda ash based pH / alkalinity adjustment facility is relatively low, and allows the final chemical solution to be made up in batch quantities at the desired concentration, it also results in a labour intensive duty for the plant operator, and is therefore typically confined to use on smaller plants (Class A and Class B facilities). Typical make up systems consist of a stainless steel make up tank, with a motor driven mixer providing agitation of the tank contents to ensure full dissolution of the sodium carbonate in the final solution. The soda ash solution is then injected into the final water by chemical dosing pumps manufactured from materials which have a high corrosion resistance. The following sections outline Uisce Éireann’s requirements for all future raw water pH / alkalinity boosting systems which utilise sodium carbonate, and the Designer shall ensure that each installation is completed in strict accordance with the details outlined herein.

### 5.3.1 GENERAL DESIGN

Each sodium carbonate pH / alkalinity boosting system installed at new treatment plants, or retrofitted at existing facilities, shall be as per outlined in the schematic overleaf. One make up tank with a capacity of 1000 litres shall be provided at a minimum, with additional tanks added as required. The Designer shall allow for a total makeup tank capacity sufficient to prevent the manual chemical batching frequency exceeding twice per week. With the exception of the make-up tanks (2 No. shown as an indicative example only) the Designer shall at a minimum allow for all equipment as shown, as well as that outlined in subsequent sections of this specification, and in addition to any other plant or instrumentation required for a complete installation.

Each make up tank will have a valved water supply which passes through a flowmeter with a localised digital display to allow the plant operator measure the exact quantity of water being used in each batch make up. The flowmeter reading shall be a totalised value (not an instantaneous reading) and shall be resettable to zero after each use. The sodium carbonate powder will be weighed, and the appropriate quantity to make up the required concentration shall be added by hand from the bagged supply on site. An industrial, floor mounted weighing scales shall be included within each proposal for a sodium carbonate make up system.

An ultrasonic level sensor (LI001 & LI002 as shown in the schematic overleaf) will be installed on each make-up tank to monitor the levels of chemical solution available for dosing and notify the plant operator when batch replenishment is required. The level sensors shall also activate the make-up tank mixers when set to ‘Automatic’ mode, and a positive level is detected within the make-up tank (mixer cut-in and cut-out levels shall be adjustable on the system HMI). Leak detection level indicators (LI003) shall be provided in all bunds, as shown in Diagram 5, and shall be of probe type instruments (conductivity probes, capacitance probes, etc.). Ultrasonic level probes will not be permitted for use as leak detection as they may return a loss of echo signal during normal operation. All bunds are to have the capacity to hold 110% of the volume of one of the make-up tanks.



LI001 = LEVEL INDICATOR MAKE UP TANK NO.1
LI002 = LEVEL INDICATOR MAKE UP TANK NO.2
LI003 = LEVEL INDICATOR LEAK DETECTOR
FI001 = FLOW INDICATOR PROCESS WATER
FI002 = FLOW INDICATOR DOSING PUMP NO.1
FI003 = FLOW INDICATOR DOSING PUMP NO.2
pH001 = pH MONITORING PROBE

| | |
|---|---|
| ━━ | PROCESS (RAW) WATER |
| ━━ | SODIUM CARBONATE (SODA ASH) |
| - - - - - | CONTROL SIGNALS |

Diagram 5: Sodium Carbonate ($Na_2CO_3$) make up system and administration system.

The pH monitor (pH001), or the pH sampling line connection, shall be installed downstream of the soda ash solution injection point at a minimum distance of 40 times the carrier pipe diameter, in order to allow sufficient mixing of the chemical with the process water. If sufficient space is not available on the site to achieve this, the Designer shall allow for the inclusion of a stainless steel static mixer, which will allow the pH probe, or the sample line connection, to be installed immediately after.

### 5.3.2 PROCESS CONTROL OF CHEMICAL ADMINISTRATION

Each soda ash dosing system shall have the capacity to be controlled on a combination of flow proportionality and pH feedback, with analogue signals from FI001 and pH001 both issued to a 'Chemtrim' type control system. During process commissioning, the Designer's commissioning staff shall set the most appropriate pH Target Set Point, based on the results of the completed jar tests and the selection of the inorganic coagulant. The 'Chemtrim' system shall use a pre-programmed algorithm to generate a refined analogue signal that will control the duty soda ash pump in order to administer an accurate chemical dose that can finely trim the pH of the raw water to achieve the pH Target Set Point.

The dominant control signal (flow from FI001, or pH from pH001) will be determined by the consistency of flow through the plant. For example, if the plant throughput is at a constant flow rate for 24 hours per day, the pH meter reading will be the dominant signal. Conversely, if the flow varies considerably during the day, the flow meter reading will be the dominant signal, and the pH probe will influence fine trimming. The ratio of control influence exerted by the 'Chemtrim' system (e.g. 70% flow readings, 30% pH feedback readings) will be determined during process commissioning, and shall be selected so that the most effective means of accurately achieving and maintaining the pH Target Set Point is implemented.

Note that the pH probe shall be installed at a distance of 40 times the diameter of the process water pipework downstream of the soda ash injection point, or immediately downstream of a static mixer if space is limited. This is to ensure that the soda ash has sufficiently mixed with the process flow before the pH is measured.

| Control Parameter | Limits |
|---|---|
| **pH Target Set-Point** | To be set during process commissioning to permit optimum performance of the selected inorganic coagulant. |
| **Plant Operator Adjustability** | Increments of 0.1 up to a maximum of ± 0.5 from the target set point |
| **System Accuracy** | ± 0.1 pH Unit for 99% of time |
| **Maximum Allowable Variability** | ± 0.5 pH Units from the pH Target Set-Point |
| **Level 2 Alarm Generated** | ± 0.2 pH Units from the pH Target Set-Point |
| **Level 1 Alarm Generated** | ± 0.5 pH Units from the pH Target Set-Point |
| **Automatic System Shutdown** | At a measured pH of ± 0.5 pH Units from the pH Target Set-Point.<br>No flow detected. |

Table 16: Control Parameters for pH / alkalinity suppression system.

The control system shall allow the plant operator the flexibility to change the pH Target Set Point, albeit within the limitations as outlined in Table 16 above. Similarly, the operator shall have the ability to change the control ratio as dictated by the 'Chemtrim' system, but again in a limited capacity. The facility to adjust both parameters shall be available via the system HMI, and the system Designer shall set the upper and lower restrictions on pH Target Set Point and control ratio changes during process commissioning. The ability to change these limitations shall be available via a password protected page on the HMI screen.

**Note that all chemical dosing shall cease if the flowrate detected by FI001 is zero, regardless of the control ratio imposed**. This is in order to prevent the creation of a low pH 'slug' within the process water pipeline during interruptions to the raw water supply.

### 5.3.3 INSTALLATION AND GENERAL LAYOUTS

All sodium carbonate based raw water pH / alkalinity boosting installations and chemical make-up systems shall be completed in accordance with TEC-600-06-02, with features specific to sodium carbonate added, as described in the following sections. Each installation shall also incorporate features that are common to both layouts, as described in Section 4.3.3.1 below.

#### 5.3.3.1 COMMON FEATURES

All chemical make-up, storage and administration facilities should be sited in a cool area out of direct sunlight, and all make-up tanks shall be installed within concrete bunds to contain spillages due to tank failure, pipework failure, etc. It is permissible to install sodium carbonate make-up tanks in the same room as other pH adjustment or coagulation chemicals, however in this type of installation, the Designer shall ensure that bunds are compartmentalised, and there is no risk of mixing of chemicals within containment bunds in the event of tank or pipework failure. Note that Uisce Éireann will not permit sodium hypochlorite dosing systems to be installed in the same room as any other chemical make-up or administration systems (see TEC-900-05 for further details).

While Uisce Éireann accepts that certain site variations may apply with regard to pipework routes, electricity supplies, access, etc., particularly on existing treatment facilities, the basic process, control systems, and installation layout as described in the *General Design* and *Indicative Layout* sections of this document should not be altered without receipt of prior approval from Asset Strategy (Water Treatment).

#### 5.3.3.2 INDICATIVE LAYOUT NO.1 – MANUAL BATCHING SYSTEMS

Please refer to TEC-600-06-02 for Indicative Layout No.1 (Manual Batching Systems) and general chemical storage and batching requirements.

*Indicative Layout No.1* shall be implemented on installations where manual batching of the chemical is sufficient and the plant operator can add chemical, in solid form, without over-extension of reach, or without entering the bund. For *Indicative Layout No.1* installations, the plant operator shall be capable of completing all routine duties, including inspection of the tank internals, mixers, instruments, etc. without entering the bunded area.

There shall be no upper limit for total make-up volumes on *Indicative Layout No.1* installations, nor shall there be a limit on the number of make-up tanks proposed, provided the Contractor has allowed for the required make up volume to ensure a maximum make-up frequency of twice per week, Each make-up tank shall however, be restricted in its footprint size so that it is capable of being removed intact from the chemical make-up and administration room.

The Designer may add make-up tanks as necessary to meet the chemical demand of the plant, provided that all requirements the *General Design* and *Indicative Layouts* are met. The concrete bund shall provide storage capacity of 110% of the volume of the largest make-up tank, but the bund wall shall not exceed 800mm in height, as measured from the finished floor level outside of the bund wall.

#### 5.3.3.3 INDICATIVE LAYOUT NO.2 – SEMI-AUTOMATED SYSTEMS

Please refer to TEC-600-06-02 for Indicative Layout No.2 (Semi-Automated Batching Systems) And general chemical storage and batching requirements. *Indicative Layout No.2* shall be implemented on installations where semi-automated batching of the chemical is required. For *Indicative Layout No.2* installations, equipment as described in TEC-600-06-02 shall be provided which shall enable the plant operator complete all routine duties, including chemical batching, inspection of the tank internals, mixers, instruments, etc. with limited manual handling and without a requirement to enter the bunded area.

There shall be no upper limit for total make-up volume on *Indicative Layout No.2* installations, nor shall there be a limit on the number of make-up tanks proposed, provided the Contractor has allowed for the required make up volume to ensure a maximum make-up frequency of twice per week. Each make-up tank shall however, be restricted in its footprint size so that it is capable of being removed intact from the chemical make-up and administration room. In addition, the maximum allowable height for a make-up tank installed under Indicative *Layout No.2* shall be 2.10m. The Designer may add make-up tanks as necessary to meet the chemical demand of the plant, provided that all requirements the *General Design* and *General Layouts* are met. The concrete bund shall provide storage capacity of 110% of the volume of the largest make-up tank, but the bund wall shall not exceed 800mm in height, as measured from the finished floor level outside of the bund wall.

#### 5.3.3.1 INDICATIVE LAYOUT NO.3 – FULLY AUTOMATED SYSTEMS

Please refer to TEC-600-06-02 for Indicative Layout No.3 (Fully-Automated Batching Systems) and general chemical storage and batching requirements. *Indicative Layout No.3* shall be implemented on installations where fully-automated batching of the chemical is required. For *Indicative Layout No.3* installations, equipment as described in TEC-600-06-02 shall be provided which shall enable the plant operator complete all routine duties, including chemical batching, inspection of the tank internals, mixers, instruments, etc. with minimal manual handling and without a requirement to enter the bunded area.

There shall be no upper limit for total make-up volume on *Indicative Layout No.3* installations, nor shall there be a limit on the number of make-up tanks proposed, provided the Contractor has allowed for the required make up volume to ensure a maximum make-up frequency of 42 per week (or 6 per day). Each make-up tank shall however, be restricted in its footprint size so that it is capable of being removed intact from the chemical make-up and administration room. In addition, the maximum allowable height for a make-up tank installed under Indicative *Layout No.3* shall be 1.20m. The Designer may add make-up tanks as necessary to meet the chemical demand of the plant, provided that all requirements the *General Design* and *Indicative Layouts* are met. The concrete bund shall provide storage capacity of 110% of the volume of the largest make-up tank, but the bund wall shall not exceed 800mm in height, as measured from the finished floor level outside of the bund wall.

### 5.3.4 CONTROL PANEL LAYOUT

The minimum control panel layout requirements for the sodium carbonate make up and dosing system *General Design* is shown in the diagram overleaf. Additional pumps, mixers, instrumentation etc. are to be added as required. For newly designed treatment plants, green-field builds, or facilities which are undergoing major upgrades which incorporate replacement of MCC facilities, the panel shown below shall be incorporated into a common centralised control panel. For all independent sodium carbonate pH / alkalinity adjustment installations, the panels shall take the form as shown. If a SCADA system is present on site, all signals shall be relayed and mimicked on the main control interface which shall replicate the functionality of the localised pH / alkalinity adjustment HMI.

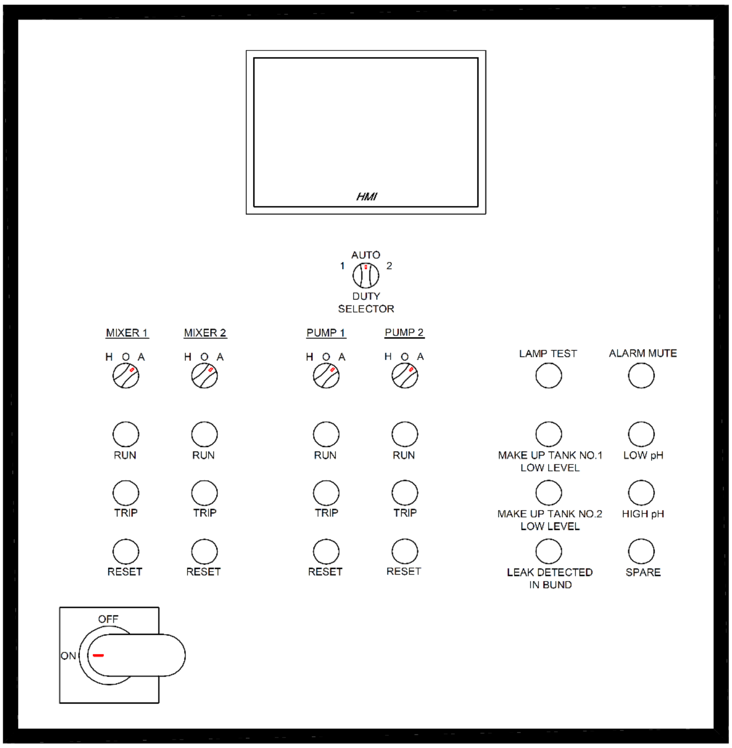


Diagram 6: MCC layout for Sodium Carbonate make-up and dosing General Design

### 5.3.5 PLC & HMI FUNCTIONALITY

The Designer shall provide PLC & HMI functionality for the installed dosing system in line with the requirements stated in the Control System Interface section of TEC-600-06-01.

## 5.3.6 SECURITY OF SYSTEM CONTROL

See TEC-600-06-01 for the requirements around security of system control for this type of installation.

## 5.3.7 AUTOMATIC CHANGEOVER OF DOSING PUMPS

In addition to the criteria set in section 4.5, changeover shall take place when one of the following applies;

- If the pH of the raw water measured by pH001 moves ± 0.3 pH units beyond the target pH set point

Once the standby pump is activated it will automatically operate on the flow proportional to target pH set point control ratio (70/30, 80/20, etc.) that has been selected by the plant operator.

If automatic changeover has been initiated by a high or low pH reading from pH001 caused by the failure of the duty pump, the PLC will not attempt to changeover again if the high/low pH level and the (now) standby pump fault signal persists. If the high/low pH fault clears, the next changeover will occur on the next scheduled time basis, provided the pump fault which caused the changeover has been eradicated.

## 5.3.8 EQUIPMENT SPECIFICATION

As stated in Section 1 of this document, the Water Industry Mechanical and Electrical Specifications (WIMES) shall form the basis of equipment selection, material selection, installation and testing for all sodium carbonate based pH / alkalinity boosting systems and, in tandem with this document, should be used as a reference point by Designers to ensure compliance with Uisce Éireann requirements. The particular WIMES documents relevant to pH / alkalinity boosting systems are as follows:

- WIMES 8.02 Chemical Dosing Equipment (General Requirements)
- WIMES 3.01 Low Voltage Switchgear and Controlgear Assemblies

In addition to the particulars outlined in the WIMES documents, Uisce Éireann has a range of specific requirements for each piece of equipment, which are outlined in the following sections. Note that where an Uisce Éireann requirement contradicts a WIMES clause, the Uisce Éireann requirement shall take precedence.

### 5.3.8.1 CHEMICAL MAKE-UP TANKS

All sodium carbonate make up tanks shall be of stainless steel (304 or 316) construction and demonstrate immunity from the corrosive capability of the chemical solution at all proposed concentrations. Sufficient bracing shall be provided on each tank to prevent warping or deformation of the tank walls throughout its design life, which shall be a minimum of 25 years. Sufficient bracketing shall be placed across the top of the tank to support the mixer assembly, which should be balanced accordingly to prevent vibration when in operation. Vibration testing of the tank shall be carried out in the presence of Uisce Éireann or their representative prior to the system being approved and signed off. The top of the tank shall be enclosed with a stainless steel cover which is to be provided with a hinged section to one side of the mixer motor to allow quick access for chemical batching or maintenance of plant and instruments. The entire cover shall also be removable to allow non-routine activities such as internal tank maintenance. The suction outlets for each tank shall be positioned at a distance of 50mm from the tanks internal floor to allow sedimentation of solids, thus minimising risk of blocking suction pipelines. A valved drain should also be provided at the base of each make-up tank, flush with the internal floor, so that the tank may be fully drained for periodic wash down or maintenance. Make up tanks should be clearly labelled with the chemical name, its 4 digit UN number and its chemical formula. All chemical make-up tanks shall be designed, built and installed in accordance with Section 6.3.2 of both WIMES 8.02.

#### 5.3.8.2 INSTRUMENTATION

The table below outlines the instrumentation required to provide a fully automated and reliable sodium carbonate pH / alkalinity boosting system. Also contained in the table is the type of I/O signal [analogue (A) and Digital (D)] required from each instrument, the instrument's function, and the data logs to be generated.

| Description | Instrument Type | I/O Type | Function | Data Log |
|---|---|---|---|---|
| **Make-up Tank Level** | Ultrasonic | A & D | Stock level management, duty / standby tank changeover, mixer control | Remaining Volume |
| **Make-up Tank Leak Detection** | Point Level | D | Alarm | - |
| **Chemical Flow** | Flowmeter | A & D | Stock level management & flow profile trend. Dosing pipework leakage alarm. | Trend |
| **Process Water Flow** | Flowmeter | A & D | Alarm, run to waste, auto shut down, dose control | Trend |
| **Make-Up Water Flow** | Flowmeter | A & D | Accurate monitoring of make-up water quantity | Trend |
| **pH Analyser** | Monitor | A | Alarm, target pH set point dose control | Trend |

Table 18: Instrumentation requirements for sodium carbonate based pH / alkalinity adjustment systems.

Ultrasonic Level Indicators

All ultrasonic level sensors used in this installation shall be suitable for use with a sodium carbonate solution at the concentration required by the process, and be capable of issuing two 4..20mA analogue signals to within ±1% accuracy of range and a minimum of 3 relay signals. Sensors and controllers shall be rated to IP68 and shall have a measurement range of 0.3 to 6.0 metres. Controllers shall be wall mounted and installed adjacent to the pH / alkalinity adjustment control panel, or within the instrumentation / control room if the control panel has been incorporated into a centralised MCC.

Point Level Indicator

All point level indicators used in this installation shall be suitable for use with sodium carbonate and be capable of issuing a digital signal to the system PLC. Point level indicators may only be used as leak detection instruments and are not permitted for installation as stock level management instruments.

Process Water Flowmeters

Process water flow measurement is to be achieved by the use of electromagnetic flowmeters, lined internally with EPDM NBR hard rubber Ebonite. The external casing of the flow meter shall be epoxy coated carbon steel and rated for a pressure of up to 16 bar, with PN16 oriented flanges. Flow meter controllers shall be wall mounted and capable of issuing a 4..20mA analogue (live measurement) and a digital signal (bulk measurement) to the control PLC to within 1% accuracy of range, with a minimum flow velocity of 5 metres/second.

Make-up Water Flowmeters

Make-up water flow measurement is to be achieved by the use of an electromagnetic flowmeter, lined internally with EPDM NBR hard rubber Ebonite. The external casing of the flow meter shall be epoxy coated carbon steel and rated for a pressure of up to 6 bar. Flow meter controllers shall be wall mounted and capable of issuing a bulk measurement (in litres) to the display readout, which shall be mounted in viewing distance of the make-up water flow control valves. A pressure reducing valve shall be included on the make-up water supply line to limit the pressure of the make-up water to 3 bar.

Chemical Flowmeters

Chemical flow measurement is to be achieved by the use of wall mounted ultrasonic flowmeters, to best accommodate pulsing flows generated by diaphragm or stepper motor driven metering pumps. All internal or wetted parts are to be resistance to corrosion by contact with sodium carbonate, using chemically resistant parts manufactured from PVDF/PTFE or similar. The chemical flowmeter should be capable of issuing a 4..20mA output signal and generate a flow measurement of < 2% accuracy of range. Connections should be available to accommodate a range of hose sizes and the instrument should be rated for a maximum operating pressure of 16 bar.

pH Monitors

All pH monitors shall be capable of immersion type installation, which shall be mounted in a sampling bath which is continuously supplied from the process water rising main. The Designer shall ensure that sufficient contact time has been allowed for the pH / alkalinity adjustment chemical to mix with the process water before the point of sample take off (i.e. a distance of 40 times the process water carrier pipe diameter, or immediately downstream of a static mixer). The pH probe itself shall be suitable for the continuous measurement of pH in aqueous solutions and shall utilise a differential electrode measurement technique. The probe shall be of robust construction, suitable for use in an industrial application and shall have a pH measurement range from 0 – 14, at a sensitivity of 0.01 pH units. It shall be capable of a pH stability of 0.03 pH units per 24 hours, non-cumulative. The probe shall be provided with an approved controller, which shall be capable of issuing a 4..20mA signal to the main system PLC, which represents the pH measurement of the final process water. The probe and immersion bath shall be installed indoors, and shall have an operating range of -5°C to 25°C. The velocity of the sample turnover shall not exceed 3m/s.

### 5.3.8.3 MIXERS

Mixers shall be top-mounted vertical agitators, with the shaft and blades of stainless steel (304 or 316) construction resistant to degradation by immersion in a sodium carbonate solution. Motors shall be flange mounted and may be of single phase or three phase electrical supply, 50 Hz and IP65 rated as they will be exposed to soda ash dust and the make-up water supply. Maximum motor speeds for mixers shall be 1450rpm and the Designer shall include for a mechanical variable speed gear box, or an electronic variable speed drive in order to achieve the optimum motor speed to achieve efficient mixing. The mixer shall be appropriately balanced and speed controlled to ensure that vibration during operation is minimised. A vibration test shall be carried out in the presence of Uisce Éireann, or their representative, as part of the process proving period.

### 5.3.9 CHEMICAL DELIVERY

The chemical shall be delivered in pallets of 50kg bags, and stored on site in a cool, dry environment out of direct sunlight. The storage area should be close to the make-up facility in order to minimise manual handling of solid chemicals during batching. Delivery and storage of chemical stocks shall be in accordance with the details outlined in Table 19 below.

| Description | Criteria | Notes |
|---|---|---|
| **Maximum Allowable Concentration** | 10% | To minimise chemical degradation |
| **Min / Max Storage Temperature** | Min 5°C, Max 20°C | Extract fans & heaters to be installed in chemical storage room & make up room |
| **Delivery Method** | Pallets of 50kg bags | - |
| **Make-Up Tank Storage Volume** | 7 days' worth of chemical storage to a minimum of 1000 litres | Make up tank volume to be selected to achieve this target |
| **Storage (Inventory) Volume** | Min 60 days, Max 120 days | Secure storage to be provided in a cool, dry environment |
| **Make up Tank Bund Volume** | Minimum 110% of volume of 1 tank | - |
| **Dosing Room Ventilation** | Directly to atmosphere external to building | - |

Table 19: Delivery and storage requirements for $Na_2CO_3$

### 5.3.10 PROCESS ALARMS AND AUTOMATIC SHUTDOWN

The Designer shall ensure that the pH / alkalinity boosting system has the capability to generate alarms in the event of an out of specification pH detected in the dosed raw water. Alarms associated with an increase or decrease in pH levels of final water should take the form of text messages to plant operators, audible alarms on site, flashing beacons on the external wall of chemical dosing buildings and flashing messages or mimics on HMI/SCADA screens. Tables 20 (below) and 21 (overleaf) outline the Alarm Generation and Plant Shutdown criteria for pH / alkalinity boosting system, and specifies the type of alarm that each occurrence should generate. Please note that alarms or plant shutdowns shall not be initiated until 3 consecutive 'out of specification' readings are detected, or if an 'out of specification' reading is sustained in excess of 3 minutes.

| Alarm & Automatic Shutdown Criteria | Minimum Target Criteria (Alarm) | Critical Control Points (Dosing System Shutdown) |
|---|---|---|
| **pH Ranges** | ± 0.2 pH units from pH Target Set Point | ± 0.5 pH units from pH Target Set Point |
| **Low Levels of Made Up Soda Ash** | ≤ 10% of total make up tank capacity | - |
| **Leak Detection** | Positive level in bund | - |
| **Pump Fault / Trip** | 1 No. Chemical Dosing Pump Trips | - |
| **Chemical Flowmeter (while positive flow from process water flowmeter)** | No flow signal from 1 No. chemical flow meter (if associated pump is running) | - |
| **Process Water Flowmeter (while positive flow from chemical flowmeter)** | No flow signal from process water flowmeter while chemical pumps are running | **Inhibit all dosing pumps**<br>(Prevent creation of pH 'slug') |

Table 20: Alarm and shutdown criteria for pH / alkalinity adjustment systems.

