FUNDAMENTALS OF ULTRAFILTRATION

FRANS KNOPS

CONTENTS

INTRODUCTION (1)

WHAT IS A MEMBRANE?

- A membrane is a selective physical barrier used to separate a stream (gases or liquids and slurries) into its components based on their permeability through the barrier.

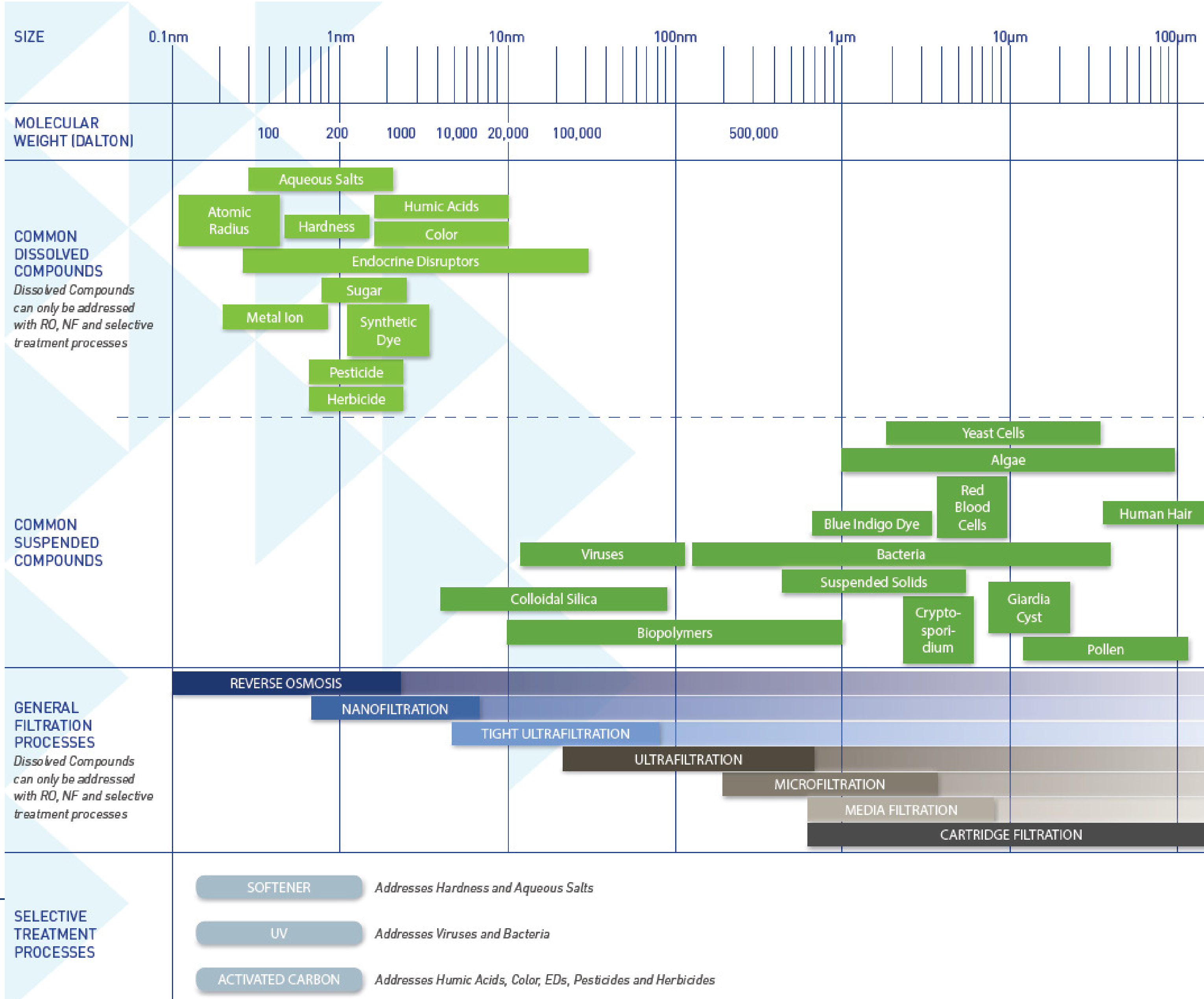
COMMON MEMBRANES PROCESSES FOR WATER TREATMENT:

