WATER
CORPORATION

Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 111

Microfiltration and Ultrafiltration Systems

VERSION 2
REVISION 1

JUNE 2023

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia's Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer, Treatment Section, Engineering.. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

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Users should use and reference the current version of this document.

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REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
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1 Introduction

1.1 Purpose

The purpose of the document is to explain the principals behind the Water Corporation's design and installation requirements for polymeric Microfiltration/Ultrafiltration Systems used in water and wastewater treatment, and to provide specific information relating to the Corporation's preferences and good practices that have evolved over many years of experience. This document is not a "Design Manual" as the detailed design of a Microfiltration (MF) or Ultrafiltration (UF) system will invariably be carried out by a vendor.

1.2 Standards

This design standard makes reference (directly or indirectly) to the following standards:

Australian & International Standards:

AS 1170.1	Structural design actions – Permanent, imposed and other actions
AS1158.3	Lighting for roads and public spaces: Pedestrian area (Category P) lighting – Performance and design requirements
AS 1318	SAA Industrial safety colour code
AS 1319	Safety signs for the occupational environment
AS 1345	Identification of the contents of pipes, conduits and ducts
AS 1657	Fixed platforms, walkways, stairways and ladders – Design, construction and installation
AS 1680.2.4	Interior Lighting – Industrial tasks and processes
AS 1688	Part 2: Mechanical ventilation for acceptable indoor air quality
AS 2032	Installation of PVC pipe systems
AS 2293.1	Emergency Escape lighting and exit signs for buildings – System design, installation and operation
AS 2634	Chemical Plant Equipment made from Glass Fibre Reinforced Plastics based on Thermosetting Resins
AS 3500	National plumbing and drainage code (provision of backflow prevention devices)
AS 3780	The storage & handling of corrosive substances
AS 3879	Solvent cements and priming fluids for PVC (PVC-U and PVC-M) and ABS pipes and fittings
AS 4041	Pressure piping
AS 4087	Metallic flanges for waterworks purposes
AS4775	Emergency eyewash and shower equipment
ASME RPT-1	Reinforced Thermoset Plastic Corrosion Resistant Equipment
BS 4994	Design & Construction of Vessels & Tanks in Reinforced Plastics
DVS 2205	Design Calculations for Containers & Apparatus Made of Thermoplastics
DVS 2207	Welding of Thermoplastics

ASTM6809	Standard Practice for Integrity Testing of Water Filtration Membrane Systems
	The ISO 8573 Air Quality standard

Water Corporation Standards:

DS20	Electrical Design Process
DS21	Major Pump Station – Electrical
DS22	Ancillary Plant & Small Pump Stations – Electrical
DS 24	Electrical Drafting
DS 25	Instrumentation
DS 26	Type Specifications – Electrical
DS 27	Regulating Valve Control – Electrical
DS 28	Water and Wastewater Treatment Plants – Electrical
DS 30	Mechanical General Design Criteria & Glossary
DS 31	Pipework, Valves & Appurtenances – Mechanical
DS 32	Pump stations – Mechanical
DS 33	Water Treatment Plants – Mechanical
DS 35	Ancillary Plant – Mechanical
DS 36	Strategic Product Specifications and Product Atlas
DS 38	Installation – Mechanical
DS 40	SCADA Standards
DS 41	SCADA Standards
DS 42	SCADA Standards
DS 43	SCADA Standards
DS 79.2	Emergency Safety Showers and Eyewash Stations Standard
S151	Prevention of Falls Standard
S399	Plant Safety Signage Standard
S393	Desalination and Membrane Terminology Standard
	The Specification for the Selection of Appropriate Turbidity Analysers

Water Corporation Documents:

SWTM	Surface Water Treatment Manual
S226	Standard 226 Surface Water Treatment Monitoring
CDWS	Criteria for Drinking Water Supply from Infrastructure Planning Branch

Regulations:

The Dangerous Goods Regulations – 2007

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1.4 Abbreviations

BOD	Biological Oxygen Demand
CEB	Chemically Enhanced Backwash
CIP	Clean In Place
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DoH	Department of Health
FFI	Feed Fouling Index
	LRV Log Removal Value
MF	Microfiltration : 0.1 – 0.2 um pore size
MOU	Memorandum of Understanding
MWCO	Molecular Weight Cut-Off
NF	Nanofiltration : 0.01-0.001um pore size
ORP	Oxidation Reduction Potential
PAC	Powder Activated Carbon
PDT	Pressure Decay Test
RO	Reverse Osmosis
SDI	Silt Density Index
SEM/EDA	Scanning Electron Microscopy and Energy Dispersive Spectroscopy
T&O	Taste and Odour
TMP	Transmembrane Pressure
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UF	Ultrafiltration : 0.01 – 0.05 um pore size
VSD	Variable speed drive

2 Membrane Filtration Overview

A detailed overview of the membrane filtration process shall be found in The Treatment Manual

3 Concept Design Issues

3.1 Level of Treatment

One of the first decisions in a project is to determine the water quality risk, the level of treatment required and the operating protocols needed to ensure the safety of water supplies; this is defined in the Surface Water Treatment Manual. The manual predominately caters for natural surface waters however it can also be applied to artificial sources such as bitumen, road catchments or water recycling projects. The level of treatment required, varies depending on the source – surface water, groundwater, waste water or recycled water.

Direction on how to define the source water quality risk categorisation is provided in the Water Corporation Manual 'Surface Water Treatment'.