Any occurrence of a Critical Control Point shown in the right hand column of the above table will result in the immediate shutdown of the dosing system. The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. The level of alarms are described in below:

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | Flashing Mimic<br>Text Message<br>Flashing Beacon<br>Audible Alarm | Dosing system shutdown for any reason<br>Positive level in bund (chemical spill or leak) |
| **Level 2** | Flashing Mimic<br>Text Message | pH ± 0.2 from Target Set Point<br>1 No. dosing pump trips<br>Transfer pump trips<br>Any other equipment trip<br>No flow signal from 1 No. chemical flow meter when associated pump is operating |
| **Level 3** | Flashing Mimic | Low sodium carbonate levels in make-up tanks |

Table 21: Alarm grades and methods of alerting supervisory staff.

## 5.4 RAW WATER PH / ALKALINITY BOOSTING USING SODIUM HYDROXIDE

Sodium Hydroxide (NaOH), commonly referred to as Caustic Soda, is one of the most widely used chemicals for pH and alkalinity boosting on Uisce Éireann treatment facilities. It is typically delivered and stored onsite in liquid form, in concentrations of 25% or 30%. While the cost of sodium hydroxide is higher than sodium carbonate (soda ash), the simplicity of installation and operation makes it an attractive means of implementing a pH / alkalinity boosting system. There is no on-site batching or chemical make-up required, resulting in lower labour costs than those typically associated with soda ash systems. For this reason, pH / alkalinity boosting processes which utilise sodium hydroxide are suitable for installation across all Uisce Éireann plant categories (Class A to E). The following sections outline Uisce Éireann's requirements for all future pH / alkalinity boosting systems which utilise sodium hydroxide, and the Designer shall ensure that each installation is completed in strict accordance with the details outlined herein.

### 5.4.1 GENERAL DESIGN

Each sodium hydroxide pH / alkalinity boosting system installed at new treatment plants, or retrofitted at existing facilities, shall be as per outlined in the schematic below. The volume of chemical storage on-site shall be determined by the Designer in accordance with chemical demands, but storage facilities should be sized to hold a minimum of 30 days' worth of chemical, and a maximum of 60 days. Bulk storage tanks for sodium hydroxide shall comply with the requirements outlined in TEC-600-06-01. .

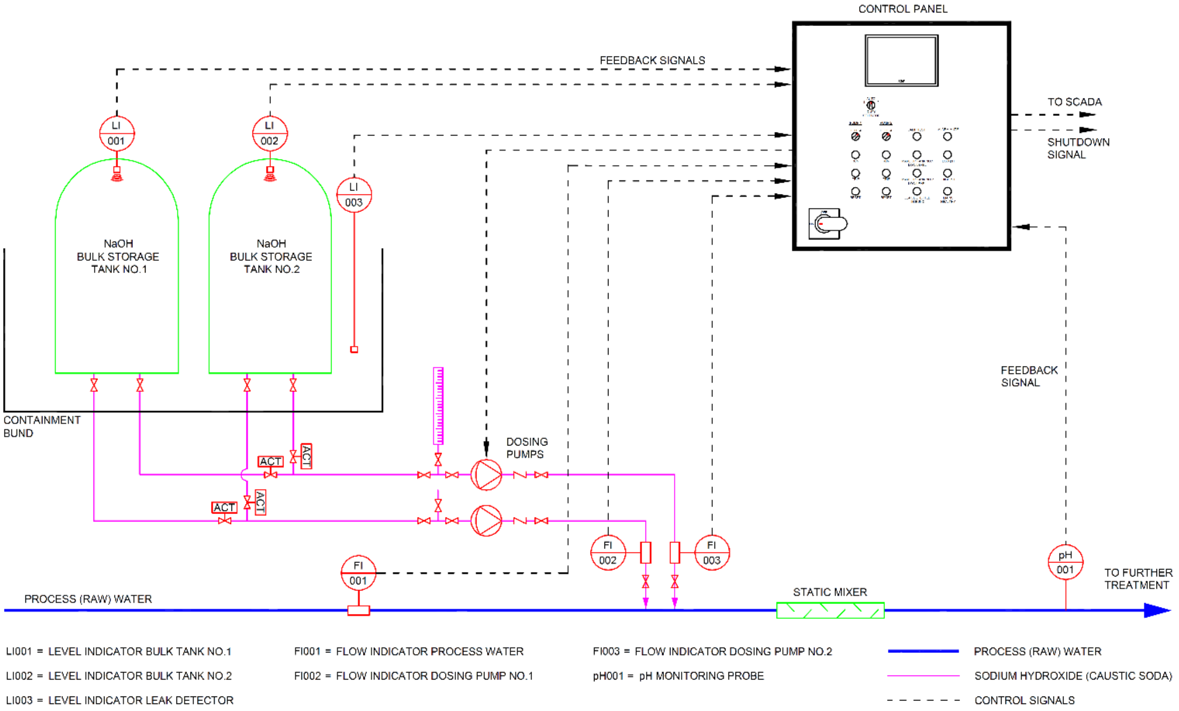


Diagram 8: General Design for sodium hydroxide storage and administration system

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### 5.4.2 PROCESS CONTROL OF CHEMICAL ADMINISTRATION

Each sodium hydroxide dosing system shall have the capacity to be controlled on a combination of flow proportionality and pH feedback, with analogue signals from FI001 and pH001 both issued to a 'Chemtrim' type control system. During process commissioning, the Designer's commissioning staff shall set the most appropriate pH Target Set Point, based on the results of the completed jar tests and the selection of the inorganic coagulant. The 'Chemtrim' system shall use a pre-programmed algorithm to generate a refined analogue signal that will control the duty sodium hydroxide pump in order to administer an accurate chemical dose that can finely trim the pH of the raw water to achieve the pH Target Set Point.

The dominant control signal (flow from FI001, or pH from pH001) will be determined by the consistency of flow through the plant. For example, if the plant throughput is at a constant flow rate for 24 hours per day, the pH meter reading will be the dominant signal. Conversely, if the flow varies considerably during the day, the flow meter reading will be the dominant signal, and the pH probe will influence fine trimming. The ratio of control influence exerted by the 'Chemtrim' system (e.g. 70% flow readings, 30% pH feedback readings) will be determined during process commissioning, and shall be selected so that the most effective means of accurately achieving and maintaining the pH Target Set Point is implemented. Note that the pH probe shall be installed at a distance of 40 times the diameter of the process water pipework downstream of the sodium hydroxide injection point, or immediately downstream of a static mixer if space is limited. This is to ensure that the caustic soda has sufficiently mixed with the process flow before the pH is measured.

| Control Parameter | Limits |
|---|---|
| **pH Target Set-Point** | To be set during process commissioning to permit optimum performance of the selected inorganic coagulant. |
| **Plant Operator Adjustability** | Increments of 0.1 up to a maximum of ± 0.5 from the target set point |
| **System Accuracy** | ± 0.1 pH Unit for 99% of time |
| **Maximum Allowable Variability** | ± 0.5 pH Units from the pH Target Set-Point |
| **Level 2 Alarm Generated** | ± 0.2 pH Units from the pH Target Set-Point |
| **Level 1 Alarm Generated** | ± 0.5 pH Units from the pH Target Set-Point |
| **Automatic System Shutdown** | At a measured pH of ± 0.5 pH Units from the pH Target Set-Point.<br>No flow detected. |

Table 22: Control Parameters for pH / alkalinity suppression system.

The control system shall allow the plant operator the flexibility to change the pH Target Set Point, albeit within the limitations as outlined in Table 22 on the previous page. Similarly, the operator shall have the ability to change the control ratio as dictated by the 'Chemtrim' system, but again in a limited capacity. The facility to adjust both parameters shall be available via the system HMI, and the system Designer shall set the upper and lower restrictions on pH Target Set Point and control ratio changes during process commissioning. The ability to change these limitations shall be available via a password protected page on the HMI screen.

**Note that all chemical dosing shall cease if the flowrate detected by FI001 is zero, regardless of the control ratio imposed**. This is in order to prevent the creation of a low pH 'slug' within the process water pipeline during interruptions to the raw water supply.

### 5.4.3 INSTALLATION AND GENERAL LAYOUTS

All sodium hydroxide based pH / alkalinity boosting installations shall be completed in accordance with TEC-600-06-01, with features specific to sodium hydroxide added, as described in the following sections.

### 5.4.4 PLC & HMI FUNCTIONALITY

The Designer shall provide PLC & HMI functionality for the installed dosing system in line with the requirements stated in the Control System Interface section of TEC-600-06-01.

### 5.4.5 CONTROL PANEL LAYOUT

The minimum control panel layout requirements for the sodium hydroxide dosing system *General Design* is shown in the below diagram. Additional pumps, instrumentation etc. are to be added as required. For newly designed treatment plants, green-field builds, or facilities which are undergoing major upgrades which incorporate replacement of MCC facilities, the panel shown below shall be incorporated into a common centralised control panel. For all independent sodium hydroxide pH / alkalinity boosting installations, the panels shall take the form as shown. If a SCADA system is present on site, all signals shall be relayed and mimicked on the main control interface which shall replicate the functionality of the localised pH / alkalinity boosting HMI.

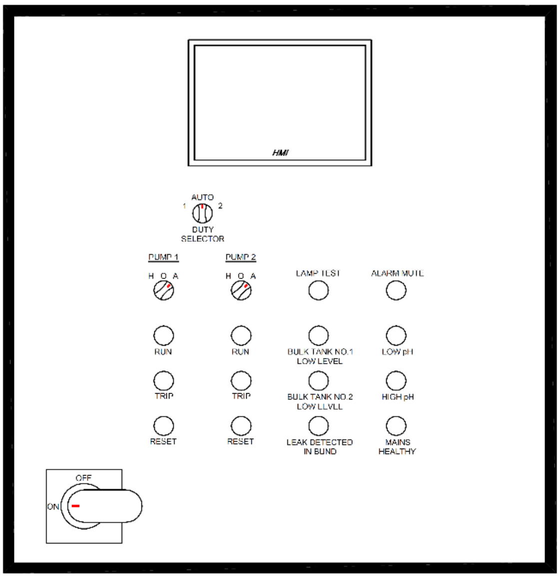


**Diagram 9: MCC for NaOH Indicative Layout No.1 & No.2**

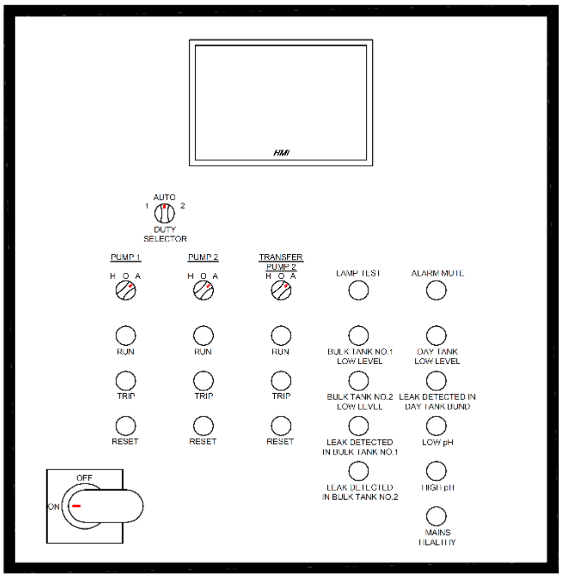


**Diagram 10: MCC for NaOH Indicatve Layout No.3**

### 5.4.6 SECURITY OF SYSTEM CONTROL

See TEC-600-06-01 for the requirements around security of system control for this type of installation.

### 5.4.7 AUTOMATIC CHANGEOVER OF DOSING PUMPS

In addition to the criteria set in section 4.5, changeover shall take place when one of the following applies;

- If the pH of the raw water measured by pH001 moves ± 0.3 pH units beyond the target pH set point

Once the standby pump is activated it will automatically operate on the flow proportional to target pH set point control ratio (70/30, 80/20, etc.) that has been selected by the plant operator.

If automatic changeover has been initiated by a high or low pH reading from pH001 caused by the failure of the duty pump, the PLC will not attempt to changeover again if the high/low pH level and the (now) standby pump fault signal persists. If the high/low pH fault clears, the next changeover will occur on the next scheduled time basis, provided the pump fault which caused the changeover has been eradicated.

## 5.4.8 EQUIPMENT SPECIFICATION

In addition to the criteria specified in section 4.6, the following criteria shall apply to equipment specification for sulphuric acid installations. WIMES 8.02 (A) Sodium Hydroxide Dosing Equipment should also be consulted in the design or refurbishment of any new installation. Note that where an Uisce Éireann requirement contradicts a WIMES clause, the Uisce Éireann requirement shall take precedence.

### 5.4.8.1 BULK STORAGE TANKS

In addition to the pre-approved materials of manufacture outlined in TEC-600-06, 304L stainless steel and mild steel lined with EPDM, PP or PTFE/PVDF, are generally accepted materials for contact with sodium hydroxide at concentrations between 25% and 30%. Glass reinforced polyester (GRP) may also be used provided it is lined on all surfaces which are liable to potential contact with the chemical with an appropriate lining material in accordance with TEC-600-06.

All bulk storage pipes, including fill pipes, for 25% NaOH shall be of PE or PP construction, however bulk storage pipes for 30% NaOH shall be of 304L stainless steel construction. Valves shall be fabricated from 304L stainless steel.

### 5.4.8.2 DAY TANKS

All day tanks and non-concrete bunds for containment of 25 - 30% sodium hydroxide shall be designed in accordance with TEC-600-06 Chemical Storage Systems and referenced documentation outlined therein. In addition to the pre-approved materials of manufacture outlined in TEC-600-06, 304L stainless steel and mild steel lined with EPDM, PP or PTFE/PVDF, are generally accepted materials for contact with sodium hydroxide at concentrations between 25% and 30%. Glass reinforced polyester (GRP) may also be used provided it is lined on all surfaces which are liable to potential contact with the chemical with an appropriate lining material in accordance with TEC-600-06.

### 5.4.8.3 DOSING & TRANSFER PUMPS

For each sodium hydroxide pH / alkalinity boosting installation, two dosing pumps will be provided which will operate in a duty/standby configuration, with dose control to be facilitated as described in Section 4.4.2. For each *General Layout No.3* installation, a single transfer pump shall also be provided to maintain stock within the day tank. Installation of all pH / alkalinity boosting dosing and transfer pumps shall be as described in Section 4.4.3 of this document, i.e. mounted in fully enclosed metering cabinets or, for larger pumps, within concrete bunds. Each dosing and transfer pump proposed should comply with Section 6.5 of WIMES 8.02 (A), with the exception of Uisce Éireann's specific dosing pump requirements, which are outlined in Table 23 below.

| Description | Criteria | Notes |
|---|---|---|
| **Pump Type** | Variable speed – servomotor driven, stepper motor driven, solenoid driven, air diaphragm driven | Required for precision flow proportional and target set point trim dosing at low flows |
| **Pump Turn Down Ratio** | Minimum of 1:800 | Required for precision flow proportional and/or target set point trim dosing at low flows at < 1MLD locations |
| **Dosing Control** | mg/l, flow pulse or 4..20mA | Input from treated water flowmeter or treated water pH analyser |
| **Fault Detection** | Over/under pressure protection, no flow, trip | Built in digital I/O for fault signal generation to PLC. |
| **User Display** | mg/l, ppm, l/h, totaliser, fault | |
| **PLC / SCADA Interface** | Fieldbus | |

Table 23: Specific requirements for sodium hydroxide dosing pumps. All additional requirements as per WIMES 8.02 (A).

All parts (dosing head, suction/pressure connectors, ball seats, seals, etc.) in contact with transfer medium are to be of materials suitable for use with sodium hydroxide (PVC, PP, stainless steel, PTFE, Viton/EPDM seals) in accordance with WIMES 8.02 (A). Each pump is to be suitable for use with a 220V or 400V, 50 Hz, single or three phase power supply and shall remain operational within permissible ambient temperatures of -10˚C to +45˚C. Each proposed pump shall also have an ingress protection rating of IP65, and an insulation class F. When installed, the suction line for each pump shall incorporate a strainer and a foot valve in order to keep each pump primed and prevent air-locking throughout the duty cycle of the make-up tank (i.e. varying chemical levels within the tank).

#### 5.4.8.4 INSTRUMENTATION

The table overleaf outlines the instrumentation required to provide a fully automated and reliable sodium hydroxide pH / alkalinity boosting system. Also contained in the table is the type of I/O signal [analogue (A) and Digital (D)] required from each instrument, the instrument's function, and the data logs to be generated. All instruments shall be in accordance with WIMES 8.02 (A), Section 6.10.3 and associated guidance text.

| Description | Instrument Type | I/O Type | Function | Data Log |
|---|---|---|---|---|
| **Bulk Tank Level** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Remaining Volume |
| **Day Tank Level** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Trend |
| **Leak Detection** | Point Level | D | Alarm | Trend |
| **Process Water Flowmeter** | Flowmeter | A & D | Alarm, run to waste, auto shut down, dose control | Trend |
| **Chemical Flowmeter** | Flowmeter | A & D | Stock level management & flow profile trend. Dosing pipework leakage alarm. | Trend |
| **pH Analyser** | Monitor | A | Alarm, target pH set point dose control | Trend |

Table 24: Instrumentation requirements for sodium hydroxide based pH / alkalinity adjustment systems.

Ultrasonic Level Indicators

All ultrasonic level sensors used in this installation shall be suitable for use with a sodium hydroxide solution at the concentration required by the process, and be capable of issuing two 4..20mA analogue signals to within ±1% accuracy of range and a minimum of 3 relay signals. Sensors and controllers shall be rated to IP68 and shall have a measurement range of 0.3 to 6.0 metres. Controllers shall be wall mounted and installed adjacent to the pH / alkalinity adjustment control panel, or within the instrumentation / control room if the control panel has been incorporated into a centralised MCC.

Point Level Indicator (Leak Detection)

All point level indicators used in this installation shall be suitable for use with sodium hydroxide and be capable of issuing a digital signal to the system PLC. Point level indicators may only be used as leak detection instruments and are not permitted for installation as stock level management instruments.

Process Water Flowmeters

Process water flow measurement is to be achieved by the use of electromagnetic flowmeters, lined internally with EPDM NBR hard rubber Ebonite. The external casing of the flow meter shall be epoxy coated carbon steel and rated for a pressure of up to 16 bar, with PN16 oriented flanges. Flow meter controllers shall be wall mounted and capable of issuing a 4..20mA analogue (live measurement) and a digital signal (bulk measurement) to the control PLC to within 1% accuracy of range, with a minimum flow velocity of 5 metres/second.

Chemical Flowmeters

Where the dosing pumps include digital flow display, these flowmeters may be used to provide dose control and the dose flow read out on the on site SCADA/HMI. Alternatively, chemical flow measurement is to be achieved by the use of wall mounted ultrasonic flowmeters, to best accommodate pulsing flows generated by diaphragm or stepper motor driven metering pumps. All internal or wetted parts are to be resistance to corrosion by contact with sodium hydroxide solution, using chemically resistant parts manufactured from PVDF/PTFE or similar. The chemical flowmeter should be capable of issuing a 4..20mA output signal and generate a flow measurement of < 2% accuracy of range. Connections should be available to accommodate a range of hose sizes and the instrument should be rated for a maximum operating pressure of 16 bar.

pH Monitors

All pH monitors shall be capable of immersion type installation, which shall be mounted in a sampling bath which is continuously supplied from the process water rising main. The Designer shall ensure that sufficient contact time has been allowed for the pH / alkalinity adjustment chemical to mix with the process water before the point of sample take off (i.e. a distance of 40 times the process water carrier pipe diameter, or immediately downstream of a static mixer). The pH probe itself shall be suitable for the continuous measurement of pH in aqueous solutions and shall utilise a differential electrode measurement technique. The probe shall be of robust construction, suitable for use in an industrial application and shall have a pH measurement range from 0 – 14, at a sensitivity of

0.01 pH units. It shall be capable of a pH stability of 0.03 pH units per 24 hours, non-cumulative. The probe shall be provided with an approved controller, which shall be capable of issuing a 4..20mA signal to the main system PLC, which represents the pH measurement of the final process water. The probe and immersion bath shall be installed indoors, and shall have an operating range of -5°C to 25°C. The velocity of the sample turnover shall not exceed 3m/s.

### 5.4.9 CHEMICAL DELIVERY

Delivery and storage of sodium hydroxide chemical stocks shall be in accordance with the details outlined in table 25 below.

| Description | Criteria | Notes |
|---|---|---|
| **Allowable Concentrations** | 25%, 30% | - |
| **Minimum / Maximum Storage Temperature** | Min 10°C, Max 20°C | Extract fans & heaters to be installed in chemical storage room. External tanks to be heated to maintain NaOH temperature > 5°C |
| **Minimum Liquid Temperature** | 5°C | Outdoor Storage Tanks to incorporate automated heating system to maintain NaOH temperature above 5°C |
| **Delivery Method** | Bulk liquid | Pumped to bulk storage from delivery tanker |
| **Bulk Storage Volume** | As per TEC-600-06-01 | Bulk tank volume to be selected to achieve this target |
| **Bulk / Day Tank Bund Volume** | As per TEC-600-06-01 | - |
| **Dosing Room Ventilation** | Directly to atmosphere external to building | Required for temperature control only |

Table 25: Delivery and storage requirements for NaOH

### 5.4.10 PROCESS ALARMS AND AUTOMATIC SHUTDOWN

The Designer shall ensure that the pH / alkalinity boosting system has the capability to generate alarms in the event of an out of specification pH detected in the dosed raw water. Alarms associated with an increase or decrease in pH levels of final water should take the form of text messages to plant operators, audible alarms on site, flashing beacons on the external wall of chemical dosing buildings and flashing messages or mimics on HMI/SCADA screens. Tables 26 and 27 (overleaf) outline the Alarm Generation and Plant Shutdown criteria for pH / alkalinity boosting system, and specifies the type of alarm that each occurrence should generate. Please note that alarms or plant shutdowns shall not be initiated until 3 consecutive ‘out of specification’ readings are detected, or if an ‘out of specification’ reading is sustained in excess of 3 minutes.

| Alarm & Automatic Shutdown Criteria | Minimum Target Criteria (Alarm) | Critical Control Points (Dosing System Shutdown) |
|---|---|---|

| | | |
|---|---|---|
| **pH Ranges** | ± 0.2 pH units from pH Target Set Point | ± 0.5 pH units from pH Target Set Point |
| **Low Levels of Made Up Soda Ash** | ≤ 10% of total make up tank capacity | - |
| **Leak Detection** | Positive level in bund | - |
| **Pump Fault / Trip** | 1 No. Chemical Dosing Pump Trips | - |
| **Chemical Flowmeter (while positive flow from process water flowmeter)** | No flow signal from 1 No. chemical flow meter (if associated pump is running) | - |
| **Process Water Flowmeter (while positive flow from chemical flowmeter)** | No flow signal from process water flowmeter while chemical pumps are running | **Inhibit all dosing pumps**<br>(Prevent creation of pH 'slug') |

Table 26: Alarm and shutdown criteria for pH / alkalinity adjustment systems.

Any occurrence of a Critical Control Point shown in the right hand column of the above table will result in the immediate shutdown of the dosing system. The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. The level of alarms are described in below:

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | ▪ Flashing Mimic<br>▪ Text Message<br>▪ Flashing Beacon<br>▪ Audible Alarm | ▪ Dosing system shutdown for any reason<br>▪ Positive level in bund (chemical spill or leak) |
| **Level 2** | ▪ Flashing Mimic<br>▪ Text Message | ▪ pH ± 0.2 from Target Set Point<br>▪ 1 No. dosing pump trips<br>▪ Transfer pump trips<br>▪ Any other equipment trip<br>▪ No flow signal from 1 No. chemical flow meter when associated pump is operating |
| **Level 3** | ▪ Flashing Mimic | ▪ Low sodium hydroxide stock (≤ 10% capacity) |

Table 27: Alarm grades and methods of alerting supervisory staff

# 6 COAGULATION SYSTEMS

Once the raw water has been pre-conditioned to the most appropriate pH and alkalinity levels, the charge neutralisation mechanism is initiated by the addition of the appropriate coagulant, and the vigorous agitation of the raw water / coagulant mixture. This agitation is known as flash mixing and is necessary both to quickly disperse the coagulant chemical throughout the raw water and to promote collisions between now neutrally charged particles to encourage their growth into a small floc. Uisce Éireann has approved the inorganic coagulants as outlined in Table 7 of this document to initiate charge neutralisation, and if required, subsequent flocculation mechanisms to promote floc growth.