- Microfiltration (MF)
- Ultrafiltration (UF)
- Nanofiltration (NF)
- Reverse Osmosis (RO)

OTHER MEMBRANE PROCESSES:

- Pervaporisation
- Membrane distillation
- Diffusion Dialysis
- Ion-exchange membranes
- Hybrid membranes

INTRODUCTION (2)



INTRODUCTION (3)

CLASSIFICATION OF MF, UF, NF AND RO:

	MF	UF	NF	RO
Pore size range (microns)	0.1 to 1	0.01 to 0.1	0.001 to 0.01	-
Typical operating pressure (bar)	0.1 to 1.0	0.1 to 2.0	5 to 30	5 to 60
Solutes removed	• Particles • Bacteria • Large microorganisms (yeast, algae)	• Colloids • Bacteria • Viruses • Partial removal of colour • Large proteins	• Polyvalent ions • Colour • Hardness • EDCs • Small proteins	• Monovalent and polyvalent ions • EDCs
Classification	• Pore size	• Pore size • MWCO	• Pressure rating • MWCO	• Pressure rating
Common applications	• *Gardia/Crytosporidium* removal • Clarification • MBR • Beer filtration • RO pre-treatment	• **RO pre-treatment** • Drinking water production • Clarification • MBR • Protein removal	• Softening • Silica removal • Metal recovery	• **Desalination** • Boiler feed water production • Effluent reuse • Ultrapure water production

INTRODUCTION (4)

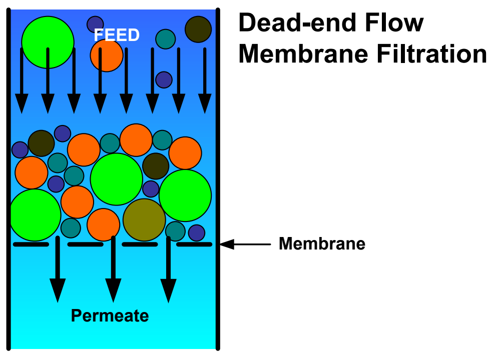
	MF	UF	NF	RO
Bacteria removal	Up to Log 4	Up to Log 6	> Log 3	> Log 3
Viruses removal	Up to Log 1	Up to Log 4	> Log 3	> Log 3
Typical filtration mode	• Dead-end	• Dead-end • Bleed	• Cross-flow	• Cross-flow

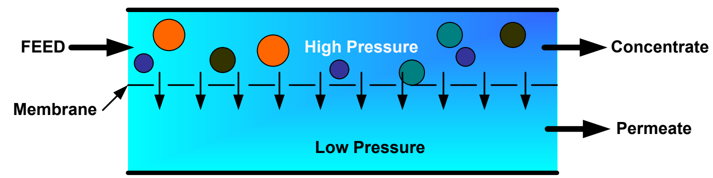
NOTES:

- EDCS: ENDOCRINE DISRUPTING CHEMICALS
- MWCO: MOLECULAR WEIGHT CUT-OFF
- MBR: MEMBRANE BIOREACTORS
- REMOVAL: VERIFIABLE REMOVAL
  EITHER BY INTEGRITY TEST (MF AND UF)
  OR BY CONDUCTIVITY / SULPHATE REDUCTION (NF AND RO)

INTRODUCTION (5)

DEAD-END VS CROSS-FLOW FILTRATION





	Dead-end	Cross-flow
Recovery	High (90 – 95%)	Low to moderate (40 – 80%)
Risk of fouling	High	Low
Energy requirements	Low (< 0.1 kW hr / m3)	High (0.5 – 4 kW hr / m3)
Feed pump capacity	Low (105% of permeate)	High (125 – 200% of permeate flow)
Susceptibility to feed quality fluctuations	High	Lower
Continuous operation	Discontinuous (BW + CEB)	Continuous (CIP)