The Water Treatment Matrix describes defines four levels of risk to the provision of safe drinking water based on raw water bacteria and virus loading, as well as cryptosporidium and giardia challenge. To mitigate these risks it goes onto prescribe Critical Control Points and associated pathogen removal points required for cryptosporidium, bacteria and viruses which become more stringent with increasing source risk ranging from 2.5 log to 5.0 log for cryptosporidium and 4.0 log to 7.0 log for bacteria and virsuses. These Pathogen Removal points can be achieved by the combination of appropriate water treatment unit processes. The Surface Water treatment manual & S226 outline the operating conditions for each treatment barrier and the monitoring that should take place, specifically with regard to critical control points, and the target criteria, critical limits and alarm limits.

3.2 Design Validation

Design validation is the process of using literature, scientific information, third party certification and feed water data to determine that the treatment process mitigates the identified hazards and meets the specified performance targets. The validation of membrane filtration systems must be consistent with the approach described in the US EPA's Membrane Filtration Guidance Manual (MFGM) in conjunction with ASTM 6908 Standard Practice For Integrity Testing and meet the expectations of our regulators or regulatory guidelines (eg. DoH, DER, ADWG, AGWR). A primary purpose of design validation is to ensure the treatment process will achieve the required LRV, set out by the treatment process requirements which are determined by the corporate Drinking Water Quality Critical Control Points Management. In the case of recycled water the process must achieve the recycled water quality guidelines set out by the regulators.

Membrane systems are currently used for two main applications within the Water Corporation; drinking water supply and non-potable water re-use supply**.** Pre-validated membrane modules are acceptable for the treatment of drinking water supplies; however these units must be operated within the range of conditions that the unit was validated under. A validation report must be provided demonstrating the range of conditions the unit was validated under.

Membrane systems for the treatment of non-potable re-use supplies must complete onsite challenge testing for demonstrating the LRV performance of the membranes. This shall be performed through assessing the MS2 coliphage that is naturally present in the feed water or by challenging the membranes in a test rig with introduced cultured MS2 coliphage.

Membrane validation involves three complementary approaches. These approaches are used in combination as they each have inherent limitations and therefore, in isolation, they do not provide effective performance monitoring. The three approaches are:

1. **Challenge testing:** This is required to demonstrate the capability of the membrane to remove the target pathogen. Although the primary focus is the removal of cryptosporidium, challenge testing may also be used to confirm removal efficiencies for other pathogens including bacteria, viruses and Giardia. This is achieved by dosing challenge organisms into the feed of the process and measuring their removal by testing the feed and the product water. The concentration of challenge particles must be able to be quantified directly rather than using gross measurements such as turbidity. It provides the most meaningful measure of pathogen removal performance and establishes the LRV that an integral membrane can achieve. The maximum reduction value that a membrane filtration system may receive is the lower of the: LRV demonstrated during challenge testing, or the maximum LRV that can be verified by an integrity test under normal plant operation. The membrane module tested must be identical in material and construction to that used in the full scale membrane system.

   Challenge testing of a membrane filter shall include:

   - Establishment of challenge testing requirements and suitable operating conditions based on the recommendations of the Regulator and the Water Corporation.
   - Development of challenge testing protocols and procedures to the satisfaction of the Regulator and the Water Corporation
   - Selection and procurement of a suitable test organism
   - Procurement and set up of all equipment necessary to conduct the challenge test
   - Executing an approved testing procedure including dosing, sampling, operational Tests
   - Laboratory analysis of the process influent and effluent samples
   - Analysis of the test results including determination of log removal value
   - Reporting of challenge test results

2. **Direct Integrity testing**: is the primary means of verifying integrity in membrane filtration systems. The following are physical tests which can be applied to a membrane unit in order to identify and isolate integrity breaches, which can be classified as two general classes of direct integrity test

   - **Pressure based tests**: are based on bubble point theory and involve applying a pressure or vacuum. The various pressure based tests are, the pressure and vacuum decay tests, the diffusive airflow test and the water displacement test.
   - **Marker based tests**: introduce a particulate or molecular marker into the feed water to verify the integrity of the membrane system.

     Independent of the method used, the following are requirements that shall be adhered to for direct integrity monitoring:

   - **Resolution** the direct integrity test must be responsive to an integrity breach on the order of 3µm or less
   - **Sensitivity**: the test must be able to verify a log removal value equal or greater than the log removal credit awarded to the membrane filtration process
   - **Frequency**: the test must be conducted on each membrane unit at a frequency no less than once each day that the unit is in operation

3. **Continuous Indirect Integrity testing** – is a secondary means of verifying membrane filtration systems integrity. This involves measuring some aspect of filtrate water quality as a surrogate measure of membrane integrity, such as turbidity or particle counting and particle monitoring.

Independent of the method used, the following are requirements that shall be adhered to for indirect integrity monitoring:

- **Independent monitoring** of the filtrate stream from each membrane unit
- **Continuous monitoring** of the filtrate from each membrane unit, defined as at least every 15 mins
- **Performance** based control limit must be established such that readings exceeding the control limit or a period of greater than 15 mins would immediately trigger direct integrity testing

3.3 Design Verification

Verification shall be undertaken to determine that the water was safe to supply to customers. It involves monitoring under actual conditions in a non-simulated environment. The purpose of verification is to confirm or reject the LRV recorded in validation testing. There are two verification monitoring methods that shall be followed:

- **Commissioning Verification** – this method shall verify the suitability of operational parameters and their associated critical limits and is generally undertaken with a planned operational monitoring program.
- **Ongoing Verification** – this monitoring shall be performed routinely and confirm that CCP's and their assigned critical control limits consistently comply with the required water quality criteria. It is generally undertaken in conjunction with a planned operational monitoring program.