In addition to the results of the jar tests as described in Section 3.2, the Designer shall consider the downstream process that is proposed (dissolved air flotation, sedimentation, etc.), as well as the attributes of each coagulant as described in Table 7, when selecting the most appropriate chemical to facilitate charge neutralisation and subsequent flocculation mechanisms. The Designer shall rationalise their coagulant selection by submitting, in addition to the results of the jar tests as described in Section 3.2, a detailed justification as to the reasons why the selected coagulant is the most appropriate for use. This justification shall consider the raw water analysis results, the proposed downstream treatment processes, operational costs and an inventory of consumers on the supply network (e.g. industrial processes, hospitals, etc.) which may be sensitive or intolerant to the residuals from one form of coagulant over another. The Designer shall consider each of the decisions outlined in Table 28 below when selecting and designing the most appropriate coagulation system.

| **Coagulation Decision Table** | |
|---|---|
| **What is the downstream process?** | Flotation – Coagulated floc to be fluffy and light<br>(charge neutralisation followed by variable speed flocculation mixing) |
| | Sedimentation – Coagulated floc to be dense and heavy<br>(charge neutralisation followed by tapered and/or sweep flocculation and chemical bridging) |
| **What is the coagulation recipe?** | Jar Test - determine most effective coagulant, taking into account raw water pH, ability to accurately control pH and background raw water alkalinity levels. |
| | Jar Test - determine the coagulant dose for most effective TOC removal (TOC removal typically required on lake water sources) |
| | Jar Test - determine the coagulant dose for most effective turbidity removal (turbidity removal typically required on river sources) |
| **What is the control mechanism?** | Flow proportional with streaming current based feedback trimming control<br>(to be used with all coagulation systems to control optimum dose for charge neutralisation) |
| | Flow proportional with UV absorbance (UVA) based trimming control<br>(to be used on surface or lake sources with where TOC removal is required, or on existing sites where there is poor flash mixing, no suitable installation location for SCM, poor/inaccurate pH control, or where there is an inappropriate coagulant being used for the raw water pH) |
| | Flow proportional with turbidity based trimming control<br>(to be used on any river sources where raw water turbidity is variable, or on existing sites where there is poor flash mixing, no suitable installation location for SCM, poor/inaccurate pH control, or where there is an inappropriate coagulant being used for the raw water pH) |
| *Note: the above descriptions of control systems are for guidance only. The source water shall not be the only criteria used in the selection of automated coagulation control. The Designer shall assess control requirements on a site by site basis, and take all available raw water analysis into account to determine the most robust and effective solution.* | |

**Table 28: Considerations to be made in the design of automated coagulation systems.**

Process control of the coagulant dosing system is critical to achieving effective NOM removal, whilst minimising chemical consumption and reducing the risk of aluminium or iron residuals remaining in the treated water. The following sections outline Uisce Éireann's requirements for all future automated coagulation systems which utilise the inorganic chemicals as listed in Table 7, and the Designer shall ensure that each installation is completed in strict accordance with WIMES 8.02(D) *Coagulant and Phosphate Removal Chemical Dosing Equipment*, as well as the details outlined herein.

## 6.1 SPECIFIC UV ABSORBANCE

The concept of Specific UV Absorbance (SUVA) shall be used as an operational indicator of the nature of NOM in raw water supplies, and the effectiveness of coagulation systems in removing NOM, TOC and disinfection by-products (DBP). SUVA is defined as the normalised UV absorbance of a water sample with respect to the measured concentration of DOC in the same sample, and offers a simple characterisation of the nature of the raw water NOM based on measurements of UVA and DOC. In surface water sources, particularly lakes with upland catchments, TOC makes up approximately 90% of the NOM concentration. Given Ireland's dependency on surface water sources, SUVA is therefore an extremely useful tool to categorise the raw water and establish the optimum means of controlling coagulation systems. The Designer shall use the results of the raw water analysis to complete the following calculation to determine the SUVA (if not already provided), thereby providing guidance on which method of dosing system control is most appropriate for the selected coagulant.

$$SUVA\ (L/mg.m) = \frac{UVA_{254}(cm^{-1})}{DOC\ (mg/L)}\ x\ 100$$

Once the SUVA has been determined, the raw water may be classified as one of the three categories as outlined in Table 29 below. It is clear that the presence of NOM incurs a larger SUVA value, and therefore gives the raw water a high disinfection by-product formation potential. This necessitates the selection of UVA and/or SCM coagulation control in order to specifically target the NOM for removal. The decision as to whether UVA or SCM or both is most appropriate control mechanism is dependent on a number of factors which are outlined in Section 5.2 of this document.

| SUVA (L/mg.m) | Contaminant Composition and Attributes |
|---|---|
| **SUVA > 4** | ▪ Presence of humic matter of high aromatic and hydrophobic character<br>▪ High UVA (or low UVT), high chlorine demand and high DBPFP.<br>▪ NOM composition is dominated by the larger dissolved humic substances<br>▪ Coagulation dose and process control best determined by TOC (or UVA as a surrogate parameter for TOC), and/or Streaming Current.<br>▪ High TOC removal expected by optimised coagulation process |
| **2 < SUVA < 4** | ▪ A mixture of humic and non-humic matter of both hydrophobic and hydrophilic character<br>▪ Medium UVA (medium UVT), lower chlorine demand and lower DBPFP<br>▪ NOM is composed of humic substances and smaller non-humic substances<br>▪ Coagulation dose and process control best determined by TOC (or UVA as a surrogate parameter for TOC) and/or Streaming Current.<br>▪ Intermediate TOC removal expected by optimised coagulation process |
| **SUVA < 2** | ▪ Indicates a high fraction of non-humic matter of hydrophilic character<br>▪ Low UVA (high UVT), low chlorine demand and low DBPFP<br>▪ NOM composition is dominated by the smaller dissolved non-humic matter<br>▪ Coagulation dose and process control best determined by turbidity<br>▪ Low TOC removal expected<br>▪ Coagulation may not be required at all if the source is a high quality ground water with low TOC concentrations and low turbidity. |

**Table 29: Selection of coagulation control system based on SUVA results.**

## 6.2 AUTOMATIC CONTROL OF COAGULATION SYSTEMS

While the completion of jar tests will allow a reasonably accurate estimation of the coagulant dose, and facilitate design decisions such as pump and bulk tank sizing; the day to day operation of all future Uisce Éireann coagulation systems, both new build and retrofitted, shall be fully automated processes. As the concentrations of contaminants, TOC included, in raw water can be a continually varying parameter, the use of manually controlled coagulation systems with dose rates determined by jar testing constitutes a system which is unable to respond to rapid and frequent changes in raw water quality. The result is usually an under dose of coagulant, leading to poor NOM removal and substandard final water quality, or an overdose of coagulant, leading to the creation of flocs incompatible with downstream clarification process (i.e. the creation of metal hydroxide precipitates on a DAF process) and the possibility of high residual metal concentrations in the treated water supply.

On a manually controlled coagulation system, correct dosage is only achieved when the raw water TOC levels happen to match those detected during process commissioning. This will occur on an infrequent basis and for very short durations on a variable TOC supply, making manual coagulation systems a very blunt instrument to achieve effective charge neutralisation. While the use of flow proportional coagulant dosing refines the process to a certain extent, it cannot account for changes in NOM concentrations (e.g. in lakes and ground waters affected by surface waters) and changes in turbidity (e.g. in rivers or meteorologically induced in lakes). For this reason, one or more of the analytical instruments outlined below shall be used in conjunction with flow proportional metering in order to trim the coagulant dose to the precise volume required for effective NOM removal.

***<u>Streaming Current Based Coagulation Control:</u>*** Streaming current monitors (SCM) measure the total charge of all the contaminants contained in the raw water sample, both organic and inorganic. As organic contaminants are much more negatively charged than inorganic, this totalised negative charge is predominantly attributed to the presence of NOM in the raw water. With the addition of a positively charged inorganic coagulant, the SCM detects the change in totalised charge, and can issue a feedback 4..20mA signal to control the coagulant dose in order to maintain the slightly negative charge required by the charge neutralisation mechanism. As the SCM is a feedback device (the sample is taken from within, or just downstream of the flash mixing tank), it also provides a process validation that the desired charge neutralisation has been achieved. This is in contrast to the UVA/UVT monitor which is a feed forward device, and therefore cannot provide validation that the appropriate coagulant dose has been administered.

| **Streaming Current Monitors** | |
|---|---|
| **Applications** | Raw water sources with SUVA > 2.0 L/mg.m |
| | All installations where charge neutralisation is the initial coagulation mechanism. |
| **Limitations** | Not suitable for use when the raw water pH cannot be finely adjusted to the necessary value for charge neutralisation to occur. pH target is dependent on the type of coagulant used. |
| | Flash mixing / static mixing of coagulant must be optimised to ensure even distribution of chemical, and consequently, stable charge readings. |
| | SCM must be installed at manufacturer’s recommended locations – not always possible. |

Table 30: Attributes of streaming current monitors for dose trimming control of automated coagulation systems.

***<u>UV Absorbance (UVA) Based Coagulation Control:</u>*** While the numerical relationship between UV absorbance (UVA) and TOC is unique to each raw water, a change in UVA readings will always indicate a change in TOC concentrations, making UVA monitoring a very effective means of detecting changes in NOM concentrations. The UVA/UVT monitor takes a sample of the raw water into a cell, and passes a beam of UV light through the abstracted sample. A UV light detector analyses the intensity of the UV light after it has passed through the cell, and compares it with the intensity of the UV light at the source. The difference between emitted light and detected light can be attributed to the UV absorbance capability of the organic matter within the raw water sample. The instrument can return the reading as a UV absorbance (UVA) value (cm$^{-1}$) or as a UV transmission (UVT) value (%) as there is a direct correlation between the two parameters. The presence of an online raw water UVA/UVT monitor, which generates real time readings, can therefore facilitate a refined method of controlling coagulant dosing which can very quickly and automatically respond to changes in raw water quality. This method of coagulant control is very effective on low turbidity, high DOC waters, and ensures reliable and robust performance across a range of varying raw water parameters. However the presence of turbidity in raw water supplies greatly reduces the performance of UVA/UVT monitors, as the light used by the instrument is scattered by the suspended solids in the water sample. The UVA/UVT monitor misinterprets this scattering of light as additional UV absorbance and, despite the presence of turbidity compensators on many UVA/UVT devices, may return an incorrect reading of increased TOC.

| UV Absorbance (UVA) Monitors | |
|---|---|
| **Applications** | All raw water sources with SUVA > 2.0 L/mg.m (typically lake sources) and turbidity < 8 NTU |
| | To be used for dose trimming control when streaming current is unsuitable. |
| **Limitations** | Feed forward system – does not offer verification of effective coagulation |
| | Cannot be used when raw water turbidity > 8 NTU |

**Table 31: Attributes of UVA monitors for dose trimming control of automated coagulation systems.**

***Turbidity Based Coagulation Control:*** The final method of facilitating automated coagulation control is the use of turbidity monitors on raw water supplies. However this method shall only be used on high turbidity sources where concentrations of TOC and SUVA are relatively low (i.e. rivers). Note that high quality ground waters with low turbidity levels and SUVA values less than 2.00 L/mg.m may not require any coagulation systems. Each coagulation system proposed shall therefore utilise either a UVA/UVT monitor or a streaming current monitor (SCM) to determine the exact trimmed dose required for optimum coagulation and NOM removal. In cases where TOC is not a concern, but there are high levels of suspended inorganic particles in the water, turbidity based control shall be used. For facilities with variable flow rates, readings for UVA, SCM and turbidity will be used in tandem with flow proportional dose control. Some highly variable raw water sources may require more than one of the instruments listed above to adequately control coagulation under all operating conditions, and in extreme cases all three may be required. While the above tables offer some guidance as to where each instrument would typically be used, the Designer shall take all the details of the raw water analysis into account when selecting the most appropriate control mechanism (i.e. it is possible to get highly turbid lakes, in which case turbidity should be considered in tandem with SCM and UVA. Similarly it is possible to get high DOC river sources in which case UVA shall be considered in tandem with SCM and turbidity.

| Turbidity Monitors | |
|---|---|
| **Applications** | All raw water sources with SUVA < 2.0 L/mg.m (typically river sources) and turbidity > 8 NTU |
| | To be used for dose trimming control when streaming current is unsuitable. |
| **Limitations** | Feed forward system – does not offer verification of effective coagulation |
| | No facility to alter dose in the event of increased DOC concentrations |

Table 32: Attributes of UVA monitors for dose trimming control of automated coagulation systems.

## 6.3 GENERAL DESIGN

All coagulation systems installed at new treatment plants, or retrofitted at existing facilities, shall be as per outlined in the schematic overleaf. Regardless of which chemical is selected to fulfil coagulation purposes, the volume of bulk storage on-site shall be determined by the Designer in accordance with chemical demands as demonstrated by the jar tests, and storage facilities should be sized to hold a minimum of 30 days' worth of chemical, and a maximum of 60 days. Bulk storage tanks for coagulants shall comply with the requirements outlined in TEC-600-06-01.

Where storage requirements are in excess of 1200 litres, then the total storage volume shall be equally divided over two storage tanks. Note that IBCs will not be permitted for use as storage tanks for coagulants.

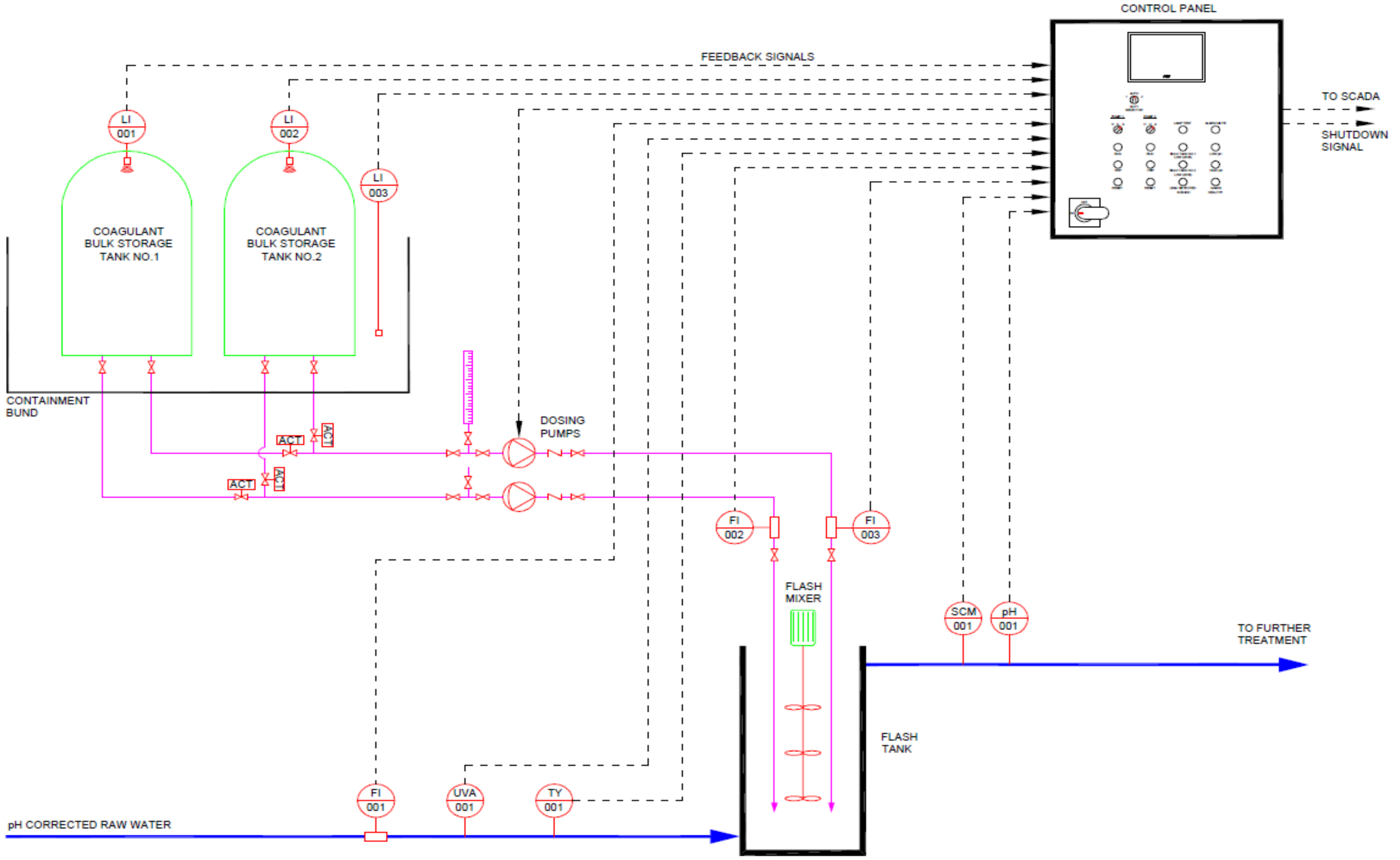
With the exception of the bulk storage tanks (2 No. shown in Diagram 12 as an indicative example only) and the dose trimming control instrumentation (SCM, UVA and Turbidity) the Designer shall at a minimum allow for all equipment as shown, as well as that outlined in subsequent sections of this specification, and in addition to any other plant or instrumentation required for a fully automated enhanced coagulation system. Ultrasonic level sensors (LI001 & LI002) will be installed on each bulk tank to monitor chemical stock levels, initiate changeover of source tank and issue alarms in the event of low stocks or overfilling. Leak detection level indicators (LI003) shall be provided in all bunds, as shown in Diagram 12, and shall be of probe type instruments (conductivity probes, capacitance probes, etc.). Ultrasonic level probes will not be permitted for use as leak detection as they may return a loss of echo signal during normal operation. All bunds are to have the capacity to hold 110% of the volume of one of the make-up tanks.

As outlined in Section 5.2, the dose trimming control function for all coagulation systems shall be controlled by streaming current monitoring regardless of the type of raw water source (lake, river, low quality ground water). UVA monitors or turbidity monitors shall be installed in tandem with streaming current monitors as a means to provide live analysis of raw water quality, but to also offer back up control in the event that SCM becomes unsuitable (i.e. failure of SCM instrument, failure of pH correction system). Whether it is UVA or turbidity meters are included in the installation can generally be determined by the type of raw water source in accordance with the table below, however the Designer shall also consider the raw water analysis on a site by site basis when making the selection between UVA and turbidity control. Note that in some scenarios (e.g. occasionally turbid lake waters), SCM, UVA and turbidity shall all be required.

| Selection of UVA v Turbidity for Raw Water Quality Monitoring and Back Up Coagulant Dose Control | |
|---|---|
| **SCM + UVA** | All lake and low quality ground water sources where SUVA > 2.00 L/mg.m and turbidity has not exceeded 8 NTU on more than 4 occasions in the previous 12 months. |
| **SCM + Turbidity** | All river sources where turbidity has exceeded 8 NTU on more than 4 occasions in the previous 12 months. |
| **SCM + UVA + Turbidity** | All lake / groundwater sources where SUVA > 2.00 L/mg.m and turbidity has exceeded 8 NTU on more than 4 occasions in the previous 12 months.<br>All river / groundwater sources where SUVA > 2.00 L/mg.m and turbidity has exceeded 8 NTU on more than 4 occasions in the previous 12 months. |

Table 33: Range of instrumentation required to implement an optimised coagulation system

The UVA, SCM and turbidity monitors shall all be capable of controlling the coagulant trim, and the system shall be commissioned to allow the primary control instrument to be changed, both manually and automatically, if required (i.e. move from SCM control to UVA or turbidity control in the event of post coagulation pH increase).



LI001 = LEVEL INDICATOR BULK TANK NO.1
LI002 = LEVEL INDICATOR BULK TANK NO.2
LI003 = LEVEL INDICATOR LEAK DETECTOR

pH001 = pH MONITORING PROBE
UVA001 = UVA / UVT MONITOR
SCM001 = STREAMING CURRENT MONITOR

FI001 = FLOW INDICATOR PROCESS WATER
FI002 = FLOW INDICATOR DOSING PUMP NO.1
FI003 = FLOW INDICATOR DOSING PUMP NO.2

pH001 = pH MONITORING PROBE
TY001 = TURBIDITY MONITOR

| | |
|---|---|
| ▬ | PROCESS WATER |
| ▬ | COAGULANT DOSE LINE |
| - - - - - - | CONTROL SIGNALS |

Diagram 12: General Design for coagulant storage, administration, monitoring and control system.

## 6.4 PROCESS CONTROL OF CHEMICAL ADMINISTRATION

As outlined in Sections 5.2 and 5.3, each coagulant dosing system shall be controlled on a flow proportional basis, but shall also incorporate a fine trimming function based on feedback from a streaming current monitor (SCM). If streaming current is not feasible for the reasons outlined in Table 30, the trim function shall be provided by either UVA or turbidity monitors, as per Tables 31 and 32. For either scenario, this method of trimmed control will be achieved by the use of a 'Chemtrim' type system, which shall take analogue signals from both the process water flowmeter (FI001) and each of the analytical instruments utilised on site. For installations which utilise all three analytical instruments [i.e. the streaming current monitor (SCM001), the UVA monitor (UVA001), and the turbidity monitor (TY001)], the 'Chemtrim' device shall accept signals from each, but only one will act as the trim control parameter at any one time. The 'Chemtrim' system shall use a pre-programmed algorithm to generate a refined analogue signal, based on the raw water flow rate and the analytical measurement, which will control the dosing pump in order to administer the most appropriate coagulant dose to achieve effective NOM removal.

The baseline ratio between flow and coagulant dose shall be determined by the Designer from the results of the jar tests, and shall be set as such on the system HMI during process commissioning, with the trimming function providing the fine tuning of the system. This baseline ratio between flow and coagulant dose shall only be capable of being changed under the highest level of security access on the system HMI. While this will be the only control mechanism available for the administration of coagulant, the system shall be programmed to allow the plant operator adjust the ratio of control between flow proportionality and SCM/UVA/Turbidity, i.e. 70% of the chemical dose based on flow proportionality, 30% based on SCM reading. This shall allow the system to be accurately tailored to suit plants which have varying flow rates, or variable TOC/turbidity concentrations at certain times of the year. However, the process Designer shall set upper and lower restrictions on this trim control ratio during process commissioning which will limit the magnitude of adjustment that can be made on site by the plant operator. The upper and lower limitations for trim control ratio adjustment shall be adjustable via a password protected page on the HMI screen.

**Note that all chemical dosing shall cease if the flowrate detected by FI001 is zero**. This is in order to prevent the creation of a high pH 'slug' within the process water pipeline.

## 6.5 FLASH MIXING

As the charge neutralisation mechanism reaction occurs within 0.5 of a second of adding an inorganic coagulant to the raw water, it is imperative that the chemical is dispersed quickly throughout the flow by a vigorous mixing process. This vigorous dispersion also causes the now neutrally charged particles to collide against one another, and thereby agglomerate together, resulting in the completion of the first stage of an effective coagulation process. If downstream flotation clarification is proposed, basic flocculation shall continue in subsequent dedicated flocculation tanks where the floc may be grown to the appropriate size.

If sweep flocculation is proposed as part of the process, then mixing in the flash tank will be less vigorous, and the retention time within the tank shall be increased to provide up to 1 minute of mixing (see Table 34 overleaf for details of mixing times). Note that sub optimal flash mixing often results in a 25 – 30% overfeed of chemical, leading to increased operational costs and a risk of iron or aluminium residuals in the final treated water.

### 6.5.1 G AND GT VALUES

A number of considerations must be made when designing an optimal flash mixing system, the most important of which is the selection of the most appropriate velocity gradient, otherwise known as the G value (measured in seconds$^{-1}$), and the subsequent dimensionless Gt value (also known as the Camp Number), which is a function of the G value and the reaction time. Another critical design decision is the selection between a mechanically driven mixer and a passive mixing system such as a static mixer or hydraulically baffled jump plates. For all Uisce Éireann flash mixing processes, passive mixing systems shall only be used on applications where the flowrate is not variable, and is above a particular threshold to ensure that sufficient chemical dispersion and effective contaminant agglomeration is achieved. The Designer shall determine the G and Gt values of the flash mixing system using the formulae below, and ensure that it is within the required ranges for the type of downstream treatment process proposed (i.e. sedimentation or flotation).