ULTRAFILTRATION (1)

MEMBRANE ELEMENT TYPES:

- Pressurised vs Submerged

- Pressurised UF
  - Pentair X-Flow
    Legacy Norit
  - Evoqua Memcor
    Legacy Siemens
  - Dow/Omexell
  - Asahi/Pall
  - Toray
  - Inge

- Submerged UF
  - GE Zenon
  - Evoqua Memcor

ULTRAFILTRATION (2)

Table 2: Main product offerings of the international UF/MF suppliers

Company	Membrane							Module									Configuration	
	Polymer		Rating	MWCO	Pore size	id	od	Designation [*1]	Diameter		Length		Fibre length		Surf Area		PDv, PDh or SUB	In or Out
		Hydrophil	UF/MF	kda	Micron	mm	mm		mm	inch	mm	inch	mm	inch	m^2	ft^2		
Aquasource	CA	✓	UF	35-100	0.01	0.93		DN 450	450	18	1320	52	1200	47	125	1345	PDv	In
Aquasource	*PS*	✓	*UF*	*35-100*	*0.01*	*1*											*PDv*	*In*
Dow/Omexell	PVDF	✓	UF?	20	0.01	0.65	1.25	SFP 2680	165	6.5	2210	87	2030	80	47.1	507	PDv	Out
Hydranautics	PES	✓	UF	100-150	0.02-0.025	0.8	1.3	HYDRAcap 60	225	9	1680	66	1500	60	46	500	PDv	In
Inge	PES	✓	UF	100-150	0.01-0.025	0.9	4.2	Dizzer 5000	250	10	1680	66	1500	60	50	538	PDv	In
Koch	PS		UF	100		0.89	1.4	PMPW-10	273	10 NB	1830	72			80.9	870	PDv	In
Memcor	PVDF	✓	MF		0.04-0.10	0.5	0.8	CMF-S(L)-S(L) 10V	150	6	1190	47	1050	40	27.9	300	SUBv(PDv)	Out
Memcor	*PP*		*MF*		*0.2*	*0.3*	*0.6*	*CMF-M10C-PP*	*150*	*6*			*1050*	*40*	*35*	*372*	*PDv/SUBv*	*Out*
Norit	PES	✓	UF	100-150	0.02-0.025	0.8	1.3	SXL-225	200	8	1500	60	1500	60	40	430	PDh	In
Pall/Asahi	PVDF		MF		0.1	0.7	1.3	Microza USV-6023	165	6 NB	2338	92	2216	87	50	538	PDv	Out
Pall/Asahi	*PAN*	✓	*UF*	*80*	*0.01*	*0.8*	*1.4*	*LOV 5210*	*140*	*5NB*	*2227*	*88*	*2210*	*87*	*41*	*441*	*PDv*	*Out*
Polymem	PS	✓		100			0.72	UF120S2	315	12 NB	980	38	800	31	114	1227	PDv	Out
Toray	PVDF		MF		0.1	0.8	1.35	HFM-2020	200	8	2160	85	2000	79	80	860	PDv	Out
Toray	*PAN*	✓?	*UF*		*0.01*			*PAN HF 4"*	*100*	*4*			*1000*	*39*	*10*	*115*	*PDv*	*Out*
Zenon	PVDF	✓?	MF		0.2-0.4	0.8	1.9	ZW 500d	1750	69	2.54 x 2.11m	100 x 83	1900	75	31.6	340	SUBv	Out
Zenon	*PVDF*	✓?	*UF?*		*0.02-0.025*	*0.4*	*0.7*	*ZW 1000*	*890*	*35*	*2.6 x 1.82m*	*102 x 72*	*600*	*24*	*37-56*	*4-600*	*SUBh*	*Out*

NB: Italics denote subsidiary offering
In configuration subscript 'v' denotes vertical fibres, 'h' denotes horizontal fibres

Adapted from "Introduction to membranes: Manufacturers' comparison: part 1", *Filtration + Separation*, October 2007

ULTRAFILTRATION (3)