4 System Components

4.1 Pretreatment Requirements

The purpose of pretreatment is to minimize membrane fouling, extend the life of membranes, reduce water loss to backwashing and perhaps meet other treatment objectives such as removing organics. The extent and type of process used for pretreatment varies greatly depending on raw water quality and treatment objectives. There is often a tradeoff between costs of pretreatment and savings from membrane fouling and replacement. In large scale plants pilot testing can be used to determine the optimum treatment. In circumstances where there is uncertainty regarding raw water quality and resulting performance, it is recommended to carry out pilot trials to determine the optimum pre-treatment.

Importantly, if a disinfectant is used upstream of the membranes to control biological growths, the membrane manufacturer shall be consulted to advise on ways to prevent damage to the membrane materials from chlorine.

4.1.1 Screening

All MF/UF modules need to be protected to prevent large particles entering the system. The type of screen or filter shall be determined by the feed water quality, the membrane manufacturer's warranty and the membrane manufacturer's recommendation.

In cases where turbidity levels are elevated, it may be more economical to provide pre-treatment upstream of the MF/UF system to reduce the solids loading on the membranes. Where the turbidity of the raw water exceeds 100 NTU on a continual basis, direct filtration (media filtration) or clarification should be investigated. This value is a guideline only, and should be confirmed with membrane suppliers.

4.1.2 Pre-coagulation

Pre-coagulation is used for the removal of TOC, colour, virus and arsenic. Generally, aluminium or iron salts such as Al2(SO4)3, Fe2(SO4)3, FeCl3, AlCl3 and Al2(OH)5Cl would be used.

4.1.3 Pre-oxidation

Pre-oxidation is used for the removal of iron, iron bacteria and manganese. Aeration, chlorine, chlorine dioxide, ozone and KMnO4 are options that may be considered for iron and manganese removal. Oxidation to remove iron bacteria is usually accomplished with chlorine.

4.1.4 Powdered Activated Carbon

Pre-dosing of powdered activated carbon (PAC) can be used for the removal of TOC, colour and pesticides in extreme cases, however it is not widely used by the Water Corporation. It should be noted that the adsorption capacity of activated carbon is affected by concentration, temperature, pH, competition from other contaminants or natural organic matter, organic preloading, contact time, mode of treatment, and physical/chemical properties of the contaminant. PAC type and dose are also key parameters.

4.2 Membranes

The selected membrane shall have demonstrated LRV performance set out in the design criteria to achieve the minimum pathogen removal credits. In addition to the demonstrated LRV performance, the selected membrane shall have a nominal pore size of 0.1-0.2μm for MF membranes and 0.001-0.05μm for UF membranes and the design shall take into consideration the hydraulics and concentration factors.

Each individual membrane element shall have a unique serial number, which shall be used for identifying the elements materials, manufacturing history, quality assurance and performance test results. Membrane performance warranties and membrane product warranties shall be provided by the membrane supplier.

4.3 Backwashing

Backwashing removes the layer of cake that has accumulated on the membrane surface. Backwashing procedures are site and manufacturer dependent but typical characteristics shall be:

A. Backwashing shall be automatic
B. Each membrane unit shall be backwashed individually in sequence so not all units are backwashed simultaneously
C. Backwash itself shall consist of a flow reversal; usually at a backwash flow rate at least twice that of the filtration flow rate, for a set period.
D. The time between backwashes shall be between 15 to 60 minutes and, shall be triggered by exceeding a form of membrane fouling, or reaching a set default operating time.
E. System production is reduced by approximately <5%
F. Pressurized air and/or chlorine can be used depending on membrane compatibility in order to increase backpulse effectiveness and control biofouling
G. In submerged systems, an air scour is generally used instead of a backwash.

The goal of the backwash is to restore the membrane to its orginal TMP and flux performance. However over time the TMP will increase at a given flux. Thus chemical cleaning is implemented periodically to restore membranes to their best practical TMP condition.

Some membrane manufacturers have developed proprietary backwash strategies, that combine backwashing with chemical cleaning, referred to as Chemically Enhanced Backwash (CEB) sequences. These methods use chlorine, acids, bases, surfactants or proprietary chemicals in order to achieve better TMP's and delay the need for chemical cleaning. In such systems careful attention must be paid to cross connection control and membrane rinsing.

4.4 Chemical Cleaning

Chemical cleaning is necessary to remove foulants such as, inorganic scaling and organic growth, which are not normally removed by backwashing. Chemical cleaning is usually applied to each membrane unit separately, and is typically staggered to minimize the number of units undergoing cleaning at any one time. The term clean-in-place (CIP) is used to describe the chemical cleaning process, as it is applied in-situ, without removing the membrane modules from the unit.

A number of different chemicals are used in membrane cleaning, and each is generally targeted to remove a specific form of fouling. Due to the variety of foulants that are present in many source waters, it is often necessary to use a combination of different chemicals, applied in series, to address multiple types of fouling. Suppliers of MF/UF systems may specify different sequences of chemicals, concentrations and cleaning frequencies.