For mechanically mixed systems: $G = \sqrt{\frac{P}{\mu V}}$

For hydraulically baffled systems: $G = \sqrt{\frac{\rho h_l}{\mu T}}$

Camp Number: $Gt = G \, x \, t$

Where,

$h_l$ = *turbulence & mixing headloss, m*
$T$ = *detention time in baffled tank, s*
$P$ = *power imparted by the mixer, Nm/s*
$Gt$ = *Camp Number, dimensionless*
$G$ = *velocity gradient,* $s^{-1}$
$\mu$ = *absolute viscosity of water* ($Ns/m^2$)
$\rho$ = *liquid density* $kg/m^3$
$V$ = *basin volume,* $m^3$
$t$ = *reaction time, s*

As outlined previously in this document, when employing a flotation process as the downstream clarification method, the intention is to create a small, light floc that can be easily attached to a microbubble and floated. Conversely, when employing a downstream sedimentation process, the intention is to create a dense, heavy floc that will easily settle. The table below outlines the target G and Gt values that the Designer shall achieve, depending on the downstream process, as well as the most appropriate methods of mixing. Note that all mechanical flash mixers shall be on variable speed drives, which shall adjust their frequency in proportion to the flow detected by the raw water flow meter. Non-mechanically driven mixing (static, hydraulic baffles, inline blender) shall only be acceptable on process where the raw water flow is constant and non-variable.

| Downstream Process | Appropriate Coagulation Mechanism | Reaction Time (t) | Detention Time (T) | Required G Value $s^{-1}$ | Required Gt Value | Appropriate Mixing Systems |
|---|---|---|---|---|---|---|
| **Flotation** | Charge Neutralisation + Basic Flocculation | 0.5 sec | 1 minute | 3,000 to 6,000 | 1,500 to 3,000 | Flash tank, static mixer (non-variable flow only), inline blender |
| **Sedimentation** | Charge Neutralisation + Basic / Tapered / Sweep Flocculation, and/or Chemical Bridging | 2.0 – 10.0 sec | 1 minute | 600 to 1,000 | 1,200 to 10,000 | Extended flash tank, hydraulically baffled jump plates (non-variable flow only) |
| *Note that the above are guideline figures only and the most appropriate mixing / detention times and G values shall be determined by the completion of jar tests on a site specific basis, as per Section 3.2* | | | | | | |

Table 34: Appropriate mixing times and ranges for G & Gt values for downstream flotation and sedimentation processes.

### 6.5.2 FLASH MIXING TANK DESIGN

The liquid depth within each flash tank should be approximately 1.1 times the flash tank diameter or width, but may be extended up to 1.6 times the flash tank diameter or width if multiple impellers are used on the mixer shaft. Each impeller diameter should be between 0.3 and 0.5 times the tank diameter or width, and the most effective mixing is achieved if the coagulant is dosed below the lowest impeller. Short circuiting of the flash tank shall be avoided by implementing bottom entry / top exit or top entry / bottom exit hydraulic arrangements.

## 6.6 INSTALLATION AND GENERAL LAYOUTS

Regardless of the type of chemical used, all coagulant based dosing installations shall be completed in accordance with TEC-600-06-01, with features specific to the selected coagulant added as described in the following sections Each installation shall also incorporate features that are common to all layouts, as described in Section 5.6.1 below. Note that all equipment used shall be in accordance with WIMES 8.02(D).

The table below outlines the minimum and maximum allowable storage temperatures for each of the approved coagulant chemicals, and the Designer shall ensure that these temperatures are maintained for all installations (indoor & outdoor), in all climatic conditions.

| Approved Coagulant | Freezing Point | Minimum Chemical Temperature | Maximum Chemical Temperature |
|---|---|---|---|
| **Ferric Sulphate** | -15°C | 5°C | 20°C |
| **Aluminium Sulphate** | -7°C | 5°C | 20°C |
| **Poly-aluminium Chloride (50% Pre-Hydrolysed)** | -5°C to -20°C | 5°C | 20°C |
| **Poly-aluminium Chloride (83% Pre-Hydrolysed)** | -5°C to -20°C | 5°C | 20°C |

Table 35: Maximum and minimum storage temperatures for approved coagulation chemicals.

## 6.7 CONTROL PANEL LAYOUT

The minimum control panel layout requirements for the each of the coagulant dosing system *General Designs* is shown in the below diagram. Additional pumps, instrumentation etc. are to be added as required. For newly designed treatment plants, green-field builds, or facilities which are undergoing major upgrades which incorporate replacement of MCC facilities, the panel shown below shall be incorporated into a common centralised Form 4 MCC, and instrument controllers shall be mounted within the panel. For all independent coagulation installations, the MCC may take the form as shown, and instrument controllers may be wall mounted units external to the panel. In the event that the pH adjustment system is also being upgraded in tandem with the coagulation system, the panels may be combined into one MCC. This applies for all processes described in this document. If a SCADA system is present on site, all signals shall be relayed and mimicked on the main control interface which shall replicate the functionality of the localised coagulant dosing / pH adjustment MCC panel.

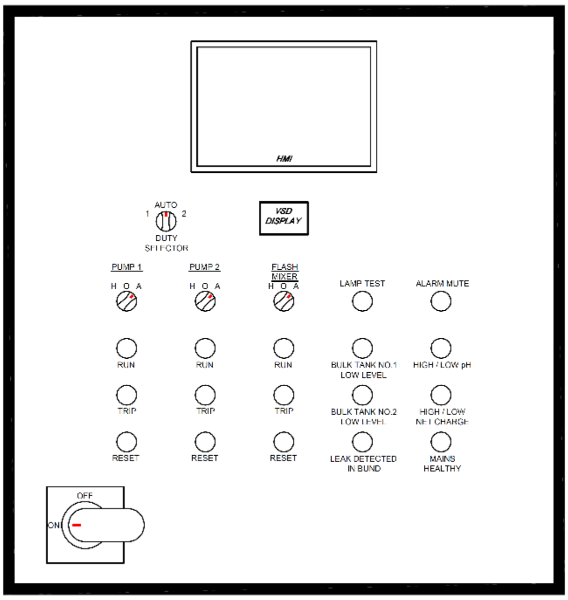


Diagram 13: MCC for General Layout No.1 & No.2

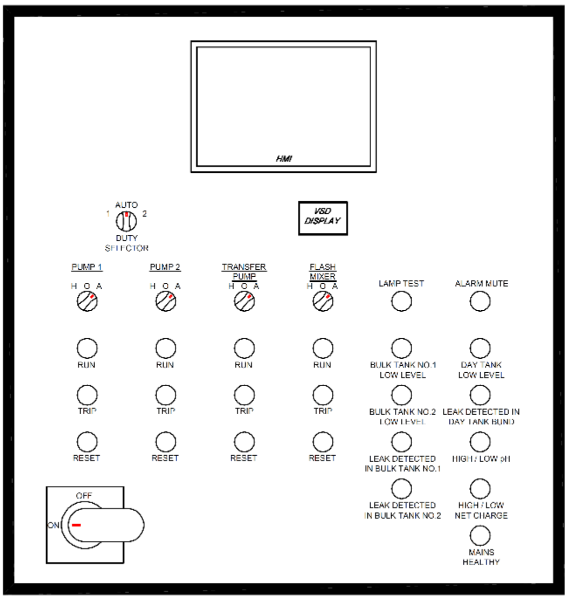


Diagram 14: MCC for General Layout No.3

## 6.8 PLC & HMI FUNCTIONALITY

The Designer shall ensure that the installed coagulation system has the capability to operate in a fully automated fashion in accordance with Uisce Éireann's requirements, and be capable of administering a refined coagulant dose to maintain the optimum charge neutralisation of organic matter in the raw water. The system shall be designed to minimise the DWSP hazards and to ensure consistent and reliable performance under normal and abnormal operating conditions (i.e. variations in flow, alkalinity, raw water pH, pump failure, etc.). A HMI touchscreen of minimum 175mm diagonal measurement shall provide the plant operator with a visual representation of the installation and will also allow process adjustments to be made in order to optimise the operation of the system.

Home Screen

The home screen of the HMI shall show the name of the plant and include four icons allowing the plant operator to select which screen he / she wishes to view. The icons shall be labelled as shown in the diagram overleaf and as follows; Coagulation System Mimic, Trends, Alarms and System Shutdown Settings, and structured in the hierarchy as shown in Diagram 15 overleaf.

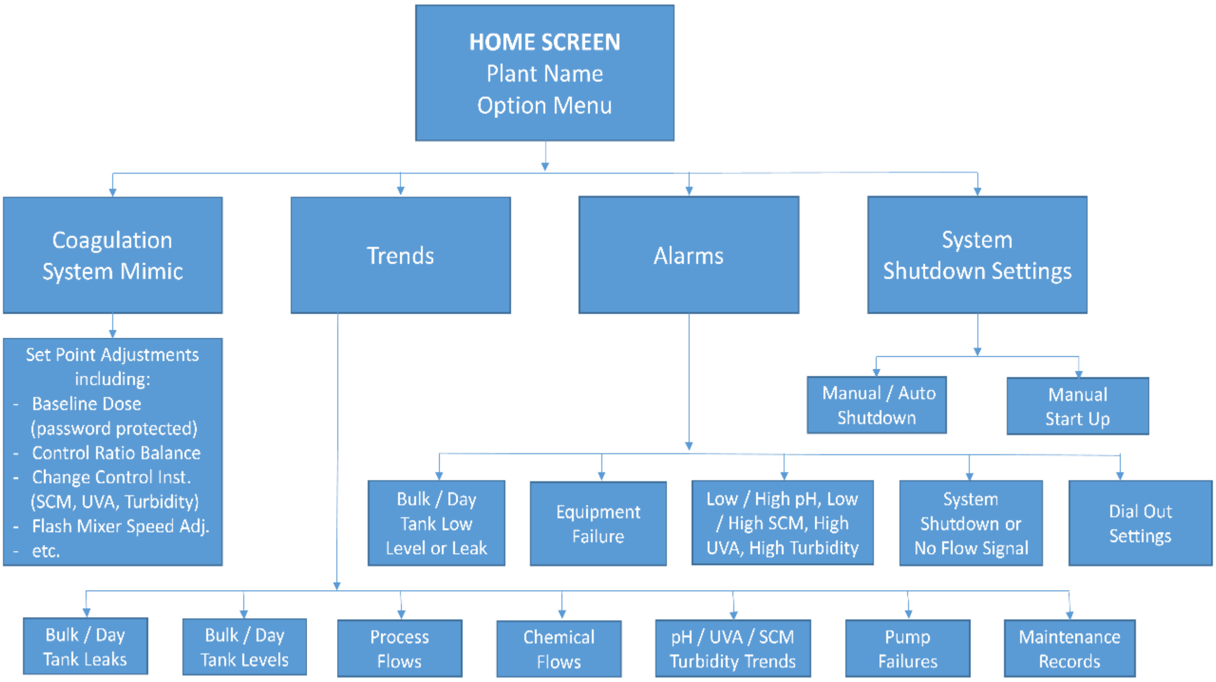


**Diagram 15: Coagulant administration system HMI screen hierarchy for all Uisce Éireann approved coagulants.**

Coagulation System Mimic

The Coagulation System Mimic will show a precise representation of the *General Design* that has been implemented on site. It should be used as an overview screen which shall allow the operator to both view and make control adjustments to the coagulant dosing process. Each element of the process shall be represented (bulk tanks, day tanks, bunds, dosing pumps, transfer pumps, actuated valves, instruments and pipework) and feedback signals from each instrument shall be used to allow the current measurement be displayed on the mimic (i.e. the level of coagulant in each bulk tank shall be displayed in real time beside the bulk tank mimic, the process water flow through FI001 shall be displayed beside the process water flowmeter mimic, etc.).

The unique tag number for each tank, pump, instrument and item of plant shall also be displayed on the screen beside the mimic of that particular item. If an item of plant has an element of functionality adjustment, then touching its mimic shall introduce a schedule of options which will allow the operator to make adjustments. For example, touching the dosing pump mimic shall open another screen which will allow the operator toggle the duty/standby pumps or adjust the control ratio between flow proportionality and measured SCM / UVA / turbidity values. Similarly, touching the SCM mimic will open a screen which allows the operator to adjust the target net charge of the organic contaminants (slightly negative charge required if using a cationic polymer for subsequent flocculation aid, slightly positive charge required if using an anionic polymer).

The mimic of operational pumps should be presented in green, and the standby pump mimic should be presented in black. If a fault signal is returned by one of the pumps or instruments then its onscreen mimic should flash between red and black, allowing the operator to see where a fault has occurred. The selected control ratio between flow proportionality and measured SCM / UVA / turbidity values shall also be clearly displayed on the mimic screen.

Every page on the HMI hierarchy should also incorporate a 'Home' button which will return the user to the Home screen, and a 'Back' button which will return the user to the previously visited page. On pages that allow functionality adjustment, an 'Apply' button should appear if any changes or adjustments are made to the current settings. New settings will not be saved until the operator presses the 'Apply' button, at which point the user will be returned to the previously visited page.

### Trends

The Trends page will allow the operator to view historical readings and graphs for the previous 30 days for each of the instruments used on the coagulation system. This page will also allow the operator to view historical records of pump, instrument and plant failures and enter details of maintenance procedures completed (maintenance dates, type of work that was carried out, date of last chemical delivery). As per previous pages, the trend screen will incorporate a 'Home' button which will return the user to the Home screen, and a 'Back' button which will return the user to the previously visited page.

### Alarms

The Alarms page will allow the plant operator to view a historical record of generated alarms for a period of up to 30 days prior to the date of access. This page shall also allow the operator to view the alarm generation set points, but shall not allow their adjustment. While the operator shall have the capability of adjusting the target net charge as measured by the SCM in order to fine tune the charge neutralisation process to suit a downstream flocculation aid (anionic or cationic polymer addition), the Level 2 alarm will automatically adjust to between ± 5.0mV of the newly selected target net charge. The record of generated alarms will show the type of alarm generated (Level 1 or Level 2) and give the date and time that the alarm was raised and inhibited. The alarm screen will incorporate a 'Home' button which will return the user to the Home screen, and a 'Back' button which will return the user to the previously visited page.

### Dosing System Shutdown

The Dosing System Shutdown Settings shall allow the operator to adjust the set points at which an automatic shutdown of the duty coagulation dosing pump occurs. This is to prevent chemical over dosing, which may result in the presence of aluminium or iron residuals in the treated water. Automatic shutdown of the dosing system will also occur upon a ‘no-flow’ detection from the raw water flowmeter. This will avoid the creation of a low pH ‘slug’ within the raw water process pipework, caused by a continued dosing of coagulant. The HMI screen shall also allow the operator to initiate a manual shutdown if required, and incorporate a function for restarting the system after a manual *or* automatic shutdown has been initiated.

## 6.9 SECURITY OF SYSTEM CONTROL

See TEC-600-06-01 for the requirements around security of system control for this type of installation.

## 6.10 AUTOMATIC CHANGEOVER OF PUMPS

In addition to the criteria set in section 4.5, changeover shall take place when one of the following applies;

- If the total net charge of the raw water measured by SCM001 moves ± 5.0 mV beyond the total net charge target set point.

Once the standby pump is activated it will automatically operate on the flow proportional to SCM / UVA / turbidity control ratio (70/30, 80/20, etc.) that has been selected by the plant operator.

If automatic changeover has been initiated by a highly negative reading from SCM001 caused by the failure of the duty pump, the PLC will not attempt to changeover again if the negative charge reading and the (now) standby pump fault signal persists. If the negative charge fault clears, the next changeover will occur on the next scheduled time basis, provided the pump fault which caused the initial changeover has been eradicated.

## 6.11 EQUIPMENT SPECIFICATION

In addition to the criteria specified in section 4.6, the following criteria shall apply to equipment specification for sulphuric acid installations. WIMES 8.02 (D) Coagulant and Phosphate Removal Dosing Equipment should also be consulted in the design or refurbishment of any new installation. Note that where an Uisce Éireann requirement contradicts a WIMES clause, the Uisce Éireann requirement shall take precedence.

### 6.11.1 BULK STORAGE TANKS

All bulk storage tanks and non-concrete bunds for containment of coagulation chemicals shall be designed in accordance with TEC-600-06 Chemical Storage Systems and referenced documentation outlined therein.

Thermoplastic valves may be used on smaller tanks (< 1.5m$^3$), but for larger installations valves shall be fabricated from lined ductile iron or lined cast steel – suitable linings include natural rubber or fluoropolymers..

### 6.11.2 DAY TANKS

All day tanks and non-concrete bunds for containment of coagulation chemicals shall be designed in accordance with TEC-600-06 Chemical Storage Systems and referenced documentation outlined therein.

### 6.11.3 DOSING & TRANSFER PUMPS

For each coagulation system installation, a minimum of two dosing pumps will be provided which will operate in a duty/standby configuration, with dose control to be facilitated as described in Section 5.4. For each *General Layout No.3* installation, a single transfer pump shall also be provided to maintain stock within the day tank. Installation of all coagulation system dosing and transfer pumps shall be as described in Section 5.6 of this document, i.e. mounted in fully enclosed metering cabinets or, for larger pumps, within concrete bunds. Each dosing and transfer pump proposed should comply with Section 6.5 of WIMES 8.02 (D), with the exception of Uisce Éireann's specific dosing pump requirements, which are outlined in Table 36 below.

| Description | Criteria | Notes |
|---|---|---|
| **Pump Type** | Variable speed – servomotor driven, stepper motor driven, solenoid driven, air diaphragm driven | Required for precision flow proportional and target set point trim dosing at low flows |
| **Pump Turn Down Ratio** | Minimum of 1:800 | Required for precision flow proportional and/or target set point trim dosing at low flows at < 1MLD locations |
| **Dosing Control** | mg/l, flow pulse or 4..20mA | Input from raw water flowmeter or raw water SCM / UVA / Turbidity monitors |
| **Fault Detection** | Over/under pressure protection, no flow, trip | Built in digital I/O for fault signal generation to PLC. |
| **User Display** | mg/l, ppm, l/h, totaliser, fault | - |
| **PLC / SCADA Interface** | Fieldbus | - |

**Table 36: Specific requirements for coagulant dosing pumps. All additional requirements as per WIMES 8.02 (D).**

All parts (dosing head, suction/pressure connectors, ball seats, seals, etc.) in contact with transfer medium are to be of materials suitable for use with the proposed coagulant (PVC, PTFE, Viton seals) in accordance with WIMES 8.02 (D). Each pump is to be suitable for use with a 220V or 400V, 50 Hz, single or three phase power supply and shall remain operational within permissible ambient temperatures of -10˚C to +45˚C. Each proposed pump shall also have an ingress protection rating of IP65, and an insulation class F. When installed, the suction line for each pump shall incorporate a strainer and a foot valve in order to keep each pump primed and prevent air-locking throughout the duty cycle of the bulk / day tank (i.e. varying chemical levels within the tank).

### 6.11.4 INSTRUMENTATION

The table below outlines the instrumentation required to provide a fully automated and reliable coagulation system. Also contained in the table is the type of I/O signal [analogue (A) and Digital (D)] required from each instrument, the instrument's function, and the data logs to be generated. All instruments shall be in accordance with WIMES 8.02 (D), Section 6.10.3 and associated guidance text.

| Description | Instrument Type | I/O Type | Function | Data Log |
|---|---|---|---|---|
| **Bulk Tank Level** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Remaining Volume |
| **Day Tank Level (if required)** | Ultrasonic | A & D | Stock level management, activation of transfer system, alarm | Trend |
| **Leak Detection** | Point Level | D | Alarm | Trend |
| **Process Water Flowmeter** | Flowmeter | A & D | Alarm, run to waste, auto shut down, dose control | Trend |
| **Chemical Flowmeter** | Flowmeter | A & D | Stock level management & flow profile trend. Dosing pipework leakage alarm. | Trend |
| **pH Analyser** | Analytical Monitor | A | Alarm, post-coagulation pH monitoring | Trend |
| **Streaming Current Monitor** | Analytical Monitor | A | Alarm, coagulant dose control | Trend |
| **UVA / UVT Monitor *** | Analytical Monitor | A | Alarm, raw water quality monitoring, back up coagulant dose control | |
| **Turbidity Monitor *** | Analytical Monitor | A | Alarm, raw water quality monitoring, coagulant dose control | Trend |

Table 37: Instrumentation requirements for automated enhanced coagulation systems.
*Not always required – see Section 5.3 for details.

Ultrasonic Level Indicators

All ultrasonic level sensors used in this installation shall be suitable for use with the selected coagulant at the concentration required by the process, and be capable of issuing two 4..20mA analogue signals to within ±1% accuracy of range and a minimum of 3 relay signals. Sensors and controllers shall be rated to IP68 and shall have a measurement range of 0.3 to 6.0 metres. Controllers shall be wall mounted and installed adjacent to the coagulation system control panel, or within the instrumentation / control room if the control panel has been incorporated into a centralised MCC.

Point Level Indicator (Leak Detection)

All point level indicators used in this installation shall be suitable for use with the selected coagulant and be capable of issuing a digital signal to the system PLC. Point level indicators may only be used as leak detection instruments and are not permitted for installation as stock level management instruments.

Process Water Flowmeters

Process water flow measurement is to be achieved by the use of electromagnetic flowmeters, lined internally with EPDM NBR hard rubber Ebonite. The external casing of the flow meter shall be epoxy coated carbon steel and rated for a pressure of up to 16 bar, with PN16 oriented flanges. Flow meter controllers shall be wall mounted and capable of issuing a 4..20mA analogue (live measurement) and a digital signal (bulk measurement) to the control PLC to within 1% accuracy of range, with a minimum flow velocity of 5 metres/second.

Chemical Flowmeters

Chemical flow measurement is to be achieved by the use of wall mounted ultrasonic flowmeters, to best accommodate pulsing flows generated by diaphragm or stepper motor driven metering pumps. All internal or wetted parts are to be resistance to corrosion by contact with the selected coagulant solution, using chemically resistant parts manufactured from PVDF/PTFE or similar. The chemical flowmeter should be capable of issuing a 4..20mA output signal and generate a flow measurement of < 2% accuracy of range. Connections should be available to accommodate a range of hose sizes and the instrument should be rated for a maximum operating pressure of 16 bar.

pH Monitors

All pH monitors shall be capable of immersion type installation, which shall be mounted in a sampling bath which is continuously supplied from the process water rising main. The Designer shall ensure that sufficient contact time has been allowed for the pH / alkalinity adjustment chemical to mix with the process water before the point of sample take off (i.e. a distance of 40 times the process water carrier pipe diameter, or immediately downstream of a static mixer). The pH probe itself shall be suitable for the continuous measurement of pH in aqueous solutions and shall utilise a differential electrode measurement technique. The probe shall be of robust construction, suitable for use in an industrial application and shall have a pH measurement range from 0 – 14, at a sensitivity of 0.01 pH units. It shall be capable of a pH stability of 0.03 pH units per 24 hours, non-cumulative. The probe shall be provided with an approved controller, which shall be capable of issuing a 4..20mA signal to the main system PLC, which represents the pH measurement of the final process water. The probe and immersion bath shall be installed indoors, and shall have an operating range of -5°C to 25°C. The velocity of the sample turnover shall not exceed 3m/s.

Streaming Current Monitor

All streaming current monitors shall be piston type instruments which take a sample of the raw water and pass it through a cell housing a reciprocating piston and two embedded electrodes. The reciprocal motion of the piston increases the velocity of the water which causes clouds of charged ions to be stripped from colloidal particles. The stripped ions result in a current between the two electrodes. If no current is detected, then charge neutralisation has been successful. Each SCM shall be capable of taking a sample flow rate, variable between 2 – 20 litres per minute. For installations where the SUVA > 4 L/mg.m, the system should be capable of taking a sample of up to 35 litres per minute. The SCM enclosure shall be IP65 rated and the materials contacting the water sample should be of Derlin, nylon, neoprene, viton, PVC or stainless steel construction. The probe and piston shall both be quick replacement items and each instrument shall be provided with a full set of spares. Each unit shall incorporate the facilities to provide an automatic sensor flush and chemical wash. The instrument shall be rated to accept a 220V

AC power supply, 50 Hz, and be capable of operation in temperature ranges of 1 - 45°C. Outdoor installation of streaming current monitors will not be permitted by Uisce Éireann.

UVA / UVT Monitor

Each UVA/UVT monitor proposed shall be capable of providing a continuous indication of natural organic matter in a flowing sample, which shall be used to serve as a continuous surrogate measurement for total organic carbon concentrations in the raw water supply. The system shall be capable of measuring a UVA range of 0 – 2$cm^{-1}$, to an accuracy of within 0.001$cm^{-1}$, and also measuring a UVT range between 0 – 100%, with an accuracy of between ±0.1%. Each system proposed shall also incorporate turbidity compensation, in order to maintain the highest levels of accuracy during periods of increased raw water turbidity. An automatic cleaning system shall be included to ensure accuracy of UV absorbance/transmission readings with minimal operator intervention or maintenance. The proposed unit shall be capable of continuous detection of excessive cell or UV light source fouling, lamp output and electrical faults, with alarm generation capability for each detected error in the form of discrete I/O. Sufficient analogue I/O shall allow UVA and/or UVT readings to be transmitted back to the system PLC in order to control coagulant dose rates and provide a real time raw water quality measurement parameter on the system HMI. All UVA readings shall be displayed in units of $cm^{-1}$, and all UVT values shall be displayed as percentage readings, measured at a path length of 10mm (i.e. UVT $_{(10)}$). The wavelength of light shall be within the range 250 – 260nm, with the optimum being 254nm. All instrument or controller casings shall be IP65 rated, and operate on a 220V power supply. All instruments are to be installed indoors and capable of operation in a temperature range of 0° - 45°C.