Table 1: Summary of the product offering of 11 international UF/MF suppliers							
Company	Customer	Market Position			Product		
		Leader	2nd Tier	New Entrant	Rating	Polymer	Config
Aquasource	In house		✓		UF	CA & PS	PDI
Dow/Omexell	OEM/System		✓		UF?	PVDF	PDO
Hydranautics	OEM		✓		UF	PES	PDI
Inge	OEM		✓		UF	PES	PDI
Koch	System		✓		UF	PS	PDI
Memcor	**System**	✓			**MF**	**PVDF**	**SUB/PDO**
Norit	**System & OEM**	✓			**UF**	**PES**	**PDI**
Pall/Asahi	**System**	✓			**MF**	**PVDF**	**PDO**
Polymem	System			✓	UF	PS	PDO
Toray	OEM			✓	MF	PVDF	PDO
Zenon	**System**	✓			**UF?**	**PVDF**	**SUB**
NB: PDI – Pressure driven, inside feed PDO – Pressure driven, outside feed SUB – Submerged, vacuum driven, outside feed				Market leaders shown in bold type.			

Adapted from “Introduction to membranes: Manufacturers’ comparison: part 1”, *Filtration + Separation*, October 2007

ULTRAFILTRATION (4)

	PES/PS	PVDF	CA	PAN	PP
Mechanical strength	++++	+++	+++	+++	++
Oxidant tolerance	+++	++++	++	+++	+
pH tolerance	+++	+++	+	++	+++
Pore size distribution	++++	++	+++	++++	++
Hydrophilicity	+++	+ / ++	++++	++	+
Biofouling resistance	++++	++++	+	+++	+++

NOTES:

-PES: POLYETHERSULFONE
-PS: POLYSULFONE
-PVDF: POLY VINYLIDENE FLUORIDE
-CA: CELLULOSE ACETATE
-PAN: POLYACRYLONITRILE
-PP: POLYPROPYLENE

- ++++ Very good
- +++ Good
- ++ Moderate
- + Poor

ULTRAFILTRATION (5)

PRESSURISED VS SUBMERGED

	Pressurised	Submerged
Feed mode	Inside-out OR outside-in Bleed flow is possible	Outside-in
Mechanical requirements	May require air scouring blowers. More complex valve units.	Requires membrane lifting equipment. Requires air scouring blowers.
Civil requirements	Lower, plinth construction only. Shorter construction lead time.	Higher, requires membrane tanks. Longer construction lead-time.
Ease of scale-up	Modular design makes it easier to scale up, especially in operational plant.	Requires additional membrane tanks or advance planning for membrane tanks.
Maintenance/membrane replacement	Easier	Harder, submerged cassettes needs to be lifted
Chemical requirements	Lower	Higher

ULTRAFILTRATION (6)

INSIDE OUT VERSUS OUTSIDE IN

	Inside out	Outside in
Feed mode	Pressurized	Pressurized or submerged
Specific surface area	Lower Based on inside fibre diameter	Higher Based on outside fibre diameter
Membrane material	PES	PVDF
Backwash	Without air scour	With Air scour
Pore size	Small (tight UF)	Larger (open UF or MF)
Susceptible to blocking	Higher (300 micron straining)	Lower (500 micron straining)
Susceptible to skin damage	Lower (skin inside fibre)	Higher (skin rubbing)

ULTRAFILTRATION (7)

Global UF/MF membrane suppliers in plants larger than 10,000m³/d	
Membrane supplier	**Market share**
Pentair X-Flow	34,4%
Asahi	22,5%
Hyflux	13,0%
GE	11,5%
Siemens Memcor	6,3%
Inge	3,6%
Metawater	2,6%
Toray	1,9%
Koch	1,6%
Others	2,6%

Global UF/MF membrane suppliers in **desalination** plants larger than 10,000m³/d	
Membrane supplier	**Market share**
Pentair X-Flow	46,7%
Hyflux	31,7%
Siemens Memcor	7,5%
GE	6,0%
Inge	5,7%
**installed or under construction ≥ 2011*	