Consideration must be given to the quality of make up water used for the preparation of CEB & CIP solutions, in some situations where scheme waters are hard or have high silica they may interfere with membrane cleaning efficiency. In these cases softened water or RO permeate should be considered to be used for CEB/CIP solution make up and pre and post membrane rinsing.

The Memorandum of Understanding between the Department of Health and Water Corporation for Drinking Water (MoU) currently requires that all materials and substances that come into contact with drinking water are approved by the Department of Health (DoH) or are AS4020 compliant. If a material or substance, not in these schedules, is intended to be used in contact with drinking water, the following procedure shall be used: Approval of Chemicals and Materials in Contact with Drinking Water to facilitate the approval process or discuss with the Distribution and Systems Manager or the Treatment Manager in Drinking Water Quality Branch.

An overview of chemicals commonly used is provided in Table 9. All of these chemical additives must be approved for use in potable water applications, or have strict off-line use protocols in place to ensure the product water cannot be contaminated.

Table 9 - Commodity Chemicals (on the Water Corporation DoH approved MOU List)

Category	Commodity chemicals	Contaminants targeted
Acid	Citric Acid ($C_6H_8O_7$) Hydrochloric Acid (HCl) Sulphuric acid (H_2SO_4)	Inorganic Scale
Base	Caustic Soda (NaOH)	Organics
Oxidants/ Disinfectants	Sodium Hypochlorite (NaOCl) Chlorine (Cl_2) Gas Hydrogen Peroxide (H_2O_2)	Organics, biofilms

Any other chemicals will require a review of the MOU schedules.

BOD_5	up to 5000 or 10000 mg/L if citric acid is used.

4.5 Residuals Management

Residuals refer to the backwash and CIP waste streams. All MF/UF systems produce residuals on an intermittent basis, and management of these streams needs to be carefully considered in planning/design.

4.5.1 Plant Start-up Residuals

In most cases, the filtered water produced during plant start-up will not be acceptable for distribution and provision will need to be made for recycling and/or temporary disposal of the feed and filtrate water. This water can usually be disposed of to the environment.

Membrane modules are typically shipped “wet” with a liquid preservative solution. Some membranes are preserved with glycerine, others with a reducing agent to control microbial growth, such as sodium bisulphite or chlorine. Disposal methods are similar to those listed below under Section

4.5.2 Backwash Residuals

As a general rule, backwashing streams have a suspended solids concentration approximately 10 to 20 times greater than that of the feed water. Disposal options for MF/UF backwash streams are similar to those for conventional water treatment plants, and include the following:

- Discharge to evaporation basins and soak wells – this is an alternative for water not contaminated by chemicals
- Discharge to sewer- this will be subject to water corporation trade-waste regulations and will be site specfic
- Onsite Treatment – is similar to conventional treatment including clarifiers, settling lagoons, gravity thickeners, centrifuges etc.
- Supernant may be recycled, however Water Quality Branch shall insist on a barrier to prevent recycling of Giarda and Crypotporidium.

4.5.3 CIP Residuals

CIP residuals are generally treated on-site. Oxidants such as chlorine can be quenched prior to discharge, and acids and bases can be neutralized. The use of other chemicals, such as surfactants or proprietary cleaning agents, may require additional treatment.

Membrane rinse-water may contain levels of chemical that must be treated.

Typical characteristics of CIP streams are shown in Table 10.

Table 10 - Typical characteristics of CIP streams

pH	2 to 14 depending on the chemicals used.
Chlorine residual	up to 1000 mg/L as Cl_2.
Surfactants	Low concentrations.
Acids	Low concentrations
Total Suspended Solids	up to 500 mg/L (neutralisation may precipitate additional solids).
TOC	10 to 30 times the feedwater concentration.
Aluminium	Dependent on MF/UF supplier specifications and pre-treatment.

4.6 Redundancy and Reliability

Careful consideration needs to be given to redundancy and reliability of the system, and consequently duty/standby units shall be provided for all critical equipment such as pumps, blowers, and compressors.

Reliability issues may be particularly pronounced in smaller MF/UF systems which typically have fewer membrane modules, as one out-of-service module may significantly impact the overall system output. In order to ensure system reliability, some measure of redundancy should be built into the system. Ideally it is always better to have two trains, each capable of producing 100% of the output required, with the other train out of service. However the level of redundancy for each site will be determined by site specific factors such as storage, demand and timeliness of operator intervention. The redundancy for each system will be addressed in the Engineering Summary Report.

Provision for out-of-service membranes needs careful consideration because of the cost implications.

A strategy commonly used to provide redundancy/reliability is, to increase the flux on operating units. This is the most cost-effective and technically feasible strategy, because the filtered water does not change as a function of membrane flux. However, when there are only a few membrane units (four or less), the increase in flux imposed on the unit remaining in operation may result in more frequent backwashing and chemical cleaning intervals. The maximum design flux rate shall not be exceeded for any system, to prevent damage to membranes.

In larger MF/UF plants, the inclusion of an additional filtration unit normally does not represent a significant increase in the overall capital cost. In such an arrangement, the system is operated with one filtration unit either out of service (for maintenance/cleaning/repair) or in standby mode, this will be defined in the Engineering Summary Report. Alternatively, all units may be operated at a lower flux to extend the interval between chemical cleaning.