Turbidity Monitor

Each turbidity monitor proposed shall be capable of measuring an NTU range of 0.001 – 100 to within an accuracy of ± 5%. The unit shall be capable of accepting a sample flow rate of between 200 – 750 mL/min, at a temperature range of between 0 - 50°C, and have the capacity to generate 2 No. analogue output signals within a response time of 1 minute. Power supplies shall be 220V AC, 50Hz.

### 6.11.5 PIPEWORK, VALVES FITTINGS & ACCESSORIES

All necessary hoses, pipework, fittings and control valves shall be of materials which have a high resistance to degradation by each of the approved coagulants at the supplied concentrations. If proposed as part of the installation, all of the following peripherals associated with coagulation systems shall be manufactured from materials in accordance with Section 6.5 and Appendix A of WIMES 8.02 (D).

- Suction & Delivery Pipework
- Isolation Valves
- Non Return Valves
- Loading Valves
- Foot Valves
- Weights
- Suction Strainers
- Pulsation Dampers
- Pressure Gauges

- Pressure Relief Valves
- Calibration Vessels
- Injection Fittings
- Degassing Valves

.

## 6.12 CHEMICAL DELIVERY

While aluminium sulphate, ferric sulphate and various grades of PACl will have differing properties, all chemicals shall be delivered in accordance with Table 38 below.

| Description | Criteria | Notes |
|---|---|---|
| **Allowable Concentrations** | Various | Aluminium Sulphate – 8%<br>Ferric Sulphate – 6% approximately<br>Poly-aluminium Chloride – 10%<br>(both 50% and 86% pre-hydrolysed) |
| **Minimum / Maximum Storage Temperature** | Storage Room Temperature 10°C - 20°C | Extract fans & heaters to be installed in chemical storage room. External tanks to be heated to maintain chemical temperature > 5°C |
| **Minimum Liquid Temperature** | 5°C | Outdoor Storage Tanks to incorporate automated heating system to maintain chemical temperature above 5°C |
| **Delivery Method** | Bulk liquid | Pumped to bulk storage from delivery tanker |
| **Bulk Storage Volume** | As per TEC-600-06-01 | Bulk tank volume to be selected to achieve this target |
| **Bulk / Day Tank Bund Volume** | As per TEC-600-06-01 | - |
| **Dosing Room Ventilation** | Directly to atmosphere external to building | Required for temperature control only |

**Table 38: Delivery and storage requirements for coagulation chemicals.**

## 6.13 PROCESS ALARMS AND AUTOMATIC SHUTDOWN

The Designer shall ensure that the coagulation system has the capability to generate alarms in the event of an out of specification parameter detected in the treated water. Alarms associated with an increase or decrease in in net charge measurement, pH levels of coagulated water, increases in UVA, etc. should take the form of text messages to plant operators, audible alarms on site, flashing beacons on the external wall of the coagulation buildings and flashing messages or mimics on HMI/SCADA screens. Tables 39 and 40 (both overleaf) outline the Alarm Generation and System Shutdown criteria for coagulation systems, and specifies the type of alarm that each occurrence should generate. Please note that alarms or plant shutdowns shall not be initiated until 3 consecutive ‘out of specification’ readings are detected, or a consistent ‘out of specification’ signal is maintained for more than 3 minutes.

| Alarm & System Shutdown Criteria | Minimum Target Criteria (Alarm) | Critical Control Points (System Shutdown) |
|---|---|---|

| | | |
|---|---|---|
| **pH Ranges** | ± 0.5 pH units from the optimum level required for charge neutralisation as determined by the jar tests | - |
| **Net Charge Measurement** | ± 5mV from selected neutral charge set point | - |
| **Turbidity** | High Turbidity<br>(set point selected during process commissioning) | |
| **UVA** | High UVA<br>(set point selected during process commissioning) | - |
| **Low Coagulant Stock** | ≤ 10% of total bulk storage capacity | - |
| **Leak Detection** | Positive level in bund | **-** |
| **Pump Fault / Trip** | 1 No. Chemical Dosing Pump Trips | - |
| **Chemical Flowmeter** | No flow signal from duty chemical flow meter while positive flow detected by process water flowmeter, or when duty dosing pump is running. | **-** |
| **Process Water Flowmeter** | No flow signal from process water flowmeter while chemical pumps are running | **Inhibit all dosing pumps**<br>(Prevent creation of pH 'slug') |

Table 39: Alarm and system shutdown criteria for coagulation systems.

Any occurrence of a Critical Control Point shown in the right hand column of the above table will result in the immediate shutdown of the dosing system. The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. The level of alarms are described in further detail in the table below.

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | ▪ Flashing Mimic<br>▪ Text Message<br>▪ Flashing Beacon<br>▪ Audible Alarm | ▪ Process water flow shutdown for any reason<br>▪ Positive level in bund |
| **Level 2** | ▪ Flashing Mimic<br>▪ Text Message | ▪ pH ± 0.5 units from the optimum level required for charge neutralisation<br>▪ ± 5mV from selected neutral charge set point<br>▪ High turbidity (exceedance of high alarm level as set during process commissioning)<br>▪ High UVA (exceedance of high alarm level as set during process commissioning)<br>▪ 1 No. dosing pump trips<br>▪ Transfer pump trips<br>▪ Any other equipment trip<br>▪ No flow signal from 1 No. chemical flow meter when associated pump is operating |
| **Level 3** | ▪ Flashing Mimic | ▪ Low coagulant stock (≤ 10% capacity) |

Table 40: Alarm grades and methods of alerting supervisory staff

# 7 FLOCCULATION SYSTEMS

Once effective charge neutralisation has been achieved, the agglomerations that have been created must be grown to a size appropriate to the selected downstream process. As stated in Table 28 of Section 5, for clarification by dissolved air flotation (DAF), a light and fluffy floc is required, whereas for clarification by sedimentation, a dense, heavy floc is required. The type of flocculation employed after charge neutralisation will determine the characteristics of the floc that is created, therefore the design of the flocculation system is completely dependent on the type of downstream treatment process proposed.

| Downstream Clarification Process | Charge Neutralisation | Basic Flocculation | Tapered Flocculation | Chemical Bridging | Sweep Flocculation |
|---|---|---|---|---|---|
| **Dissolved Air Flotation (Small & Light Floc Required)** | ü | ü | - | - | - |
| **Sedimentation (Large & Dense Floc Required)** | ü | ü | ü | ü | ü |
| **Adsorption Clarification** | ü | ü | - | - | - |

Table 41: Various flocculation mechanisms as they apply to differing downstream clarification processes.

Table 41 above offers general guidelines as to which flocculation mechanisms are most appropriate for the type of floc required for the selected downstream clarification process. However, each flocculation system shall be designed on a site by site basis, using iterative jar testing to determine the most suitable mechanism(s). While charge neutralisation shall be used as the initiation point for all coagulation and flocculation systems, it may be found that sufficient floc growth requires the combination of charge neutralisation with one, or more, of the flocculation mechanisms listed above. The most effective and efficient combination of flocculation mechanisms shall be determined by the completion of a comprehensive suite of jar tests.

## 7.1 FLOC GROWTH, G AND GT VALUES

The extent of floc growth under basic flocculation conditions depends on the vigorousness of the agitation within the flocculation tanks, and also for how long the flocculation continues (i.e. the retention time within the tanks). Consequently, the G and Gt values described in Section 5.5.1, also play an important part in the design of effective flocculation systems. Regardless of the flocculation mechanism proposed, the following rule of thumb applies:

- High G value and short retention time creates small and dense flocs
- Low G value and long retention time creates large and light flocs

Neither of the above floc types suit flotation, sedimentation or adsorption clarification processes. Therefore the flocculation system must be manipulated in order to obtain the small and light floc required by flotation, or the large and dense floc required by sedimentation.

## 7.2 BASIC FLOCCULATION

Basic flocculation mechanisms may be employed post charge neutralisation, and are suitable to create flocs applicable to both flotation and sedimentation clarification processes. Within the 'basic flocculation' category, mechanisms can be further subdivided into mechanically mixed or hydraulically mixed processes.

### 7.2.1 MECHANICALLY MIXED BASIC FLOCCULATION

Mechanically mixed basic flocculation mechanisms that are approved by Uisce Éireann consist of vertical turbine mixers and vertical paddle mixers. These systems are described in more detail in the following sections

#### 7.2.1.1 VERTICAL TURBINE MIXERS

Vertical turbine mixers shall operate in a similar fashion to flash mixers, except at a reduced G value and a longer retention time. The G value of the vertical turbine mixer shall be adjustable by the inclusion of a mechanism to vary the speed of the mixer (either via VSD or by mechanical speed variation). While the retention time shall only vary with flow rate, the flocculation tank should be sized such that the minimum required retention time is achieved at the maximum design flowrate. All figures given are for guidance only, and initial G values and retention times shall be determined based on the results of a comprehensive suite of jar tests. Finalised G values shall be determined during process commissioning.

| Downstream Clarification Process | Minimum G Value to Maintain Solid Suspension | Recommended G Value ($s^{-1}$) | Minimum Retention Time (s) | Recommended Gt Value |
|---|---|---|---|---|
| **Dissolved Air Flotation (Small & Light Floc Required)** | 15 | 50 – 120 | 900 – 1,200 | 45,000 – 144,000 |
| **Sedimentation (Large & Dense Floc Required)** | 15 | 20 – 80 | 900 – 1,800 | 18,000 – 144,000 |
| **Adsorption Clarification** | n/a | n/a | n/a | n/a |

Table 42: G values, retention times and Gt values for vertical turbines upstream of various clarification processes.

The footprint of flocculation tanks which utilise vertical turbine mixers shall, as close to as reasonably practicable, be square, and the mixer impeller diameter shall be between 0.2 and 0.5 times the chamber width. Short circuiting of the flocculation tank shall be avoided by implementing bottom entry / top exit or top entry / bottom exit hydraulic arrangements.

#### 7.2.1.2 VERTICAL PADDLE MIXERS

Vertical paddle mixers shall operate in a principle similar to vertical turbine mixers, albeit at lower G values, thereby making them applicable for the growth of floc suitable for sedimentation clarification processes. Vertical paddle mixers shall typically consist of two picket fence type gates, mounted at right angles to each other, and driven by geared down motors. Because of the wide 'picket gates', vertical paddle mixers cannot provide rapid mixing, and are therefore unsuitable for the growth of flocs for dissolved air flotation applications. Note that vertical paddle mixers may be used for sweep flocculation purposes as well as basic flocculation applications. The efficacy of the adsorption and enmeshment mechanisms which make up sweep flocculation may be maximised in the flocculation tank by the use of vertical paddle mixing.

Notwithstanding, all vertical paddle mixers shall be provided with variable speed drives, or mechanical speed variation functionality so that the most effective G value can be identified during process commissioning. While the retention time shall only vary with flow rate, the flocculation tank should be sized such that the minimum required retention time is achieved at the maximum design flowrate. All figures given are for guidance only, and initial G values and retention times shall be determined based on a comprehensive suite of jar tests.

The footprint of flocculation tanks which utilise vertical paddle mixers shall, as close to as reasonably practicable, be square, and the picket fence gate rotational diameter shall be between 0.2 and 0.5 times the chamber width. Short circuiting of the flocculation tank shall be avoided by implementing bottom entry / top exit or top entry / bottom exit hydraulic arrangements.

| Downstream Clarification Process | Minimum G Value to Maintain Solid Suspension | Recommended G Value ($s^{-1}$) | Minimum Retention Time (s) | Recommended Gt Value |
|---|---|---|---|---|
| **Dissolved Air Flotation (Small & Light Floc Required)** | n/a | n/a | n/a | n/a |
| **Sedimentation (Large & Dense Floc Required)** | 15 | 20 – 80 | 900 – 1,800 | 18,000 – 144,000 |
| **Adsorption Clarification** | n/a | n/a | n/a | n/a |

Table 43: G values, retention times and Gt values for vertical paddle mixers upstream of various clarification processes.

### 7.2.2 HYDRAULICALLY MIXED BASIC FLOCCULATION

Hydraulically mixed basic flocculation mechanisms that are approved by Uisce Éireann consist of horizontally baffled and vertically baffled flocculation tanks. The formula for predicting the G value for hydraulically mixed flocculation tanks is given in Section 5.5.1 and this type of system is described in more detail in the following sections. Note that this type of flocculation is only applicable for creating flocs suitable for downstream sedimentation clarification

#### 7.2.2.1 HORZONTALLY BAFFLED FLOCCULATION TANKS

Horizontally baffled flocculation tanks, also known as ‘around the end’ baffled channels offer a gentle mixing process by redirecting the directional flow of the water by 180° at the end of each baffle. Each horizontally baffled flocculation tank shall have a minimum of 6 flow channels (i.e. 5 internal baffle walls), with a minimum distance between the baffles of 0.75m for ease of construction and to facilitate cleaning. Minimum water depth in this type of flocculation tank should be 1.00m. More effective flocculation can be achieved by introducing a tapering of the distance between the baffles, i.e. narrower at the beginning of the tank (while remaining wider than 0.75m) to encourage more vigorous mixing, and wider towards the end of the tank to promote a more gentle mix. The target headloss across the tank should be 0.08 to 0.12m in order to achieve a G value of between 30 – 40s$^{-1}$. If a velocity in excess of 0.25m/sec cannot be maintained in every channel, there is a high risk of sedimentation in the flocculation tank, and the Designer shall propose a mechanically mixed flocculation system such as vertical turbine (see Section 6.2.1.1) or vertical paddle (see Section 6.2.1.2) mixer.

| Downstream Clarification Process | Minimum Velocity to Maintain Solid Suspension (m/s) | Recommended G Value (s$^{-1}$) | Minimum Retention Time (s) | Recommended Gt Value |
|---|---|---|---|---|
| **Dissolved Air Flotation (Small & Light Floc Required)** | n/a | n/a | n/a | n/a |
| **Sedimentation (Large & Dense Floc Required)** | 2.5 | 30 - 40 | 1,200 – 1,800 | 36,000 – 72,000 |
| **Adsorption Clarification** | n/a | n/a | n/a | n/a |

Table 44: G values, retention times and Gt values for horizontally baffled hydraulic mixers.

#### 7.2.2.2 VERTICALLY BAFFLED FLOCCULATION TANKS

Vertically baffled flocculation tanks, also known as 'over and under' baffled channels offer a gentle mixing process by redirecting the directional flow of the water by 180° at the end of each baffle. Each horizontally baffled flocculation tank shall have a minimum of 6 flow channels (i.e. 5 internal baffle walls), with a minimum distance between the baffles of 0.75m for ease of construction. The joint between lower walls and the tank base shall have small openings which will permit draining and wash down of the system. Minimum water depth in this type of flocculation tank should be 1.00m. More effective flocculation can be achieved by introducing a tapering of the distance between the baffles, i.e. narrower at the beginning of the tank (while remaining wider than 0.75m) to encourage more vigorous mixing, and wider towards the end of the tank to promote a more gentle mix. The target headloss across the tank should be 0.08 to 0.12m in order to achieve a G value of between 30 – 40s$^{-1}$. If a velocity in excess of 0.25m/sec cannot be maintained in every channel, there is a high risk of sedimentation in the flocculation tank, and the Designer shall propose a mechanically mixed flocculation system such as vertical turbine (see Section 6.2.1.1) or vertical paddle (see Section 6.2.1.2) mixers.

| Downstream Clarification Process | Minimum Velocity to Maintain Solid Suspension (m/s) | Recommended G Value (s$^{-1}$) | Minimum Retention Time (s) | Recommended Gt Value |
|---|---|---|---|---|
| **Dissolved Air Flotation (Small & Light Floc Required)** | n/a | n/a | n/a | n/a |
| **Sedimentation (Large & Dense Floc Required)** | 2.5 | 30 - 40 | 1,200 – 1,800 | 36,000 – 72,000 |
| **Adsorption Clarification** | n/a | n/a | n/a | n/a |

Table 45: G values, retention times and Gt values for vertically baffled hydraulic mixers.

## 7.3 TAPERED FLOCCULATION

Tapered flocculation shall be used to promote the growth of a large, dense floc that is suitable for downstream sedimentation processes. The process can be implemented on hydraulically mixed systems by widening the space between the baffles as the flow progresses through the flocculation tank. The decreasing velocity of the flow reduces the intensity of the collisions between neutrally charges flocs, allowing them to grow into larger agglomerations. The addition of an organic coagulant (typically cationic polymer) may aid this process.

For mechanically mixed systems, tapered flocculation shall be implemented by the construction of 3 No. flocculation tanks in series, with a vertical turbine (see Section 6.2.1.1) or a vertical paddle mixer (see Section 6.2.1.2) installed in each. The G values for each of the mixing systems are given in the below table, with the first flocculation tank in the process train having the highest, and the last having the lowest.

| **Downstream Clarification Process** | **Floc Tank 1 G Value ($s^{-1}$)** | **Floc Tank 2 G Value ($s^{-1}$)** | **Floc Tank 3 G Value ($s^{-1}$)** | **Min. Total Retention (s)** | **Sequential Gt Values** |
|---|---|---|---|---|---|
| **Dissolved Air Flotation** | n/a | n/a | n/a | n/a | n/a |
| **Sedimentation** | 70 | 40 | 20 | 1200 – 1,800 (Tanks 1, 2 & 3) | 84,000 – 126,000<br>48,000 – 72,000<br>24,000 – 36,000 |
| **Adsorption Clarification** | n/a | n/a | n/a | n/a | n/a |

Table 46: G values, retention times and Gt values for Tapered Flocculation.

When proposing tapered flocculation, the Designer shall prevent short circuiting of the mixing systems by utilising perforated baffle walls between each of the flocculation cells. These perforations shall be evenly distributed on the baffle wall at a frequency of 1 No. perforation per $1m^2$ of baffle wall. Each perforation should be sized such that the maximum design flowrate can be accommodated through each baffle wall, with minimal head losses. Vertical baffles (“over and under”) and horizontal baffles (“around the end”) are also acceptable means of reducing the risk of floc tank short circuiting. If vertical turbine mixers are proposed by the Designer to achieve tapered flocculation, shearing of previously created flocs shall be prevented by limiting their angular velocity to 10 radians/second. Each of the vertical turbines / vertical paddle mixers shall be operated on variable speed drives to allow adjustment of the G value energy in order to achieve optimal flocculation performance.

## 7.4 CHEMICAL BRIDGING

Chemical bridging is a flocculation aid process and refers to the practice of binding coagulated contaminants together by the addition of an organic coagulant such as a cationic (positively charged) or anionic (negatively charged) polymer. Organic polymers have a long chainlike structure, which allows particles of similar charge to be bound together, by forming a ‘chemical bridge’ between the two normally repulsive contaminants. The relative length of the polymer chain means that normally repulsive colloids may attach to the structure, maintaining a significant distance between each other such that their repulsive forces are too weak to prevent formation of the chemical bridge. The post coagulation net charge of the organic contaminants in the water will determine whether an anionic or cationic polymer is to be used.

Ideally, if chemical bridging is proposed for use, the coagulation process shall strive to maintain a slightly negative net charge (as measured by SCM) on the organic contaminants. The addition of a positively charged cationic polymer will build an extremely large, heavy and robust floc as the negatively charge contaminants attach to the polymeric chain. The opposite can also be the case – if the net charge of the organic contaminants is positive, then a negatively charged anionic polymer may be added to form the chemical bridge. However, a slight positive charge on the organic contaminants as detected by the SCM may be a sign of coagulant overdose, and as such indicates sub-optimal performance of coagulation control. The use of cationic polymer is therefore Uisce Éireann's preferred method of achieving chemical bridging.

Cationic polymer may be added to the flow immediately after the flocculation mechanism has been completed. While the polymeric solution does not need to be mechanically mixed with the water, it shall be added in such a way so as to achieve sufficient hydraulic mixing and contact with the entire flow. Suitable poly addition locations include the point where the water overflows the outlet weir from the flocculation tank, or into the upturned belmouth of a floc tank outlet. The turbulence of the water as it overflows the weir, or as it enters the belmouth will provide sufficient dispersion of the polymer solution. If tapered flocculation is proposed, then it shall be acceptable to add the polymer solution to the final mixing tank in the tapered flocculation process train.

Polymers used as coagulation aids shall be cationic (positively charged) in nature, but Asset Strategy shall consider the use of anionic polymers on a case by case basis. The Designer shall outline the reasons for the selection of anionic polymers, and provide justification as to why it is more suitable than cationic poly each time it is proposed. Notwithstanding, Uisce Éireann shall reserve the right to reject any proposal that includes the use of anionic polymers.

For Class A plants, the Designer may propose that a liquid poly solution at the desired concentration is delivered to site, but for Class B to Class E plants (inclusive) only deliveries of powdered poly shall be acceptable. For all Class B to Class E plants, a polymeric solution shall be made up on site to the desired concentration. Where powdered poly is proposed, manual make-up systems similar to those specified for sodium carbonate make-up systems (see Section 4.3) may be used on Class A and Class B plants, but all Class C, Class D and Class E plants shall utilise automatic poly make- up systems. The automatic poly make-up system will only require plant operator intervention on occasions when the polymer feed hopper needs replenishment, and the machine shall be capable of automatically making up a polymer solution to the required concentration.

Dose control of polymer will be on a flow proportional basis, with an initial approximation of dose to flow ratio and required concentration established by completion of a comprehensive suite of jar tests. The optimum dose to flow ratio and chemical concentration shall then be determined during the systems process commissioning. The plant operator shall have the capability to change the dose to flow ratio on the system HMI under Level 2 security clearance. All systems proposed for polymer dosing shall replicate those specified for sodium carbonate in Section 4.3 of this document. All make up systems (manual and automatic) shall be bunded, duty/standby dosing pumps shall be provided in pump enclosures, and each pump shall have its own suction and delivery pipework and fittings.

| **Chemical Bridging Requirements** | |
|---|---|
| **Type of Polymer** | Cationic (Anionic may be considered on a case by case basis) |
| **Concentration (% w/w)** | Typically 0.1 – 0.5% |
| **Chemical Delivery** | Powder (Class A – E Plants) |
| | Liquid Solution (Class A Plants Only) |
| **Make Up Systems** | Manual Make Up Tanks (Class A and Class B Plants Only) |
| | Automatic Make Up Tanks (Class A – Class E Only) |

Table 47: Properties for organic polymer flocculation aids.

## 7.5 SWEEP FLOCCULATION

The conditions for sweep flocculation are created during the coagulation process by increasing the pH of the raw water to such an extent that the solubility of the metal hydroxides created by the addition of the selected coagulant is minimised. At a particular pH level, higher than that at which optimum charge neutralisation occurs, increased dosages of metal salt coagulants react with the alkalinity in the raw water to form an amorphous precipitate [aluminium hydroxide $Al(OH)_{3(am)}$, iron oxide hydroxide $Fe(OH)_{3am}$], which acts like a sponge to soak up both organic and inorganic contaminants through adsorption and enmeshment mechanisms.

However, sweep flocculation and charge neutralisation should not be thought of as mutually exclusive processes, as both mechanisms take place across typical raw water pH ranges. At a lower pH, charge neutralisation is the dominant mechanism, but limited precipitation of metal hydroxides still exists. At a higher pH, sweep flocculation is the dominant mechanism, but a limited amount of charge neutralisation exists. The upper and lower pH levels for which sweep flocculation and charge neutralisation are optimal is different for each of the approved coagulants (see Table 9 of Section 4.1), thereby emphasising the importance of accurate pH control in the coagulation and flocculation process stages of water treatment.

For downstream sedimentation processes, the most effective and efficient system for developing a large, dense and settleable floc is to maintain a raw water pH such that both charge neutralisation and sweep flocculation mechanisms are occurring. Lowering the pH slightly will increase the influence of charge neutralisation, and increasing the pH slightly will increase the influence of sweep flocculation. Finding the balancing point pH in order to create the optimum conditions will require the Designer to consider the raw water pH, the alkalinity, the coagulant (PACl transitional range from charge neutralisation to sweep flocculation occurs at a higher pH than for aluminium sulphate – therefore the use of PACl in place of alum may significantly reduce costs associated with pH suppression) and the downstream treatment process. The Designer shall estimate the most appropriate pH target set point by the completion of a comprehensive suite of jar tests, with final optimisation taking place during process commissioning.