4.7 Membrane Integrity Tests

One of the most critical aspects of membrane technology is to ensure that the membranes are intact and continue to provide a barrier between the feedwater and the permeate. There are two categories of integrity tests direct & indirect. Both these methods shall be undertaken according to the protocol outlined in detail in section 3.2, however briefly these consist of:

Direct Integrity testing - are physical tests which can be applied to a membrane unit in order to identify and isolate integrity breaches. The most common type of direct test is the pressure decay test which measures the rate of decline of pressure across a membrane and compares it to acceptable values. The exact location of the leak may be located by submerging the membrane in water and forcing air through it and observing the air bubbles. The main disadvantage of this test is that it does not provide continuous monitoring.

Pressure decay testing shall be fully automatic, and shall be implemented on a daily basis during office hours. The integrity test must be validated to confirm that the specified pressure was achieved. This shall be implemented by a signal sent to the PLC, confirming that a pressure of x bar was met in t minutes. If the specified pressure is not achieved, the PLC must trigger a PDT alarm and shut down the plant.

The design of the system must take into account the time taken to fully complete a PDT including flushing, as this has a significant impact on production availability.

Indirect Integrity testing – Turbidity is selected as the default integrity monitoring parameter, any unusual rise in turbidity is potentially a sign of a compromised membrane, in which case a direct integrity test must be conducted.

Turbidity is the chosen operational parameter for critical control point monitoring and the criteria outlined in the surface water treatment manual S226 must be monitored. Typical values are:

- Critical Limit: 0.15 NTU, should this critical limit be breached the plant must shutdown
- Target criteria: <0.1 NTU is more stringent than critical limit, which allows time for corrective action before and unacceptable health risk occurs.
- Alarm Limit: 0.1 NTU, must give warning the target has been breached and there is a potential for critical limit to be breached.

5 Mechanical Requirements Associated with MF/UF Units

5.1 Filtration

5.1.1 Feed and Filtrate Pumps

In pressurised systems, a VSD centrifugal pump shall be employed as a feed pump, to deliver raw water to a membrane block at the required flow and operating pressure. In submerged membrane systems, VSD centrifugal pumps shall be employed as a filtrate pump and, are installed downstream of the membranes block, and operate in suction mode

Ranges of feed water quality and ambient temperatures shall be considered for the design pressure.

The operating pressure in pressurised systems is generally between 1.4 and 2.0 bars. In submerged systems, the operating pressure is around -0.6 bar. In this application, the filtrate pump NPSH may be critical and needs to be carefully checked. If the difference between the water level inside the tank and the centre-line of the pump is less than 2 meters, a split case pump should be considered. If the difference is greater than 2 meters, an end-suction pump may be utilised.

In small plants, it is normally preferred to dedicate an individual feed pump to each membrane block. However, in large plants, a single feedwater pumping station with VSD pumps or flow control valves, can feed a number of membrane banks, reducing the total number of pumps required and improving energy efficiency.

In both pressurized and submerged systems the feed or filtrate pumps must always be arranged in duty standby configuration.

5.1.2 Recirculation Pumps

Recirculation pumps are required in cross-flow MF/UF systems. Depending on the raw water quality (particularly turbidity and TOC), the pump shall be capable of providing a recirculation flow to feed flow ratio of between 3 to 1 and 6 to 1.

5.1.3 Neutralistion Pumps

Pumps will usually be standard end-suction pumps in accordance with DS32; the flow rate and pressure should be specified by the membrane supplier. The designer shall check to ensure that the frequency of pump start-stop cycles does not exceed the pump manufacturer’s limit. Materials of construction and seals shall be carefully selected to ensure compatibility with the CIP chemicals.

5.1.4 Filtrate and Feed Tanks

Filtrate and feed tanks will usually be in GRP, HDPE or stainless steel. Coated mild steel is not acceptable. Concrete tanks may be an option for submerged systems. Coating of concrete tanks shall be considered if there is likely to be exposure to corrosive cleaning solutions. All tanks must comply with tank standard DS61.

5.1.5 Neutralisation Tank and Pumps

Acid, base and oxidizing solutions discharged during CIP sequences should be collected and neutralised in a tank provided for that purpose, where practical. The utilization of membranes modules or units for neutralization or closed loop cleaning, is not acceptable.

The neutralisation process shall be fully automated, and the tank shall be sized to be capable of neutralizing spent CIP waste on the highest CIP frequency.

Neutralisation tanks will be usually be in GRP, HDPE or stainless steel. Coated mild steel is not acceptable. If concrete tanks are used, a suitable coating must be applied.

Safety systems shall be provided to prevent the hypochlorite CIP solution and the acid CIP solution from mixing within the neutralisation tank.

5.2 Backwash and Cleaning Systems

5.2.1 Backwash and CIP Pumps

CIP and backwash pumps will usually be standard end-suction pumps; the flow rate and pressure should be specified by the membrane supplier. The designer should check to ensure that the frequency of backwash pump start-stop cycles does not exceed the pump manufacturer's limit.

Where chemicals are dosed into the backwash pumping line, the materials of construction and seals shall be carefully selected. Likewise, the materials of construction and seals should be carefully selected when considering CIP pumps.

5.2.2 Backwash and CIP Waste Tanks

Backwash waste shall be discharged to a tank for treatment prior to disposal. The volume and inlet/outlet configuration of the tank shall be specified by the membrane supplier.