While the conditions for sweep flocculation are created during coagulation, flocs are grown through one or more of the dedicated mechanisms described in in previous sections; vertical turbine mixing (Section 6.2.1.1), vertical paddle mixing (Section 6.2.1.2), hydraulic mixing (Section 6.2.2), tapered flocculation (Section 6.3) and chemical bridging (Section 6.4). However, one of the major advantages of the adsorptive and enmeshment properties of the amorphous precipitates created by sweep flocculation is that the process continues within downstream sedimentation tanks. When the sludge blanket is formed from a sweep flocculated process, the adsorptive and enmeshment properties of the precipitated hydroxides remain, and the blanket acts like a very fine net or filter. Organic and inorganic contaminants which may not have agglomerated during the upstream coagulation and flocculation processes rise slowly in the sedimentation tank until they reach the very dense sludge blanket, where they are invariably removed from the flow. Sweep flocculation is therefore an extremely effective tool, and if optimised, may result in a highly clarified process water which has been superbly prepared for subsequent filtration processes.

# 8 CLARIFICATION – SEDIMENTATION SYSTEMS

Clarification is a key process element of high production water treatment plants, and if designed correctly in tandem with an upstream coagulation system, offers a reliable and efficient method of reducing suspended solids, turbidity, colour and organic carbon concentrations in advance of filtration. Reducing the loading applied to the filters by removal of the heavier contaminants greatly increases the run time and efficiency of the filtration stages, and consequently decreases operational costs, treated water wastage and filtration down time – mostly due to less frequent backwashing. For sedimentation systems, the agglomeration of contaminants during coagulation and flocculation, and the subsequent formation of a sludge blanket, also acts a primary, albeit coarse, barrier against pathogens, which may become bound to settleable solids, or enmeshed in the sludge blanket during sweep flocculation. The inclusion of a clarification step in the water treatment process allows the filtration stage to specifically concentrate on the very fine contaminants that remain. While sedimentation tanks have historically had a very large footprint, the development of high rate clarification systems (i.e. lamella tube settlers) have allowed this footprint to be greatly reduced, and the uncomplicated nature of sedimentation tank operation (when compared to coagulation or filtration) makes clarification by sedimentation an attractive process stage in the design of water treatment infrastructure.

Clarification systems shall be implemented upstream of filtration processes on all treatment plants which take their raw water supplies from surface water (rivers, lakes or impoundments) or low quality groundwater (boreholes in karst limestone areas, unprotected wells, etc.) sources. The type of clarification system proposed will be dependent on the raw water quality parameters, but generally, sedimentation systems are most suited to raw waters with moderate to high turbidity levels (i.e. rivers, as well as certain lakes and reservoirs). The table below outlines a generalised guide as to where sedimentation or flotation systems should be used, but ultimately the decision is more complex than the table suggests, and the Designer shall determine the most appropriate clarification process by taking account of all pertinent parameters on a site by site basis. For example, if there is a particular concern regarding non-settleable contaminants such as algae, then flotation technologies may be considered, regardless of whether the source experiences occasional high turbidity levels.

| Peak Raw Water Turbidity | Raw Water TOC | Seasonal Algal Load | Typical Clarification |
|---|---|---|---|
| < 10 NTU | < 2 mg/L | High | Dissolved Air Flotation |
| < 10 NTU | > 2 mg/L | High | Dissolved Air Flotation |
| > 10 NTU | < 2 mg/L | Low | Sedimentation |
| > 10 NTU | > 2 mg/L | Low | Sedimentation |

Table 48: General guidance for the selection between sedimentation or flotation clarification processes.

Sedimentation, or gravity separation, is the physical treatment process by which suspended solids are removed from water by the force of gravity. By the selection of appropriate coagulation and flocculation mechanisms (as described in Section 5 and Section 6), the Designer shall ensure that the flocs created are suitable for settlement, i.e. large and dense, and that raw water has been appropriately conditioned before being passed forward for sedimentation. A number of differing processes exist to achieve clarification by sedimentation, namely:

- Horizontal Sedimentation Tanks (commonly used in the U.S., but not in the U.K. or Ireland),
- Up-flow Sedimentation Tanks (not commonly used in Ireland)
- Sludge Blanket Clarifiers Sedimentation Tanks (very common in the U.K. and Ireland)

Of the three sedimentation clarification processes listed above, sludge blanket clarifiers shall be the only method acceptable to Uisce Éireann. As mentioned previously, this does not preclude of lamella or tube settler based clarification, but all other design criteria listed must still be met. Designers are encouraged to highlight the potential benefits of systems that make use of ballasted clarification, however, these installations shall still be subject to approval via the derogation process.

While hopper bottomed sludge blanket clarifiers are very effective due to the continued promotion of particle collision beneath the sludge blanket, they are expensive to construct, and as such all sludge blanket clarifiers proposed shall be flat bottomed structures. Asset Strategy may consider the use of alternative sedimentation tanks on a case by case basis, provided the Designer can satisfactorily justify the omission of the sludge blanket clarification mechanism, or the inclusion of the hopper bottom. However, Uisce Éireann shall reserve the right to reject all proposed designs in favour the systems outlined in this specification.

All sedimentation processes are based on Stoke’s Law, which describes the velocity at which a particle or floc settles from suspension in a liquid. The growth of floc to an appropriate size for sedimentation, as described in Sections 5 and 6 of this document, is critical to ensure that the settling velocity of the particle ($V_s$) to be removed is in excess of the up-flow velocity ($V_o$) of the flow passing through the sludge blanket clarifier.

$$V_s = \frac{g(\rho_p - \rho)D_p^2}{18\mu} \qquad V_O = \frac{Q}{A} \qquad V_S > V_O \quad for\ effective\ settlement$$

Where,

$V_s$ = settling velocity of particle (m/s)
$V_O$ = up-flow velocity in clarifier (m/s)
$\rho_p$ = density of the particle (kg/m$^3$)
$\rho$ = density of the water (kg/m$^3$)
$D_p$ = diameter of the particle (m)
$\mu$ = viscosity of the water (Pa.s)
g = gravitational accel. (m/s$^2$)
Q = flow rate (m$^3$/s)
A = Clarifier surface area (m$^2$)

Just as the size of the floc, and therefore it’s settling velocity, shall be determined by the type of coagulation and flocculation systems proposed, the up flow velocity of the process water in the sedimentation tanks shall be controlled by the surface area of the clarifiers. The Designer shall ensure that the settling velocity of the created floc is in excess of the up-flow velocity of the flow in the clarifier, in accordance with the following sections of this specification, thereby ensuring the sedimentation of contaminants within the clarification process stage.

## 8.1 WATER QUALITY PERFORMANCE GOALS

Unless a lower design value limit is specified and agreed with the UE project manager in the project requirements, proposed clarification systems in conjunction with the upstream coagulation and flocculation processes, shall be capable of continually producing a water with a turbidity of < 1 NTU. This standard of water is required by all physical clarification processes so that subsequent filtration stages may achieve the < 0.1 NTU turbidity standards required (see Uisce Éireann specification TEC-900-04: Filtration). Effective coagulation, flocculation and clarification is also essential to ensuring that a UVA of 0.035cm$^{-1}$ (92% UVT) is achieved in filtered water, thus removing the potential for disinfection by-product formation. All sedimentation systems proposed shall incorporate turbidity monitors on the outlet from each tank to verify that effective clarification is achieved.

| Water Quality Requirements | Parametric Design Value | Performance Requirements |
|---|---|---|
| **Turbidity** | < 1 NTU | 99% of samples |

Table 49: Water quality performance goals post clarification and prior to filtration.

## 8.2 DETERMINATION OF MAXIMUM DESIGN FLOW

One of the key factors influencing the performance levels of a coagulation and sedimentation clarification water treatment plant is the stabilisation of the hydraulic load over each 24 hour period. Sludge blanket clarifiers that operate sporadically tend to suffer from reduced settlement tank performance due to the intense hydraulic pulse experienced by the sludge blanket when flow to the sedimentation tanks is re-initiated following a shut down. Consequently, this results in a higher solids loading rate applied to the downstream filtration system. Daily hydraulic loading shall therefore be, as much as is reasonably practicable, evenly distributed over a 24 hour period. As such, Uisce Éireann shall require maximum, minimum and average design flows to be determined in accordance with Table 50 below, across all new build water treatment infrastructure.

| Design Flow | Calculated Figure |
|---|---|
| **Minimum Design Flow (m$^3$/h)** | Daily Design Demand (m$^3$/d) / 22 hours |
| **Average Design Flow (m$^3$/h)** | Daily Design Demand (m$^3$/d) / 20 hours |
| **Maximum Design Flow (m$^3$/h)** | Daily Design Demand (m$^3$/d) / 18 hours |

Table 50: Determination of maximum, average and minimum design flows.

## 8.3 SLUDGE BLANKET CLARIFIER DESIGN

This section of the document outlines Uisce Éireann's baseline requirements for the initial process design and subsequent operation of up-flow sludge blanket clarification systems. While the Designer may configure their arrangements and layouts to best suit site restrictions, the upstream process and raw water quality parameters, the figures quoted in this section indicate the minimum requirements for robust clarification performance and the Designer shall, at a minimum, ensure that their proposal meets the criteria as set out in the following sections. Included in Appendix A of this document is a table which the Designer shall complete and submit with their tender, which outlines their proposed design criteria for the sedimentation process. This table shall be used to determine if the Designer’s proposal has met the minimum design requirements as set out below.

### 8.3.1 GENERAL DESCRIPTION

All sludge blanket clarification systems proposed for construction on Uisce Éireann treatment facilities shall be flat bottomed structures, which will allow water that has previously undergone pre-conditioning, coagulation and flocculation to enter the clarification basins via networks of low level inlet distribution pipework. The up-ward flow velocity of the water in the clarifier shall be less than the settling velocity of the coagulated contaminants, thereby ensuring that the contaminants fall out of suspension, and that a sludge blanket is created and maintained within the tank. Beneath this sludge blanket, flocculation shall continue to take place, typically by chemical bridging or sweep flocculation mechanisms, and the sludge blanket shall also act as a physical barrier by straining smaller and lighter flocs from the flow, which may not have agglomerated to the extent that they have a sufficient settling velocity to overcome the up-ward flow.

The level of the sludge blanket shall be controlled by the presence of a sludge concentration channel within the clarifier, which shall facilitate periodic bleeds of the sludge blanket. Inadequate sludge bleeding from the blanket will cause it to increase in weight and sink towards the floor of the clarifier, resulting in blockages to the inlet distribution pipework, and a reduction of the space beneath the blanket where flocculation continues to take place. Excessive sludge withdrawal will result in the lighter flocs (with settling velocities less than the surface loading rate) exiting the clarifier to the filters due to the removal of the sludge blanket straining mechanism.

A series of v-notch weir channels shall be mounted across the width of each sludge blanket clarifier, and shall allow the now clarified water to be decanted from the tank to a channel which will convey the flow towards the 1st stage filters. Each of the above clarifier characteristics is described in more detail in the following sections.

### 8.3.2 NUMBER OF SLUDGE BLANKET CLARIFIERS

While the Designer may propose additional sludge blanket clarifiers if required for hydraulic, treatment or redundancy purposes, they shall ensure that, at a minimum, the number of sedimentation tanks as outlined in Table 51 below is provided for within each proposal. The maximum hydraulic load to each sedimentation tank shall be determined by the *Maximum Design Flow* (i.e. daily design demand / 18 hours), with the precise up-flow clarification rate to be determined by the type of high rate clarification system selected (i.e. surface loading rates as recommended by suppliers of lamella or tube settling systems - see Section 7.3.8 below). Regardless of the format of the high rate clarification system, the Designer shall ensure that the full hydraulic load of the plant is evenly distributed over the entire number of clarifiers proposed, in accordance with the following formula.

$$Maximum\ Clarifier\ Capacity\ \left(\frac{m^3}{h}\right) = \frac{Maximum\ Design\ Flow\ (\frac{m^3}{h})}{Total\ No.of\ Clarifiers}$$

| Plant Class | Capacity ($m^3$/d) | Minimum No. of Sludge Blanket Clarifiers |
|---|---|---|

| | | |
|---|---|---|
| **Class A** | < 1,000 | 2 |
| **Class B** | < 5,000 | 3 |
| **Class C** | < 10,000 | 4 |
| **Class D** | < 20,000 | 4 |
| **Class E** | 20,000 – 40,000 | 5 |
| | 40,000 – 60,000 | 6 |
| | > 60,000 | Works capacity ($m^3/d$) / 10,000 |

Table 51: Determination of minimum quantity of sludge blanket clarifiers based on plant capacity and classification.

### 8.3.3 SURFACE LOADING RATES

As stated in the opening paragraph of this section, the aim of the sedimentation process is to create a floc which has a higher settling velocity than the up-flow velocity of the process water as it passes through the clarifier. Maintaining a low flow rate through the clarifier is therefore just as critical to ensuring adequate physical separation as the size of the floc that has been created during coagulation and flocculation. The up-flow velocity ($V_o$) through the clarifier is also known as the surface loading rate, and is expressed in m/h (or $m^3/m^2/h$), and shall be the main parameter used to determine the surface area of the sludge blanket clarification tanks. The use of high rate clarification aids in the form of inclined tube or lamella plate settlers can greatly increase the allowable surface loading rate and as a result decrease the surface area of the sedimentation tanks. In order to minimise capital costs for the construction of sedimentation clarification systems, all sludge blanket clarification processes proposed to Uisce Éireann shall therefore incorporate high rate clarification aids, in accordance with section 7.3.4 overleaf. Precise surface loading rates shall be specified by the manufacturer of the proprietary high rate clarification aid, but shall not exceed the rates as outlined below. All proposals made by Designers shall include documentation which specifies the surface loading rates for the selected clarification aid.

| Description | Allowable Surface Loading Rate (SLR) |
|---|---|
| **No high rate clarification aid used*** | 2 m/h |
| **Lamella Plate Settlers used as high rate clarification aids** | 4 m/h |
| **Inclined Tube Settlers used as high rate clarification aids** | 6 m/h (or as per supplier's literature) |

Table 52: Allowable Surface loading rates. *For comparison only, all Uisce Éireann sludge blanket clarifiers must incorporate high rate clarification aids.

### 8.3.4 SLUDGE BLANKET CLARIFIER SIZING

The minimum allowable surface area dimensions of each sludge blanket clarifier is a function of the *Maximum Clarifier Capacity* as determined in Section 7.3.2, and the *Surface Loading Rate* as determined in Table 52 of Section 7.3.3, and shall be calculated in accordance with the formula below. When the surface area of each sedimentation tank is calculated using these values, the clarification system has been sufficiently sized to accommodate the entire daily hydraulic load of the plant, in a period of 18 hours. Running the plant over a 24 hour period should therefore ensure that the SLR for each clarifier is minimised to the greatest possible extent.

$$Minimum\ Sludge\ Blanket\ Clarifier\ Surface\ Area\ (m^2) = \frac{Maximum\ Clarifier\ Capcity\ (m^3/h)}{Surface\ Loading\ Rate\ (m/h)}$$

Once the Minimum Sludge Blanket Clarifier Surface Area has been established, the physical dimensions of each sedimentation tank shall be determined in accordance with Table 53 below. The Designer shall note that large tanks are susceptible to water turbulence caused by high winds, which may result in the disruption of the sludge blanket and thereby release contaminants to the clarified water. Sludge blanket clarifiers with square footprints will therefore only be permitted for tanks up to 25m$^2$ in surface area. Any tanks with a surface area in excess of this shall be designed to have a long narrow footprint, as outlined in the below table.

| Design Parameter | Dimensional Limits |
|---|---|
| **Minimum Water Depth of Sludge Blanket Clarifier** | 4.00m |
| **Maximum Clarifier Width** | 5.00m |
| **Maximum Clarifier Length** | 24.00m |
| **Maximum Allowable Sludge Blanket Clarifier Surface Area** | 120.00m$^2$ |
| **Minimum Distance from TWL to Top of Sludge Blanket** | 1.20m |
| **Minimum Distance from TWL to Top of Sludge Concentrator Weir** | 1.50m |

Table 53: Determination of sludge blanket clarifier dimensions.

### 8.3.5 CLARIFIER INLET PIPEWORK DESIGN

All flows shall enter the flat bottomed sludge blanket clarifier via a network of pipework laterals from a central distribution header pipe or channel. The laterals shall utilise the full floor area of the clarifier, and ensure that the flow is evenly distributed over the entire surface area of the clarifier. All of the outlet openings in the pipework laterals shall face the floor of the clarification basin, thereby ensuring the up-flow velocities of flocs are minimised by the interruption of their momentum as they leave the lateral pipework. The pipework laterals shall be suspended by a minimum distance of 300mm from the tank floor to allow sufficient space for this to occur. All header pipework over 150mm in diameter shall be of ductile iron construction in accordance with EN545. Header pipework of 150mm diameter or less may be completed in uPVC. All lateral pipework shall be completed in uPVC. The Designer shall ensure that an isolation valve / penstock arrangement in incorporated into the inlet pipework to allow the isolation of each clarifier if required, or to adjust flow rates through each clarifier for flow balancing purposes. An electromagnetic flowmeter shall be installed at the inlet of each sludge blanket clarifier to allow the plant operator to monitor the exact flow entering each basin and to ensure that the hydraulic load is evenly distributed over each clarifier. Uneven hydraulic loading will result in the sup-optimal performance of the overloaded clarifier, and the Designer shall ensure that the hydraulic load is adequately balanced during process commissioning.

### 8.3.6 SLUDGE CONCENTRATOR WEIR AND CHANNEL

The sludge concentrator weir and channel shall be designed as a submerged structure, which has an overflow level at a minimum distance of 1.50m below the top water level (TWL) of the sludge blanket clarifier. The weir and channel shall run the full length of the clarifier basin (perpendicular to the decant launders) and it is common practice to construct the sludge concentrator channel directly above the raw water inlet distribution channel. As the sludge blanket builds, its upper surface (i.e. the most concentrated sludge) shall spill over the sludge concentrator weir and collect in the sludge concentrator channel. This mechanism will continually skim the top layer of the sludge blanket into the concentrator channel, provided that the channel is periodically drained of its contents by the sludge bleeds. Upon initial commissioning of the sludge concentrator system, before the blanket has been fully developed, the sludge channel may possibly be filled with water. However, as the blanket builds during process commissioning, the concentrated sludge that overflows the weir into the channel shall have a higher density than the water in the channel and will displace it. Once the sludge blanket has matured fully, and its level within the tank is carefully managed, then the contents of the sludge concentrator channels should only be alum sludge of a reasonably consistent dry solids content. The time is takes to build an adequate sludge blanket, and also the delicacy of the blanket to pulsating flows, is one of the primary reasons why a sludge blanket clarifier should be operated on a 24 hour basis, with shutdowns confined to periods of essential maintenance only.

### 8.3.7 SLUDGE BLEEDS

Sludge shall be bled from the concentrator channels on a periodic basis, the duration and frequency of which shall be established during process commissioning. Control of the sludge blanket is critical to the optimum performance of the clarifier, and as stated earlier in this section, inadequate sludge bleeding from the blanket will cause it to increase in weight and sink towards the floor of the clarifier, resulting in blockages to the inlet distribution pipework, and a reduction of the space beneath the blanket where the final stage of flocculation continues to take place. Conversely, excessive sludge withdrawal will result in the lighter flocs (with settling velocities less than the surface loading rate) exiting the clarifier to the filters due to the removal of the sludge blanket straining mechanism.

Sludge bleed pipework shall be placed at regular intervals along the length of the sludge concentrator channel, but positioned no further than 1.00m apart in order to ensure equal reduction of sludge content over the channels entire length. Bleeding shall be controlled by an actuated valve on each of the bleed pipes, which may take the form of a solenoid valve, and electrically actuated valve or a pneumatically actuated valve. The bleed valves shall be programmed to open at operator adjustable timed intervals, and remain open for an operator adjustable duration. All of the bleed valves on an individual clarifier shall open simultaneously to ensure than sludge levels are draw down evenly within the sludge channel. Where there are multiple sludge blanket clarifiers on site, the time intervals for bleeding of individual sludge channels shall be staggered so that the hydraulic load to the bled sludge holding tank(s) is distributed evenly throughout the day.

Typical systems allow for 2 minutes of bleeding at 20 minutes intervals on each clarifier, but this will vary from plant to plant, and as such shall be determined on a site by site basis. While initial timings will be set during process commissioning, the system PLC shall allow the operator to adjust bleed duration and interval times.

### 8.3.8 CLARIFICATION AIDS

As described in Section 7.3.3, the surface loading rate of a sludge blanket clarifier may be increased dramatically by the installation of clarification aids in the form of lamella plate or tubular settlers. The ability to increase the surface loading rate will reduce the footprint of the clarifier basins and the additional costs associated with the installation of clarification aids will be offset by a significant reduction in costs associated sedimentation tank construction. The major parameters to be considered when designing a clarification aid for a sedimentation tank are outlined in Table 54 below.

| Design Parameter | Lamella Plate Settlers | Tube Settlers |
|---|---|---|
| **Installed Angle of Inclination (θ)** | 50° - 60° to horizontal plane | 50° - 60° to horizontal plane |
| **Allowable Surface Loading Rate** | 4.00 m/h | 6.00 m/h<br>(or as per supplier's literature) |
| **Allowable distance between plates / Hydraulic diameter of tubes** | 100mm – 200mm | 30mm – 80mm |
| **Minimum Detention time within lamella / tube settler zone** | 20 minutes | 10 minutes |

Table 54: Major design parameters to be considered when designing clarification aid systems.

#### 8.3.8.1 LAMELLA PLATE SETTLER DESIGN

Lamella plate settlers may be sourced from a proprietary supplier or may be designed and built internally by the Contractor. If choosing to proceed in the latter fashion, the Designer shall ensure that the lamella plates are designed and installed in accordance with the requirements of this section of the specification. The principle of design shall be to establish an *Effective Settling Area* within the tank that is at least 2.0 times greater than the actual surface area of the tank, while fulfilling the design criteria as outlined in Table 54.

The *Effective Settling Area* is described by the following formula:

$$Effective\ Settling\ Area = A\ x\ B\ x\ Cos\ \theta\ x\ Minimum\ Number\ of\ Lamella\ Plates$$

Where,

*A = length of lamella plate (m)* *B = width of lamella plate (m)* *Θ = angle of inclination (°)*

As the *Effective Settling Area* is the product of the plate dimensions, the angle of installation and the number of lamella plates, reducing the size of the lamellas will increase the number that need to be installed to achieve an adequate *Effective Settling Area*, and vice versa. The surface loading rate of the clarifier with installed lamellas shall there for be determined using the following formula:

$$Surface\ Loading\ Rate\ (using\ Lamella\ Plate\ Settlers) = \frac{Effective\ Settling\ Area}{Surface\ Area\ of\ Clarifier}\ x\ 2$$

All lamella plates shall be manufactured from PVC, PPTV (talcum reinforced polypropylene), stainless steel or aluminium. Where polymeric based materials are used they shall be UV stabilised to protect against damage from sunlight. All support systems shall be designed with reference to the operational load of the lamellas (i.e. including the weight of attached sludge) and not based on the product weight alone.

#### 8.3.8.2 TUBE SETTLER DESIGN

Tube settlers shall be sourced from proprietary suppliers and the Designer shall submit full manufacturer specifications for each system proposed. All tube settlers shall be manufactured from PVC or PPTV (talcum reinforced polypropylene) and be UV stabilised to protect against damage from sunlight. All support systems shall be designed with reference to the operational load of the tubular blocks (i.e. including the weight of attached sludge) and not based on the product weight alone. An anti-flotation restraint must also be mounted above the blocks to ensure the system stays in position during periods when sludge has not adhered to the surface (i.e. during initial commissioning, building of the sludge blanket or post wash down. The anti-flotation restraint shall also serve a secondary purpose of supporting a GRP open grid decking which will allow plant operators to walk freely over the surface of the tube settlers for inspection and maintenance purposes. GRP panels shall be removable to allow operational staff ease of access to the tube settlers.

### 8.3.9 DECANT LAUNDER

The decant launders shall consist of a series of v-notch weir channels which shall be mounted across the width of each sludge blanket clarifier, and shall allow the now clarified water to be decanted from the tank to a channel which will convey the flow towards the 1st stage filters. The launders shall be fabricated in stainless steel, galvanised mild steel, or GRP and shall not exceed 5m in length. The number of decant launders shall be established by the use of the maximum weir overflow rate, as outline in Table 55 below:

| Design Parameter | Design Criteria |
|---|---|
| **Maximum Weir Overflow Rate** | 10 $m^3/m/h$ ($m^2/h$) |

Table 55: Maximum allowable weir overflow rate.