The CIP tank is used to prepare the chemical cleaning solutions and also to collect the CIP waste stream. Some suppliers may offer a package that does not include a CIP tank, in which the pipework is used as the CIP reservoir, referred to as closed loop cleaning, such arrangements are not acceptable.

When CIP cleaning solutions need be heated, the temperature will be specified by the membrane supplier and consideration shall be given to insulation of the tank to minimize heat loss. The water heating system shall be automatically controlled to switch on when CIP is due.

5.2.3 Air compressors

MF/UF systems require a considerable amount of compressed air. Because most systems will be of a proprietary design, the air supply will usually be designed by the supplier as part of the equipment package. Compressed air is required for membrane integrity testing, pressurisation of the membranes for specific sequences in backwash, and to drain the system.

Compressed air systems shall be designed to produce filtered, dry, oil-free air to The ISO 8573 Air Quality standard, and shall comply with the Water Corporation's Design Standard DS 35: Ancillary Plant – Mechanical, and must be in duty standby configuration.

5.2.4 Blowers

Submerged membrane systems and pressurised membrane system utilising out-in filtration will usually require blowers. Positive displacement blowers are usually the most cost-effective, compared to centrifugal blowers, and this will be documented in the Engineering Summary Report. Air-flow monitoring shall be provided on all blower streams. Blowers shallcomply with the Water Corporation's Design Standard DS 35: Ancillary Plant - Mechanical, and must be in duty standby configuration.

5.3 Valves and Piping

Valves and pipework shall comply with the following Water Corporation standards:

- DS 31-01 - Pipework – Mechanical;

- DS 31-02 - Valves and Appurtenances – Mechanical; and
- DS 36 - Strategic Product Specifications and Product Atlas – Mechanical.

All major process valves shall be automatic and fitted with pneumatic actuators. Electrical actuators shall not be used. In sizing the system the designer shall ensure that the duration of backwash sequences allow for realistic opening and closing times for valves and that those actuation rates do not cause water hammer. All valve components must be fully compatible with the fluids in the system including the chemicals for cleaning. All actuated valves shall be fitted with limit switches to determine valve position and ensure that inappropriate valve and sequence combinations cannot occur. The system shall be designed to ensure all piping is of suitable material for the application it performs.

6 Operability and Maintainability Design Requirements

The purpose of this chapter is to identify design issues that have an effect on the operability and maintainability of a MF/UF plant.

6.1 Instrumentation and Control

6.1.1 Introduction

All instrumentation shall comply with the Water Corporation's:

1. Design Standard - Part No. DS 25: Electronic Instrumentation;
2. Preferred Instrumentation List; and
3. S226 Surface Water Treatment Monitoring.
4. The Specification for the Selection of Appropriate Turbidity Analysers

6.1.2 PLCs and SCADA

The MF/UF plant shall be controlled by dedicated local PLC equipped with an Ethernet TCP/IP communication module for integration with the plant control system. SCADA shall be provided for remote supervision and control, duty and standby communications. Alarms must be immediately transferred via SCADA to the Operations Centre.

CIP and CEB functions must be provided with retentive PLC logic. If a power failure were to occur during a CIP/CEB cycle, the membranes would contain chemical solution. Hence the plant must not be allowed to return to service without the CIP/CEB cycle being completed.

6.1.3 Operator Interface Panels

All key performance indication, instrumentation, controls and monitoring of the MF/UF plant must be communicated to an Operator Interface Panel. The Operator Interface Panel shall contain a data-logging system, alarming of key process variables and parameter set-points which are capable of meeting the equipment monitoring OEM requirements. The Operator Interface Panel shall be a touch-screen colour display type and a minimum of 12 inches. The Water Corporation's preference is to utilise "smart" intelligent monitoring and control, including FFI, resistance, permeability, backwash efficiency, CIP efficiency, etc.

6.1.4 Instrumentation

As a minimum, the instrumentation listed in Table 12 shall be provided on each MF/UF train to enable each train to be monitored independently, and to enable diagnostic testing to be carried out on individual trains.

Table 12 - Minimum instrumentation requirements for MF/UF systems

FEED WATER	PRESSURE
	FLOW RATE
	TURBIDITY
	TEMPERATURE
FILTRATE	PRESSURE
	FLOW RATE (IN CROSS-FLOW SYSTEMS ONLY)
	PH
	TEMPERATURE
	ORP
	TURBIDITY
AIR SUPPLY	PRESSURE (COMPRESSORS AND BLOWERS)
	FLOW RATE (COMPRESSORS AND BLOWERS)
CIP	FLOW (DISCHARGE OF CIP PUMPS)
	PRESSURE (OF CIP PUMPS)
	TEMPERATURE IN CIP TANK
	PH ON THE RECIRCULATION LOOP OF CIP
	ORP ON THE RECIRCULATION LOOP OF CIP
CIP WASTE STREAM	PH
	FLOW TOTALISATION
NEUTRALISATION TANK	PH
	ORP
	LEVEL

Continuous monitoring of filtrate turbidity shall be carried out with the Water Corporation approved unit outlined in The Specification for the Selection of Appropriate Turbidity Analysers. A turbidity instrument shall be provided on the filtrate outlet of each array and on the combined filtrate. The working range of the turbidity instrument used to monitor the filtrate must be sufficiently low (less than 0.1 NTU) and not prone to fine air entrainment issues.