The number of weirs required shall be determined by the below formulae. Note that the maximum width of any clarifier basins shall not exceed 5.0m, thereby limiting the maximum length of decant launders to 5.0m also.

$$Meters\ of\ weir\ required\ (m) = \frac{Total\ flow\ through\ clarifier\ (\frac{m^3}{h})}{Maximum\ Weir\ Overflow\ Rate\ (\frac{m^2}{h})}$$

$$Number\ of\ weirs\ required = \frac{Meters\ of\ weir\ required\ (m)}{Width\ of\ clarifier\ basin\ (m)}$$

Once the number of weirs is established, the width and depth of each weir shall be determined to adequately convey the proportion of water carried by that weir, in accordance with the following formulae:

$$Flow\ conveyed\ by\ each\ weir\ (\frac{m^3}{h}) = \frac{Total\ flow\ through\ clarifier\ (\frac{m^3}{h})}{Number\ of\ weirs\ required}$$

$$Cross\ sectional\ area\ of\ each\ weir = \frac{Flow\ conveyed\ by\ each\ weir\ (\frac{m^3}{s})}{Maximum\ allowable\ velocity\ (\frac{m}{s})}$$

Note that the maximum allowable velocity in the decant launders shall not be permitted to exceed 0.4 m/s, and the entire cross sectional area required to adequately convey the flow in each channel must be contained below the level the v-notch weir.

## 8.4 INSTRUMENTATION

The operation of sludge blanket clarifiers shall not require automation and are therefore not an instrument heavy process. Instrumentation shall be provided only to monitor and assess the performance of each clarifier proposed. The Designer shall allow for the instruments outlined in Table 56 below to be included in each sludge blanket clarifier proposed. Real time readings from each instrument shall be displayed on the system HMI screen next to a mimic of the instrument, and touching the mimic shall bring up an options page which shall allow the operator to reset alarms, and make adjustments to alarm set points.

| Instrument | Installation Location | Purpose |
|---|---|---|
| **Flow Monitoring** | Each Individual Sludge Blanket Clarifier Inlet | ▪ Monitoring of hydraulic loading<br>▪ Monitoring of hydraulic distribution<br>▪ Flow differential / no flow / high flow alarms |
| **Turbidity Monitors** | Common Outlet Channel on each Sludge Blanket Clarifier | ▪ Monitoring of clarifier performance<br>▪ Monitoring of coagulation and flocculation performance<br>▪ High level alarms |
| **Sludge Blanket Level Monitors** | On each Sludge Blanket Clarifier | ▪ Monitoring of sludge blanket levels to determine optimum bleed duration and frequency<br>▪ High level / low level alarms |

Table 56: Instrumentation required for effective sludge blanket clarifier performance.

## 8.5 PROCESS ALARMS

The Designer shall ensure that the sludge blanket clarification system has the capability to generate alarms in the event of an out of specification clarified water, a hydraulic load imbalance between clarifiers or a significant change in the level of the sludge blanket within the clarifier. Alarms associated with an increase in clarified water turbidity, flow imbalances or sludge blanket variation shall take the form of flashing messages or mimics on the HMI/SCADA screen, text messages to the plant operator and audible alarms or flashing beacons on site. Tables 57 (below) and 58 (overleaf) outline the alarm generation criteria for sludge blanket clarifier performance, and the type of alarm that each occurrence should generate. Unlike Disinfection or Filtration alarm systems, a sludge blanket clarification system alarm may not automatically shut down any stage of the treatment process. Please note that alarms shall not be initiated until 3 consecutive 'out of specification' readings are detected, or until the alarm parameter has persisted for a pre-set, operator adjustable time duration (initially set at 3 minutes).

| Alarm Criteria | Minimum Target Criteria (Alarm) | Critical Control Point (Clarification Shut Down) |
|---|---|---|
| **Clarifier Inlet Flow Rate** | > 5% Imbalance between flow readings | n/a |
| **Clarifier Outlet Turbidity** | > 1 NTU from any individual clarifier | n/a |
| **Clarifier Sludge Blanket Level** | > 20% increase or decrease in sludge blanket level | n/a |

Table 57: Alarm criteria for sludge blanket clarification systems.

The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. However, as Level 1 alarms are only generated in the event of an automatic system shut down, they shall not apply to sludge blanket clarification systems. Table 58 overleaf describes the type of alarm to be issued for each of the alarm generation criteria outlined above.

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | ▪ Flashing Beacon<br>▪ Test Message<br>▪ Flashing Beacon<br>▪ Audible Alarm | ▪ Any breach of Critical Control Point as described in Table 57. (Not applicable to Sludge Blanket Clarifiers) |
| **Level 2** | ▪ Flashing Mimic<br>▪ Test Message | ▪ Individual clarifier turbidity limit exceeded<br>▪ Sludge blanket level increase/decrease threshold exceeded<br>▪ Irregular hydraulic flow imbalance between clarifiers |
| **Level 3** | ▪ Flashing Mimic | ▪ No flow to clarifier (clarifier isolated for cleaning or maintenance purposes) |

Table 58: Alarm grades and methods of alerting supervisory staff for sludge blanket clarification systems.

## 8.6 TESTING

Performance tests on the sludge blanket clarifier shall not commence until the sludge blanket has fully formed, which may take up to 5 days from the initial filling of the tanks, depending on the hydraulic load, the raw water quality and the efficacy of the pH correction and coagulation/flocculation systems. Once upstream processes have been satisfactorily tested, the following shall be completed on the sludge blanket clarifiers.

Demonstration of Maximum Hydraulic Load

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative, that the maximum hydraulic design load can be passed through the clarification system, and achieve the turbidity limits as set out in Table 49. As well as demonstrating the effectiveness of the sludge blanket clarification system, this test will also demonstrate the efficacy of the upstream pH and alkalinity adjustment processes and the coagulation and flocculation systems. Flow to each of the clarifiers will be balanced by the adjustment of the inlet valves to the sedimentation tanks and the Designer shall demonstrate that the hydraulic loads are adequately distributed within the allowable threshold as set out in Table 57. The maximum hydraulic load test will be completed at full hydraulic capacity over a period of 4 hours.

Maintenance of Sludge Blanket

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative, that the sludge bleed rates, durations and frequency are sufficient to maintain the sludge blanket at the desired level, and that increases and decreases in sludge blanket level are maintained within the thresholds as set out in Table 57. Once the sludge bleed frequencies and durations are established, the Designer shall record the increase and decrease in the sludge blanket level every day for a period of 14 consecutive days, and present the results to Uisce Éireann or their representative.

Turbidity and TOC Removal

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative that the turbidity and TOC of the water entering the downstream filtration system is of an acceptable level. The turbidity shall be continually measured by the online turbidity monitor installed at each clarifier outlet and shall be compliant with the limits as set out in Table 49. The TOC may be determined by laboratory testing or by the installation of a temporary UVA monitor, and shall be shown to be consistently less than 3.00mg/L for each test completed. Turbidity and UVA testing shall be completed once per day for a period of consecutive 14 days.

# 9 CLARIFICATION – DISSOLVED AIR FLOTATION (DAF) SYSTEMS

Clarification is a key process element of high production water treatment plants, and if designed correctly in tandem with an upstream coagulation system, offers a reliable and efficient method of reducing suspended solids, turbidity, colour and organic carbon concentrations in advance of filtration. Reducing the loading applied to the filters by removal of the heavier contaminants greatly increases the run time and efficiency of the filtration stages, and consequently decreases operational costs, treated water wastage and filter down time; mostly as a result of less frequent backwashing. The inclusion of a clarification step in the water treatment process allows the filtration stage to specifically concentrate on the very fine contaminants that remain. While sedimentation processes have historically been used to achieve clarification, there are some types of raw waters where flotation of the contaminants is a more appropriate solution. Light waters with low turbidity, but high colloidal solids and TOC levels (typically found in lake sources) often contain very small contaminants which may be difficult to settle, even with an effective coagulation and flocculation system. In addition, biological contaminants such as algae can be extremely difficult to remove in a sedimentation system, and must therefore be floated out of the process flow to facilitate effective removal of taste and odour causing compounds (Methylisoborneol and Geosmin). The most appropriate way to achieve this is by a dissolved air flotation (DAF) process.

Clarification systems shall be implemented upstream of filtration processes on all treatment plants which take their raw water supplies from surface water (rivers, lakes or impoundments) or low quality groundwater (boreholes in karst limestone areas, unprotected wells, etc.) sources. The type of clarification system proposed will be dependent on the raw water quality parameters, but as described above, flotation systems are most suited to light raw waters with low turbidity levels and high colloidal / TOC concentrations (i.e. lakes and impoundments). The table below outlines a generalised guide as to where sedimentation or flotation systems should be used, but ultimately the decision is more complex than the table suggests, and the Designer shall determine the most appropriate clarification process by taking account of all pertinent parameters on a site by site basis. For example, if there is a particular concern regarding non-settleable contaminants such as algae, then flotation technologies may be considered, regardless of whether the source experiences occasional high turbidity levels.

| Peak Raw Water Turbidity | Raw Water TOC | Seasonal Algal Load | Typical Clarification |
|---|---|---|---|
| < 10 NTU | < 2 mg/L | High | Dissolved Air Flotation |
| < 10 NTU | > 2 mg/L | High | Dissolved Air Flotation |
| > 10 NTU | < 2 mg/L | Low | Sedimentation |
| > 10 NTU | > 2 mg/L | Low | Sedimentation |

Table 59: General guidance for the selection between sedimentation or flotation clarification processes.

Dissolved air flotation is an effective alternative to sedimentation because it utilises minute air bubbles which attached to light suspended contaminants and encourages them to float. As such, the importance of how a differing coagulation and flocculation system is required for DAF and sedimentation processes becomes clear; for DAF the aim is to create a small, light floc that will be easily floated, whereas for sedimentation the aim is to create a large heavy floc that will rapidly settle. The challenge for DAF Designers is to create an appropriately sized floc, as well as an appropriately sized microbubble which will facilitate effective attachment and flotation.

Once the contaminants have been floated in the DAF process, they will attach to a layer of sludge which sits on the water's surface. From here the sludge is skimmed off, leaving clarified water at the base of the tank. Due to the requirements for smaller flocs, the time required for flocculation is less than that required for sedimentation, and the hydraulic surface loading rate of a DAF tank may be up to 10 times that of an unaided (i.e. no lamella / tubular settlers) conventional sedimentation system. In addition, because the sludge 'blanket' in the DAF sits on the clarified water's surface and is not submerged as it is a sedimentation system, the dry solids content of the sludge is greatly increased. It is typical for DAF sludge to have a dry solids content (DSC) of 2 – 3%, whereas sludge bled from a sedimentation process will typically have a DSC of 0.5%. This has enormous implications on the cost of storing and/or dewatering sludge onsite.

As the contaminants in a dissolved air flotation system are floated to the surface of the tank, the clarified water sits at the bottom of the tank. It is therefore possible to incorporate an integrated filter to the base of a DAF tank resulting in both clarification and filtration stages occurring within the one structure. This process is known as dissolved air flotation and filtration (DAFF) and is discussed further in Section 8.3.10, as well as throughout this section of the specification. The Designer shall note however, that DAFF systems shall only be acceptable to Uisce Éireann on Class A (< 1,000 m$^3$/d) and Class B (< 5,000 m$^3$/d) treatment plants. All Class C, D and F plants which utilise flotation processes shall have separated DAF and filtration stages.

## 9.1 WATER QUALITY PERFORMANCE GOALS

The proposed clarification system, in conjunction with the upstream coagulation and flocculation processes, shall be capable of continually producing a water with a turbidity of < 1 NTU. This standard of water is required by all physical clarification processes so that subsequent filtration stages may achieve the < 0.1 NTU turbidity standards required (see Uisce Éireann specification TEC-900-04: Filtration). Effective coagulation, flocculation and clarification is also essential to ensuring that a UVA of 0.035cm$^{-1}$ (92% UVT) is achieved in filtered water, thus removing the potential for disinfection by-product formation. All dissolved air flotation systems proposed shall incorporate turbidity monitors on the outlet from each tank to verify that effective clarification is achieved.

| Water Quality Requirements | Parametric Design Value | Performance Requirements |
|---|---|---|
| **Turbidity** | < 1 NTU | 99% of samples |

Table 60: Water quality performance goals post clarification and prior to filtration.

## 9.2 DETERMINATION OF MAXIMUM DESIGN FLOW

One of the major benefits of a DAF system over a sedimentation process is the ability to vary the flow or shut down the flow entirely without affecting the quality of performance. Because a DAF does not depend on the gradual development and maintenance of a sludge blanket, the process can be shut down and restarted at any time, with effective clarification achievable almost immediately once the floc and bubble sizes are optimised. This characteristic allows variation of the hydraulic load to the clarification system, or complete system shut down if receiving reservoirs are full, or if planned or emergency maintenance is required. It also allows the completion of periodic filter backwashing where DAFF systems are proposed. This is in contrast to sedimentation plants which require constant and consistent flow in order to operate effectively, with the hydraulic load evenly distributed over a 24 hour period. Nevertheless, all Designers proposing DAF or DAFF systems proposed shall, as much as is reasonably practicable, ensure that the entire design hydraulic load is evenly distributed over a 24 hour period. In order to build some flexibility into system designs, and to allow for fluctuations in hydraulic loading, the Designer shall use the maximum, minimum and average design flows in accordance with Table 61 below when sizing DAF or DAFF systems across all new build water treatment infrastructure.

| Design Flow | Calculated Figure |
|---|---|
| **Minimum Design Flow ($m^3/h$)** | Daily Design Demand ($m^3/d$) / 22 hours |
| **Average Design Flow ($m^3/h$)** | Daily Design Demand ($m^3/d$) / 20 hours |
| **Maximum Design Flow ($m^3/h$)** | Daily Design Demand ($m^3/d$) / 18 hours |

Table 61: Determination of maximum, average and minimum design flows.

## 9.3 DAF / DAFF DESIGN

This section of the document outlines Uisce Éireann's baseline requirements for the initial process design and subsequent operation of dissolved air flotation (DAF) and dissolved air flotation filtration (DAFF) systems. While the Designer may configure their arrangements and layouts to best suit site restrictions, the upstream process and raw water quality parameters, the figures quoted in this section indicate the minimum requirements for robust clarification performance and the Designer shall, at a minimum, ensure that their proposal meets the criteria as set out in the following sections. Included in Appendix B of this document is a table which the Designer shall complete and submit with their tender, which outlines their proposed design criteria for the DAF / DAFF process. This table shall be used to determine if the Designer's proposal has met the minimum design requirements as set out below.

### 9.3.1 GENERAL DESCRIPTION

Coagulation for DAF/DAFF clarification systems shall be as described in Section 5 of this document, with high rate G values as described in Table 34 specifically selected to initiate growth of a floc suitable for flotation. Mixing may be achieved by the use of a flash mixer, inline blender or static mixer – however static mixers shall only be used when the flow is non-variable as reduced flow results in a reduced G value. Flocculation of the charge neutralised contaminants shall be as described in Section 6 of this document, with the G values as described in Tables 42 specifically selected to grow the floc to an appropriate size for attachment to a generated microbubble. Flocculation for DAF/DAFF processes shall be completed by a vertical turbine mixer mounted in a tank sized in accordance with Table 42. Note that flocculation for DAF/DAFF processes requires high speed mixing with low retention times, in contrast with flocculation for sedimentation which requires low speed mixing with high retention times.

Coagulated and flocculated water shall enter the DAF/DAFF contact zone at a low level where it will be mixed with the white water (air saturated water) that has been recirculated from the separation zone. It is in the contact zone that the microbubbles attach to the small agglomerated contaminants. The flow will be forced upwards, until it overflows the baffle wall that divides the contact zone from the separation zone. The top of this baffle wall will be inclined toward the separation zone to reduce disruption to the floating sludge layer. As the water flows over the baffle wall, a certain proportion of the contaminants will become enmeshed at the base of the sludge layer, but the majority will enter the separation zone with the process flow. However, the process water / white water mixture shall have such a high concentration of air that the bubbles will continue to float to the surface, bringing the attached contaminants with them. This will continue over the entire length of the DAF/DAFF tank, with contaminants continually attaching to the base of the floating sludge layer. The result is that the clarified water is contained within the lower regions of the tank, with the contaminants collected on the water surface. For DAF plants, the clarified water continually flows from the lower regions of the tank and is forwarded to 1st stage filtration, typically by gravity. For DAFF plants, the low level water in the tank continually passes through the integrated filtration system in the base of the DAFF prior to disinfection.

### 9.3.2 NUMBER OF DAF/DAFF TANKS

While the Designer may propose additional dissolved air flotation tanks if required for hydraulic, treatment or redundancy purposes, they shall ensure that, at a minimum, the number of DAF/DAFF tanks as outlined in Table 62 below is provided for within each proposal. The maximum hydraulic load to each DAF/DAFF tank shall be determined by the *Maximum Design Flow* (i.e. daily design demand / 18 hours). Regardless of the number for DAF/DAFF tanks proposed, the Designer shall ensure that the full hydraulic load to the plant is evenly distributed over the entire number of tanks proposed, in accordance with the following formula.

$$Maximum\ DAF/DAFF\ Capacity\ \left(\frac{m^3}{h}\right) = \frac{Maximum\ Design\ Flow\ (\frac{m^3}{h})}{Total\ No.of\ DAF\ /\ DAFF\ Tanks}$$

| Plant Class | Capacity ($m^3$/d) | Minimum No. of DAF / DAFF Tanks |
|---|---|---|
| **Class A** | < 1,000 | 1 |
| **Class B** | < 5,000 | 2 |
| **Class C** | < 10,000 | 3 |
| **Class D** | < 20,000 | 4 |
| **Class E** | < 30,000 | 5 |
| | < 40,000 | 6 |
| | < 50,000 | 8 |
| | > 60,000 | As required |

**Table 62: Determination of minimum quantity of DAF / DAFF clarification systems based on plant classification.**

### 9.3.3 SURFACE LOADING RATES

The surface loading rate that may be applied to the separation zone of a DAF/DAFF is much higher than that which can be applied to a sedimentation tank, resulting in a much reduced tank footprint. However the surface loading rate shall be used to determine the appropriate size of the separation zone only; coagulation and flocculation tanks, as well as the contact zone must be sized separately. High rate DAF technologies are available from proprietary manufacturer's which offer a surface loading rate which is higher again than conventional DAFs. Precise surface loading rates for proprietary systems shall be specified by the manufacturer/designer of the high rate DAF systems but shall not exceed the rates as outlined below. Note that high rate systems may not incorporate filtration stages (DAFF) as the surface loading rates are too high for an integrated filter.

| Description | Allowable Surface Loading Rate (SLR) |
|---|---|
| **Conventional DAF / DAFF** | 10 m/h |
| **High Rate DAF** | < 30 m/h |

**Table 63: Allowable Surface loading rates. *For comparison only, all Uisce Éireann sludge blanket clarifiers must.**

### 9.3.4 DAF / DAFF SIZING

Coagulation and flocculation systems for DAF/DAFF clarification plants shall be sized as described in Sections 5.5 and 6.2 of this document. Flash tanks and flocculation tanks may be integrated into a common wall tank which also contains the contact zone and separation zones of the DAF/DAFF system. Each contact zone and separation zone shall be sized in accordance with the figures outlined in Table 64 and 65 below. Note that the separation zone is defined as the area between the contact zone baffle wall and the sludge beach.

| Contact Zone Design Parameter | Design Criteria |
|---|---|
| Contact Zone Detention Time | 60 – 240 s |
| Contact Zone Hydraulic Loading Rate | 35 – 100 m/h |
| Contact Zone Baffle Angle | 60° - 90° to the horizontal |

**Table 64: Critical figures for DAF / DAFF Contact Zone design.**

The minimum allowable surface area dimensions of each separation zone is a function of the *Maximum DAF / DAFF Capacity* as determined in Section 8.3.2, and the *Surface Loading Rate* as per Table 63, and shall be calculated in accordance with the formula below. When the surface area of each separation zone is calculated using these values, the clarification system has been sufficiently sized to accommodate the entire daily hydraulic load of the plant, in a period of 18 hours. Running the plant over a 24 hour period should therefore ensure that the SLR for each DAF is minimised to the greatest possible extent.

$$Minimum\ Separation\ Zone\ Surface\ Area\ (m^2) = \frac{Maximum\ DAF\ /\ DAFF\ Capcity\ (m^3/h)}{Surface\ Loading\ Rate\ (m/h)}$$

Once the Minimum Separation Zone Surface Area has been established, the physical dimensions of each separation zone shall be determined in accordance with Table 65 below. To facilitate construction of the chain and flight sludge removal system, DAF/DAFF systems shall be no wider than 3.00m. DAF/DAFF systems with square footprints will therefore only be permitted for separation zones up to 9m$^2$ in surface area. Any separation zones with a surface area in excess of this shall be designed to have a long narrow footprint, as outlined in the below table. Note that all DAF/DAFF systems that are installed outdoors shall be fully enclosed with a clear poly-carbonate cover to allow observation while also preventing disruption to the sludge layer by rain and high winds.

| Separation Zone Design Parameter | Design Criteria |
|---|---|
| Surface Loading Rate (Conventional DAF/DAFF) | 10.00 m/h |
| Surface Loading Rate (High Rate DAF) | < 30.00 m/h |
| Maximum Separation Zone Length | 11.00m |
| Maximum Separation Zone Width | 3.00m |
| Minimum Separation Zone Depth* (DAF) | 3.00m |
| Minimum Separation Zone Depth* (DAFF) | 4.50m |

**Table 65: Critical figures for DAF / DAFF Separation Zone design. *From TWL to Tank Floor – DAFF requires extra 1.50m to accommodate filter underdrain, media support system and sand/anthracite dual media filter bed.**

Where DAFF systems are proposed, they shall consist of dual media filters and be in full accordance with Uisce Éireann Design Specification TEC-900-04 in order to allow a filtration rate of 10m/h. This will facilitate the operation of an effective system as the surface loading rates for the conventional DAFF and the filtration rate for the integrated filter are equal. An integrated filter cannot be proposed on a high rate DAF system as the surface loading rate will typically be far in excess of the maximum allowable filtration rate.

### 9.3.5 DAF / DAFF RECIRCULATION SYSTEM

For a DAF process, the recirculation system shall take its supply either from a tee on the clarified water outlet, or from an independent outlet located at a distance of between 0.50m and 0.75m from the floor of the tank. For a DAFF process, the recirculation system shall be taken from a tee on the filtered water outlet, or from an independent outlet located between the DAF false floor and the base of the tank. Design of the recirculation system shall be in accordance with the Table 66 below. All recirculation pumps shall be operated on variable speed drives so that the flow and pressure can be adjusted in order to generate the optimum bubble size.

| Recirculation System Design Parameter | Design Criteria |
|---|---|
| Recirculation Flowrate | 8 – 12% of flow through DAF / DAFF |
| Recirculation System Pressure | 5 – 7 bar |

Table 66: Critical figures for DAF / DAFF recirculation system design.

### 9.3.6 WHITE WATER GENERATION SYSTEM

The micro-bubbles, or white water, which form the basis for dissolved air flotation shall be formed in one of two ways; by routing the recirculated water through an air saturator or by using a dedicated micro-bubble generator turbo pump. These methods are described in more detail in the following sub-sections, but regardless of which method is proposed, the generated micro-bubbles shall be in accordance with the contents of Table 67 below.

| Microbubble Design Parameter | Design Criteria |
|---|---|
| Micro-bubble Size | 10 – 100 µm |
| Micro-bubble Concentration | 1 – 2 x $10^5$ bubbles / mL |

Table 67: Critical figures for DAF / DAFF microbubble generation.

#### 9.3.6.1 AIR SATURATION SYSTEM

Air saturation systems shall comprise of a saturator pressure vessel which is packed with an inert mass transfer media such as pall rings. Recirculated clarified water shall be pumped through the saturator, entering the vessel at a high level. A supply of compressed air shall also be injected into the vessel at a high level and at a pressure higher than that of the recirculated water. As the air and water mixture passes over the mass transfer media, the saturation efficiency of the system is greatly enhanced. At the base of the vessel, air saturated water will pool, and will be transferred under pressure to the DAF/DAFF contact zone. A level switch, typically a Mobrey float switch, will control the recirculation pump and air compressor to ensure the top water level of the air saturated water pool remains consistent. Sufficient back pressure shall be maintained in the system by a series of valves on the white water injection drop nozzles. A pressure drop across the saturation vessel shall be expected, and the recirculation pumps and air compressor shall be sized sufficiently so as to maintain the pressures required at the vessel outlet to generate an appropriately sized bubble for effective DAF/DAFF operation. Air saturation vessels shall be design in accordance with the contents of Table 68 below.

| Air Saturation Design Parameters | Design Criteria |
|---|---|
| Air Saturator Hydraulic Loading Rate | 60 – 80 m/h |
| Mass Transfer Media Packing Depth | 1.0 – 1.50m |
| Air Loading | 6 – 10 g Air / $m^3$ Process Water |

| | |
|---|---|
| Saturation Vessel Rated Pressure | 10 bar |
| Air Compressor Rated Pressure | 10 bar |

**Table 68: Critical figures for air saturation vessel design.**

#### 9.3.6.2 MICRO-BUBBLE GENERATION PUMP

An alternative system to the air saturation pressure vessel method is the use of a micro-bubble generation system which shall comprise a micro-bubble turbo mixer pump and an excess air separation tank. No mass transfer media or compressed air system is required. This type of pump shall have the capability to recirculate the clarified water at the required rate and pressure, but shall also incorporate an air intake which will allow the generation of the micro-bubble in the volute of the pump. The air intake nozzle shall incorporate an air filter, flow control valves, non-return valves and an air flow meter so that the quantity of air entering the process flow can be measured and adjusted. The excess air separation tank shall be a bottom entry / bottom exit pressure vessel rated for a maximum pressure of 10 bar. Air that has not been saturated in the process water will collect at the top of the tank and be released via an adjustable air release valve. The white water may be injected directly to the DAF/DAFF contact zone inlet pipe, or via a series of injection drop nozzles. Valves on the nozzles (or a valve on the single injection pipe) shall be utilised to maintain an adequate backpressure on the system.