All online instrumentation shall be selected from the Water Corporation Electrical Preferred equipment list and shall be installed to the manufacturers specifications. Online instruments should be positioned as close as possible to the point of sampling to minimize loop times. In addition to the MF/UF system, all the usual instrumentation for tanks, and pumps shall need to be considered, in accordance with DS25-01.

6.1.5 Correlation of PDT/MIT with Log Removal

Some membrane suppliers have developed an empirical relationship which enables a theoretical log removal to be calculated in terms of the filtrate flow rate, water temperature, TMP and other parameters; this shall be incorporated into the PLC. Programming of this relationship in the PLC shall enable the operator to correlate the theoretical log removal with the current operating parameters. All alarms shall be date and time stamped on the local OIP.

6.1.6 Alarms

The alarms required need to be assessed on a site-by-site basis. An example of an alarm list is provided in Appendix B for guidance (note that alarms for associated systems or external systems are not included in this list). Two types of alarm shall be considered – Shutdown Alarms and Warning Alarms.

6.1.6.1 Warning Alarms

Warning Alarms may occur at any time the MF/UF unit is powered up. Multiple Warning Alarms can be active at any given time. Warning Alarms usually indicate a minor abnormal condition and will not cause a MF/UF unit shutdown. They are designed to provide early warning of faults or operation outside normal limits and should always be investigated and the cause determined so that more serious problems can be avoided.

6.1.6.2 Shutdown Alarms

Shutdown Alarms may occur at any time the MF/UF unit is powered up. The MF/UF unit should not have to be running for some Shutdown Alarms, such as Emergency Stop Shutdown, to be activated. If a Shutdown Alarm occurs, the MF/UF unit should immediately stop and enter the SHUTDOWN ALARM state. The Shutdown Alarm that caused the MF/UF unit to stop should be displayed on the ALARMS screen. Only one Shutdown Alarm should be active at a given time.

6.1.7 Process Monitoring

Turbidity Monitoring

Turbidity monitoring must include alarms for a hierarchy of alarm ranges – target, critical limit and alarm. Reference should be made to the Water Corporation document S226 - Surface Water Treatment Monitoring for requirements relating to Target Criteria, Critical Limits and Alarm Limits. An auto shut-down shall be included for when the unit breaches the critical limit. The turbidity alarms must be set up in accordance with document S226.

Membrane fouling Monitoring

The buildup of fouling on the membrane surface shall be measured either by TMP, resistance, permeability, and this measurement shall be monitored to track membrane fouling status. As these parameters on a system increase, a backwash, CEB or chemical clean shall be triggered.

Membrane integrity testing

Integrity testing shall be fully automatic, and shall be implemented on a daily basis during office hours. The integrity test must be validated to confirm that the specified pressures are achieved. This is normally implemented by a signal sent to the PLC, confirming that a pressure of x bar was met in t minutes. If the specified pressures are not achieved, the PLC must trigger a PDT alarm and shut down the plant.

6.2 Electrical

All electrical equipment must be in accordance with the Water Corporation and Australian Standards listed in Section 0.

6.2.1 Electrical Enclosures

All electrical enclosures shall be suitably rated for the application they are intended for: for example IP rated for outdoor areas, with powder-coated finish.

6.2.2 Motors

Motors shall preferably be three-phase with variable speed drive or soft starters on all drives. Wherever possible, large kW drive pumps should be avoided. All motors shall be high efficiency and low noise in accordance with Water corporation standard DS32, and consideration given to the IP rating.

6.3 Layout, Storage and Replacement

6.3.1 Housing

Pressurised MF/UF systems shall be housed in a building – typically steel-framed with cladding. Shipping containers are not acceptable. Buildings are usually erected on an in-situ concrete slab containing pipe and cable trenches to dimensions and layout specified by the supplier. Small packaged submerged MF/UF systems shall housed in a building as well.

6.3.2 Accessibility

All equipment in a MF/UF system must be readily accessible for inspection and maintenance. Safe and adequate access must be provided around all equipment for operation and maintenance purposes and shall include a minimum of:

- 1000 mm around all major equipment and in front of control panels; and above;
- 800 mm width for all equipment access platforms.
- Particular attention must be given to the size and location of doorways to maintain access

All equipment that is removable (for maintenance, repair or replacement) must be provided with sufficient access to enable the unit to be removed without the need for dismantling other components on the skid.

Suppliers of MF/UF packages shall supply a drawing(s) with shaded areas around each train, defining the minimum access envelope.

6.3.3 Membrane Replacement and Storage

Timely membrane replacement is another consideration for maintaining system performance and reliability. Membrane replacement is usually undertaken on an as-needed basis, typically in cases where the membranes have been damaged or when the flux has declined to an unacceptable level as a result of irreversible fouling. The useful life of membranes is in the range of 5 to 10 years.

To control bacterial growth and prevent damage caused by drying out, the UF/MF modules should be wetted and stored in a suitable solution as recommended by the manufacturer. On re-installation, the preservative should be flushed to waste. Disposal of solutions containing glycerine may pose a problem because of the BOD and treatment/disposal may need to be considered.

Modules shall be stored according to membrane manufacturers recommendations, typically this in a cool, dry, normally ventilated area protected from direct sunlight with an ambient temperature of 20 to 35 ºC.

6.4 Shut-down

In the case of a shut-down (MF/UF systems shall include an auto-shut off capability in case the unit breaches a critical limit), the manufacturer's instructions shall be closely followed. UF/MF systems are designed to run continuously and perform better when operated continuously. However, in reality UF/MF systems will start-up and shutdown according to demand and the storage available in the system.