### 9.3.7 WHITE WATER INJECTION SYSTEM

White water that has been created by an air saturation system or by a micro-bubble generation pump may be injected into the inlet pipe to the DAF/DAFF contact zone, or alternatively, injected directly to the contact zone by a series of injection drop nozzles. For designs where the flocculation tank has been incorporated into the main DAF/DAFF structure, there is typically no contact zone inlet pipe, as the water will generally flow under a low level baffle between the flocculation tank and the contact zone. In such instances the drop nozzle system shall be used. Regardless of the method chosen, a valve system shall be employed to maintain the backpressure required for micro-bubble generation. For drop nozzle systems, each drop pipe will have its own ball valve so that the pressure can be equalised across the length of the header pipe; i.e. valves on drop pipes furthest from the air supply shall be opened slightly more to ensure even distribution of white water across the full width of the contact zone. Note that injection drop nozzles shall be spaced no further than 0.2 – 0.3m apart. Systems which inject to the contact zone inlet pipe shall incorporate a flow control valve, as well as a non-return valve to prevent back flow in the event of recirculation system shutdown.

### 9.3.8 SLUDGE REMOVAL SYSTEM

The sludge layer shall be removed by a chain and flight scraper system which shall rotate continuously, and move the sludge layer towards a sludge pocket which will be mounted at the other end of the DAF/DAFF from the contact zone. Sludge will be transferred to the sludge pocket via a sludge beach, which shall extend beneath the base of the sludge layer. The chain and flight blades will drag the sludge up and over the beach until it falls into the trough. As the sludge from a DAF/DAFF process typically has a dry solids content of 2 – 3%, the walls of the pocket shall be at an angle of no less than 60° to the horizontal. The pocket outlet shall direct the sludge to a sludge holding tank for storage or dewatering prior to removal off site. Transfer of sludge from pocket to storage may be pumped or by gravity, depending on the hydraulics or proximity of the sludge tank. On the rare occasions where DAF systems are deployed on high turbidity water sources (i.e. for algae removal purposes, etc.) where turbidity occasionally exceeds 25 NTU, a base scraper system shall also be incorporated on the floor of the DAF to remove heavier solids that may have settled out of the process. Base scrapers shall discharge sludge to a low level trough at one end of the DAF from where it will be occasionally pumped to storage as required.

### 9.3.9 DAF OUTLET ZONE

All DAF systems shall incorporate an outlet zone which shall prevent variation of the top water level within the DAF separation zone. This is important because if the level of the floating sludge layer is reduced, then it will fall below the sludge beach and effective sludge removal will not be possible. The outlet zone will be created by the construction / fabrication of a baffle wall between the sludge pocket and the outlet of the DAF. This baffle will force the flow of clarified water under the sludge pocket and subsequently over the baffle, thereby maintaining a consistent top water level within the DAF separation zone. The diagram below shows the outlet zone, as well as other component parts of a DAF system as discussed in previous sections. The Designer may choose to propose a micro-bubble generation pump system in place of the illustrated air saturation system.

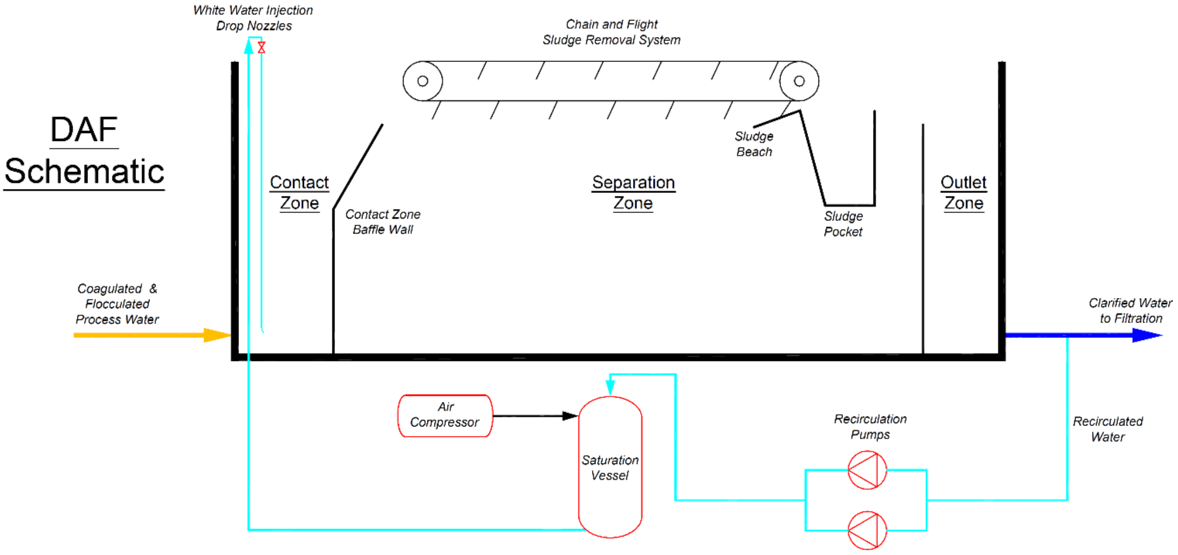


Diagram 16: DAF Schematic showing contact, separation and outlet zones, in addition to major component parts.

### 9.3.10 DISSOLVED AIR FLOTATION & FILTRATION (DAFF)

For DAFF systems, the tank layout shall take the general form as shown below, and all filtration details shall be in accordance with Uisce Éireann’s design specification TEC-900-04. Note that no outlet zone is required on a DAFF tank. The Designer may choose to propose a micro-bubble generation pump system in place of the illustrated air saturation system. DAFF systems shall only be proposed on Class A or Class B treatment plants.

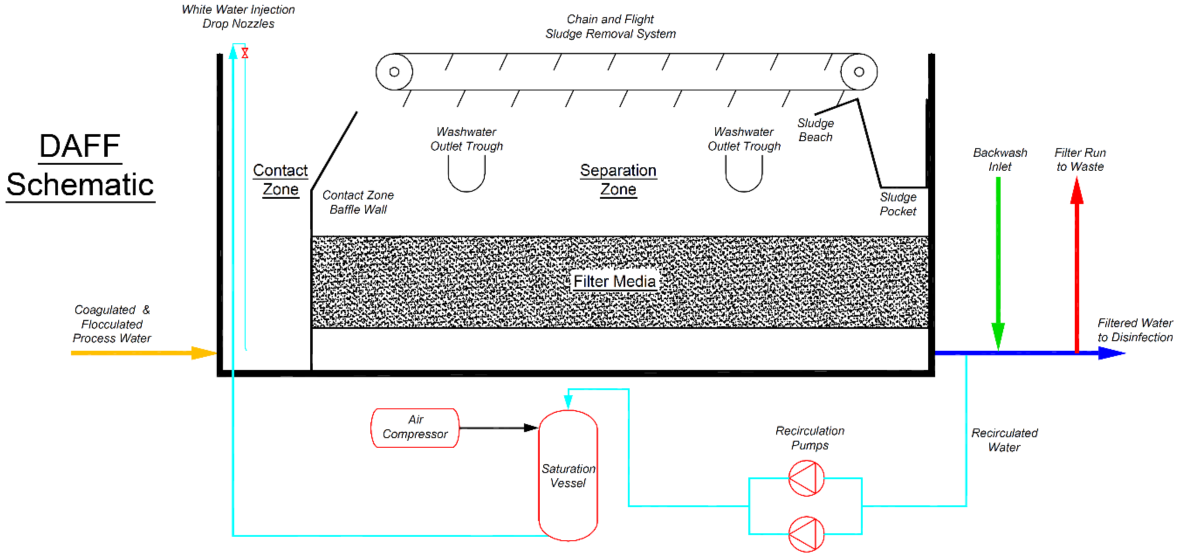


Diagram 17: DAFF Schematic showing contact, separation and filtration zones, in addition to major component parts.

## 9.4 INSTRUMENTATION

While using a DAF/DAFF process will allow a smaller clarification footprint, the operation of a flotation clarification system is a reasonably complex process when compared to a sludge blanket clarifier, and shall therefore require a significant amount of instrumentation for automation and performance monitoring. The Designer shall allow for the instruments outlined in Table 69 below to be included in each DAF/DAFF system proposed. Real time readings from each instrument shall be displayed on the system HMI screen next to a mimic of the instrument, and touching the mimic shall bring up an options page which shall allow the operator to reset alarms, and make adjustments to alarm set points.

| Instrument | Installation Location | Purpose |
|---|---|---|
| **Water Flow Monitoring** | Each individual DAF/DAFF Inlet | - Monitoring of hydraulic loading<br>- Monitoring of hydraulic distribution<br>- Flow differential / no flow / high flow alarms |
| | Recirculation Line *(downstream of saturation vessel)* | - Control and Monitoring of recirculation rate |
| **Turbidity Monitors** | DAF Outlet Zone<br>or<br>DAF Outlet Pipe | - Monitoring of clarifier performance<br>- Monitoring of coagulation and flocculation performance<br>- High level alarms (> 1 NTU) |
| | DAFF *(from a sampling point above the filter media)* | - Monitoring of clarifier performance<br>- Monitoring of coagulation and flocculation performance<br>- High level alarms (> 1 NTU) |
| | DAFF *(on outlet pipe to determine turbidity of filtrate)* | - Monitoring of combined clarifier and filter performance<br>- Monitoring of coagulation and flocculation performance<br>- Control of filter backwashing<br>- High level alarms (> 0.1 NTU for 95% of filter run time) |
| **Level Monitoring** | Saturation Vessel *(typically a Mobrey float switch)* | - Monitoring TWL of air saturated water pool<br>- Control of recirculation pump<br>- High / low saturated water pool level alarms |
| | Sludge Pocket *(only required if sludge is pumped to storage)* | - Monitoring TWL of sludge in sludge pocket<br>- Control and protection of sludge transfer pump<br>- High sludge level alarms |
| **Pressure Monitoring** | Recirculation Line *(after sat. vessel)* *Pressure Transducer and Mechanical Gauge required* | - Monitoring white water pressure to confirm effective micro-bubble generation<br>- Upstream and downstream of micro-bubble generation turbo pumps<br>- High / low pressure alarms |
| | Saturation Vessel *(Mechanical Gauge only)* | - Monitoring pressure in saturation vessel<br>- High / low pressure alarms |
| | DAFF *(Loss of Head Monitor)* | - Control of filter backwashing in addition to turbidity and interval timer (see TEC-900-04 for details). |
| **Air Flow Monitoring** | Air Intake of each micro-bubble generation turbo pump | - Monitor air flow rate to allow adjustment of air loading<br>- High / low air flow alarms |
| **Torque Overload** | Chain and flight sludge removal system | - Shut down of chain and flight system upon detection of high torque<br>- High torque alarm |

**Table 69: Instrumentation required for effective DAF/DAFF clarifier performance.**

## 9.5 PROCESS ALARMS

The Designer shall ensure that the DAF/DAFF clarification system has the capability to generate alarms in the occurrence of any of the alarm criteria listed in Table 70 below. Alarms shall take the form of flashing messages or mimics on the HMI/SCADA screen, text messages to the plant operator and for certain incidences, audible alarms or flashing beacons on site. Tables 70 and 71 below outline the alarm generation criteria for DAF / DAFF performance, and the type of alarm that each occurrence should generate. Please note that alarms shall not be initiated until 3 consecutive 'out of specification' readings are detected, or until the alarm parameter has persisted for a pre-set, operator adjustable time duration (initially set at 3 minutes).

| Alarm Criteria | Minimum Target Criteria (Alarm) | Critical Control Point (Clarification Shut Down) |
|---|---|---|
| **DAF / DAFF Inlet Flow Rate** | > 5% Imbalance between flow readings | No inlet flow (shut down of chain & flight and recirculation system) |
| **DAF / DAFF Recirculation Line** | 10% increase/decrease in flow | No recirculation flow (while inlet flow is positive) |
| **DAF / DAFF Outlet Turbidity** | > 1 NTU from any individual DAF<br>> 1 NTU above the media in any DAFF<br>> 0.1 NTU from any individual DAFF (for 95% of filter run time) | - |
| **Air Saturated Water Level** | To be determined during process commissioning | - |
| **Sludge Pocket Level** | To be determined during process commissioning | - |
| **Recirculation Line Pressure** | ± 0.5 bar from optimum pressure as set during process commissioning | - |
| **Air Flow Monitoring** | 10% reduction from optimum air flow as set during process commissioning | - |
| **Torque Overload** | 5% increase in measured torque | 10% increase in measured torque (shut down chain and flight system only) |

Table 70: Alarm criteria for DAF / DAFF clarification systems.

The system shall be capable of generating three different alarm grades, Level 1 being the most serious, and Level 3 being the least. Table 71 below describes the type of alarm to be issued for each of the alarm generation criteria outlined above.

| Alarm Level | Alarms Generated | Generation Criteria |
|---|---|---|
| **Level 1** | ▪ Flashing Beacon<br>▪ Test Message<br>▪ Flashing Beacon<br>▪ Audible Alarm | ▪ No recirculation flow when inlet flow is positive<br>▪ Increase in chain and flight measured torque |
| **Level 2** | ▪ Flashing Mimic<br>▪ Test Message | ▪ Individual DAF / DAFF turbidity limit exceeded<br>▪ Consistent low level for air saturated water<br>▪ Consistent high level in sludge pocket<br>▪ Increase / decrease in recirculation line pressure<br>▪ Irregular hydraulic flow imbalance between clarifiers<br>▪ 10% reduction in air flow rate from optimum set point |
| **Level 3** | ▪ Flashing Mimic | ▪ No flow to DAF/DAFF (clarifier isolated for cleaning or maintenance purposes) |

Table 71: Alarm grades and methods of alerting supervisory staff for sludge blanket clarification systems.

## 9.6 TESTING

Performance tests on the DAF/DAFF clarification may commence once the system is operational. Once upstream pH / alkalinity adjustment, coagulation and flocculation processes have been satisfactorily tested, the following shall be completed on each of the DAF/DAFF tanks.

Demonstration of Maximum Hydraulic Load

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative, that the maximum hydraulic design load can be passed through the clarification system, and achieve the turbidity limits as set out in Table 60. As well as demonstrating the effectiveness of the flotation system, this test will also demonstrate the efficacy of the upstream pH and alkalinity adjustment processes and the coagulation and flocculation systems. Flow to each of the DAF/DAFF systems will be balanced by the adjustment of the inlet valves/penstocks to the head of each process stream (which may be a flash tank or a flocculation tank if the systems have been combined into one structure), and the Designer shall demonstrate that the hydraulic loads are adequately distributed within the allowable threshold as set out in Table 70. The maximum hydraulic load test will be completed at full hydraulic capacity over a period of 4 hours.

Sludge Float Efficiency and Removal

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative, that the contaminants are adequately floated and the creation of the sludge float is sufficient. In addition, the effectiveness of the sludge removal system (chain and flight system) shall be demonstrated and shown to not have detrimental effects relating to the re-release of flocs to the clarified water beneath (caused by disturbance of the sludge as the blades enter and leave the float).

Turbidity and TOC Removal

The Designer shall demonstrate, to the satisfaction of Uisce Éireann or their representative that the turbidity of the water entering the downstream filtration system is of an acceptable level. The turbidity shall be continually measured by the online turbidity monitor installed at each DAF outlet and shall be compliant with the limits as set out in Table 60. For DAFF systems a sampling outlet shall be provided above the filter level to allow measurement of the turbidity of the clarified water, and the turbidity shall also be measured at the filtrate outlet. Turbidity and testing shall be completed once per day for a period of consecutive 14 days.

# 10 COMPLIANCE SAMPLING POINTS

The Contractor shall install a raw water sampling point and a clarified water sampling point for microbial compliance sampling and testing. The raw water sampling point shall be located upstream of any treatment processes so that it is representative of the raw water entering the works. The clarified water sampling point shall be located between the clarification process (sedimentation / DAF) and the downstream filtration process. The distance of the raw water sampling point upstream of the first treatment process intervention shall be kept to a minimum. Similarly, the distance of the clarified water sampling point downstream of the clarification process shall be kept to a minimum.

The Contractor shall refer to the UÉ Draft Sample Point Specification for the requirements relating to sampling points. If not otherwise set out by the Sample Point Specification, the compliance sampling points shall comply with the below requirements:

- All materials used for the construction of sampling points shall be approved for use in contact with drinking water;
- The compliance sampling points shall be solely for the purpose of manual microbial-compliance sampling, i.e. they shall be completely separate from any instrument sampling lines. The sampling line shall be dedicated use only and not connected to any other equipment, or used for other purposes;
- The sampling point shall be located on the main water pipe and not on a branch line, spur main, dead leg or a location where the water flow is otherwise considered not to be representative of the water in the main process pipe;
- The sampling line shall tap into the main process pipework by a reducing tee fitting or a purpose-made tapping saddle, and it shall not protrude inside the pipe wall of the water main;
- The sampling line shall be a short as possible (e.g. shall not be routed back to a centralised sampling area), not to include any fittings or junctions that could cause stagnation, and installed in a manner that facilitates routine flushing at maximum flow rate;
- The sampling line should connect to the main piping immediately downstream form a valve, elbow or fitting that cause turbulent flow (i.e. from a point where the sample is well mixed);
- The sampling line shall incorporate a shut-off valve immediately downstream of the tapping point on the main water pipe;
- The sampling line and tap shall be adequately protected from frost and extreme weather, as well as protected against contamination and vandalism;
- There should be adequate supply of water to the tap at all times to allow a steady unchanging even flow. Appropriate drainage shall be provided for discarded and flushing water;

Note that unlike microbial sampling points installed at any point downstream of the filtration process, there is no requirement for the raw water and clarified water sampling points to be sterilised by flame

# APPENDIX A – SLUDGE BLANKET CLARIFIER DESIGN

The designer shall complete the below questionnaire for each sludge blanket clarification system proposed. The completed questionnaire shall be submitted with the designer's tender to demonstrate compliance with the Uisce Éireann CFC Design Specification.

| **B1.0 – GENERAL INFORMATION** | | | |
|---|---|---|---|
| **Project Title** | | **Document Reference** | |
| **Project Reference Number** | | **Revision** | |
| **Project Location** | | **Date** | |
| **Designer** | | **Reference Drawings** | |

| **B2.0 – APPLICATION** | |
|---|---|
| **Plant Class** | |
| **No. of S.B. Clarifiers Proposed** | |

| **B3.0 – DESIGN FLOWS** | |
|---|---|
| **Minimum Design Flow (m$^3$/h)** | |
| **Average Design Flow (m$^3$/h)** | |
| **Maximum Design Flow (m$^3$/h)** | |

| **B4.0 – CLARIFICATION AIDS** | |
|---|---|
| **Clarification Aid Proposed (Lamella Plates or Tubular Settlers)** | |
| **Lamella Plate Settlers** | |
| **SLR Used (m/h)** | |
| **Angle of Inclination (°)** | |
| **Distance Between Plates (m)** | |
| **Detention Time within Settler Zone (mins)** | |
| **Effective Surface Area (m$^2$)** | |
| **Tubular Settlers** | |
| **SLR Used (m/h)** | |
| **Angle of Inclination (°)** | |
| **Distance Between Plates (m)** | |
| **Detention Time within Settler Zone (mins)** | |
| **Effective Surface Area (m$^2$)** | |

| **B5.0 – DECANT LAUNDER DESIGN** | |
|---|---|
| **No. of Weirs Proposed (per tank)** | |
| **Weir Dimensions** | |

| **B6.0 – SLUDGE BLEED SYSTEM** | |
|---|---|
| **No. of Sludge Bleeds (per tank)** | |
| **Opening Duration (seconds)** | |
| **Opening Frequency (per hour)** | |

| **B7.0 – SLUDGE BLANKET CLARIFIER DIMENSIONS** | |
|---|---|
| **Tank Surface Area (m$^2$)** | |
| **Tank Length (m)** | |
| **Tank Width (m)** | |
| **Water Depth (m)** | |
| **Free Board (m)** | |
| **Distance from TWL to Top of Sludge Blanket (m)** | |
| **Distance from TWL to Top of Sludge Concentrator Weir (m)** | |

| **B8.0 – INSTRUMENTATION INCLUDED (ü)** | |
|---|---|
| **Flow Monitoring to Each Tank** | |
| **Turbidity Monitors at each Tank Outlet** | |
| **Sludge Blanket Level Monitors on Each Tank** | |

## APPENDIX B – DAF / DAFF DESIGN

The designer shall complete the below questionnaire for each individual DAF / DAFF clarification system proposed. The completed questionnaire shall be submitted with the designer's tender to demonstrate compliance with the Uisce Éireann CFC Design Specification.

| **B1.0 – GENERAL INFORMATION** | | | |
|---|---|---|---|
| **Project Title** | | **Document Reference** | |
| **Project Reference Number** | | **Revision** | |
| **Project Location** | | **Date** | |
| **Designer** | | **Reference Drawings** | |

| **B2.0 – APPLICATION** | |
|---|---|
| **System Proposed (DAF or DAFF)** | |
| **No. of DAF / DAFFs Proposed** | |

| **B3.0 – DESIGN FLOWS** | |
|---|---|
| **Minimum Design Flow (m$^3$/h)** | |
| **Average Design Flow (m$^3$/h)** | |
| **Maximum Design Flow (m$^3$/h)** | |

| **B4.0 – DAF/ DAFF SYSTEM DESIGN** | |
|---|---|
| **Contact Zone Detention Time (s)** | |
| **Contact Zone Hydraulic Loading Rate (m/h)** | |
| **Baffle Wall Clearance Velocity (m/h)** | |
| **Contact Zone Baffle Angle (°)** | |
| **Separation Zone Surface Loading Rate (m/h)** | |

| **B5.0 – DAFF FILTER CELL SIZING** | |
|---|---|
| **Filter Cell Surface Area (m$^2$)** | |
| **Maximum Filtration Rate (m/h)** | |
| **Filter Cell Length (m)** | |
| **Filter Cell Width (m)** | |

| **B7.0 – TYPE OF BACKWASH PRPOSED (DAFF) (ü)** | |
|---|---|
| **Separate Air and Water (SAW)** | |
| **Combined Air Limited Water (CALW)** | |

| **B8.0 – DAF / DAFF DIMENSIONS** | |
|---|---|
| **Contact Zone Dimensions (m)** | |
| **Separation Zone Dimensions (m)** | |
| **Overall Tank Depth (m)** | |

| **B9.0 – RECIRCULATION SYSTEM** | |
|---|---|
| **Air Saturation or Microbubble Generation (Specify)** | |
| **Recirculation Flowrate (m$^3$/h)** | |
| **Recirculation Pressure (bar)** | |
| **Air Saturator Loading Rate (m/h)** | |
| **Air Loading (g Air / m$^3$ water)** | |
| **Micro Bubble Size (μm)** | |
| **Microbubble Concentration** | |

| **B8.0 – INSTRUMENTATION INCLUDED (ü)** | |
|---|---|
| **Flow Monitoring to Each DAF / DAFF** | |
| **Flow Monitoring on Each Recirculation Line** | |
| **Turbidity Monitoring on DAF / DAFF Outlet** | |
| **Level Monitors on Sat. Vessel** | |
| **Level Monitors in Sludge Pocket** | |
| **Pressure Monitor on Each Recirculation Pipe** | |
| **Pressure Gauge on Sat. Vessel** | |
| **Loss of Head Monitor on DAFF** | |

| | |
|---|---|
| **Air flow monitor (turbo pump)** | |
| **Torque overload on chain and flight sludge removal system** | |

| **B6.0 – DAFF FILTER MEDIA SELECTION** | |
|---|---|
| **Media No.1** | |
| **Description** | |
| **Uniformity Coefficient** | |
| **Depth Proposed (m)** | |
| **Media No.1** | |
| **Description** | |
| **Uniformity Coefficient** | |
| **Depth Proposed (m)** | |