The manufacturer's manual shall be consulted to determine the recommended sequence of steps during a shut-down.

If the system is to be out of service for an extended period, consideration shall be given to removing the membrane modules to avoid the routine operations as defined above. The accessibility for the removal of the membranes shall be taken into account in design.

A maximum drain down timer with alarm per membrane array shall be considered in order to avoid membranes exposed to air (drying out risk).

7 Appendix A Checklist

ITEM	DETAILS	TO BE COMPLETED BY SUPPLIER
MEMBRANE AND MODULES CHARACTERISTICS:		
MEMBRANE MATERIAL		
PORE SIZE (NOMINAL)	IN μM	
TYPE OF MODULE		
MODULE DIMENSIONS	DIAMETER (OR WIDTH AND LENGTH) AND HEIGHT IN M	
NUMBER OF MODULES	UNITS	
TOTAL SURFACE AREA	M^2	
SYSTEMS DETAILS:		
HYDRAULIC CONFIGURATION	DEAD-END OR CROSS-FLOW (OR BOTH)	
TYPE OF SYSTEMS	SUBMERGED OR PRESSURISED	
GENERAL ARRANGEMENT	VERTICAL OR HORIZONTAL	
NUMBER OF UNITS IN OPERATION	UNITS	
UNIT CAPACITY	M^3/DAY	
STAND-BY UNIT OR SPARE CAPACITY FOR UNITS IN OPERATION	YES OR NO	
IF YES, PROVIDE DETAILS		
OPERATING CONDITIONS IN FILTRATION:		
FLUX AT 20 °C	L/M^2.H	
TMP AT 20 °C	BAR.	
TYPE OF MEMBRANE INTEGRITY TESTING		
FREQUENCY OF MEMBRANE INTEGRITY TESTING	NUMBER PER DAY	
OPERATING CONDITIONS IN BACKWASH:		
BACKWASH SEQUENCES	WATER / AIR / CEB	
FREQUENCY FOR EACH SEQUENCE	PER DAY	
CONDITIONS OF BACKWASH (FLOW AND PRESSURE) AND DURATION FOR EACH SEQUENCE		

ITEM	DETAILS	TO BE COMPLETED BY SUPPLIER
OPERATING CONDITIONS FOR CIP:		
CIP SEQUENCES	ACID / BASE / OXIDANTS…	
FREQUENCY FOR EACH SEQUENCE	PER YEAR	
CONDITIONS OF CIP (FLOW AND PRESSURE) AND DURATION FOR EACH SEQUENCE		
OVERALL RECOVERY RATE	%	
PERFORMANCE:		
FILTRATE QUALITY	LOG REMOVAL	
EXPECTED PRE-TREATMENT	YES/NO	
EXPECTED MEMBRANE LIFE	IN YEARS	
GUARANTEED MEMBRANE LIFE	IN YEARS	
POWER CONSUMPTION AT 20 °C (FOR FILTRATION ONLY)	KWH/M^3	
OTHERS		
NSF ANSI IN AUSTRALIA	YES/NO	
COMPLIANT WITH WATER CORPORATION STANDARDS AND AUSTRALIAN STANDARDS	YES/NO	
DRY AND WETTED MODULE WEIGHT	KG	

8 Appendix B Example Alarm List

SHUTDOWN ALARMS

- Control air pressure low-low
- Feed flow transmitter fault
- Feed inlet valve not closed
- Feed CIP return not closed
- Filtrate CIP return not closed
- Filtrate discharge valve not closed
- CIP inlet/drain valve not closed
- Filtration flow low-low
- Filtration flow high-high
- Filtration FFI high-high
- PDT pressure decay rate high-high
- Aeration flow rate low-low
- Shell fill failed at the end of the CIP fill shell step
- MF/UF unit in manual mode
- Process validation failed
- Device on the MF/UF unit has been put into manual mode from the OIP

WARNING ALARMS

- Feed flow control at maximum
- Filtration flow rate low
- Filtration flow rate high
- Filtration TMP exceeds maximum allowable
- Filtration FFI high
- Backwash requested too soon
- CIP requested too soon
- Backwash & CIP at fixed interval

- Shell fill failed at the end of the startup fill shell step
- Lumen fill failed at the end of the startup fill lumens step
- Filter down failed at the end of the filter down step of backwash
- Filtrate backwash failed at the end of the filtrate backwash step of backwash
- Aeration flow rate low
- Aeration pressure high
- Aeration pressure low
- Shell fill failed at the end of the startup fill shell step
- Lumen fill failed at the end of the startup fill lumen step
- PDT lumen drain fail
- PDT initial pressure out of range
- PDT pressure decay rate high
- Sonic test lumen drain fail
- Sonic test pressure out of range
- Draindown fail
- Shell fill failed at the end of the integrity test exhaust fill shell step
- Lumen fill failed at the end of the integrity test exhaust fill lumens step
- Lumen fill failed at the end of the CIP fill lumens step
- CIP request – resistance high
- CIP request – maximum time
- Standby on backwash request timeout
- Standby on TMP high
- Acid rinse solution strength high
- Chlorine rinse solution strength high
- The MF/UF Unit has remained in Manual Mode for more than the preset maximum time
- Feed pressure transmitter fault
- Filtrate pressure transmitter fault

END OF DOCUMENT