Source Global Water Intel Aug 2012

ULTRAFILTRATION (8)

One of the main requirements of governments and drinking water companies worldwide in providing drinking water: public safety

REQUIRED REMOVAL

- Bacteria (e.g. Fecal bacteria)
- Protozoa (e.g. Cryptosporidium and giardia)
- Viruses (e.g. Enteric viruses like hepatitis)

DIRECTIVES

- WHO
- European directive
- Long term 2 surface water treatment (USA)

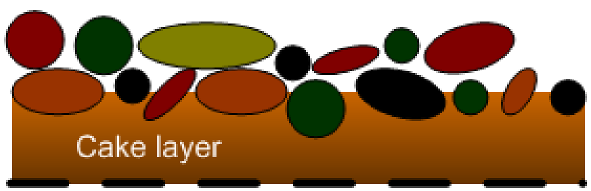
APPROVALS

- Potable water approvals: UK, USA, F, D, NL, AUS, JAP…

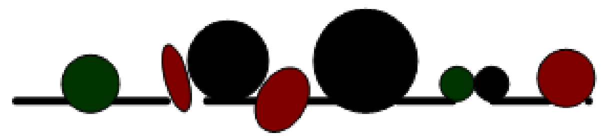
MEMBRANE FOULING AND CLEANING (1)

TYPES OF FOULING ON UF MEMBRANES:

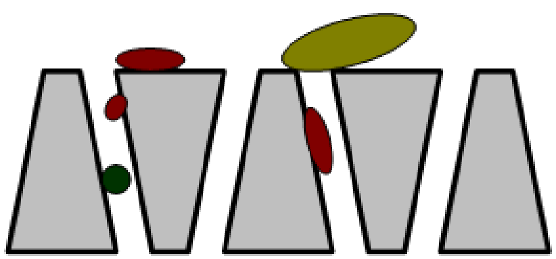
- Cake formation
- Pore blocking
- Adsorption
- Concentration Polarization



Cake Formation



Pore Blocking



Adsorption

Concentration Polarization

MEMBRANE FOULING AND CLEANING (2)

CLEANING MODES:

- Backwash (BW)
- Air-scouring or Air-Flush
- Relaxation
- Chemical Enhanced Backwash (CEB)
- Clean-In-Place (CIP)

MEMBRANE FOULING AND CLEANING (3)

BACKWASHING

- Reverse the flow of filtrate at higher flux for short duration to flush out foulants from membrane surface and pores.
- Effective against surface foulants, loose cake layer and partially effective against adsorbed foulants.

AIR SCOURING/AIR FLUSH

- Air bubbles are passed along the feed surface of membranes to dislodge surface foulants.
- Cannot remove foulants in pores and thick cake layer.
- Sustained during filtration or applied intermittently for submerged UF.

RELAXATION

- Short stoppages of filtration. (air scouring may run concurrently).
- Loosen cake layer and loosely attached foulants.

CHEMICAL ENHANCED BACKWASH

- Chemical cleaning involving a short soak duration.
- Effective against adsorbed foulants.

CLEAN-IN-PLACE

- Long duration, chemical cleaning involving recirculation-soak cycles.
- Use for recovery cleaning or with specialised chemicals for particular foulants.

MEMBRANE FOULING AND CLEANING (4)

UF CLEANING CHEMICALS

	Type	Effective against
NaOH KOH	Caustic	Organic/biological foulants
H_2SO_4 HCl	Inorganic acids	Inorganic foulants Inorganic scaling
NaOCl H_2O_2	Oxidants	Organic/biological foulants
EDTA	Chelating agents	Hardness scaling
Organic acids (citric, oxalic, ascorbic acid etc)	Organic acids	Fe and Mn fouling, Other specific types of foulants
Surfactants	Surface active agents	Oil and grease Certain organic polymers

* It is important to check back with UF supplier on chemical compatibility and dosage

COMPONENTS OF AN UF PLANT (1)

COMPONENTS OF AN UF PLANT

- Pre-treatment
- Pre-screen
- UF skid
- Chemical dosing unit(s)
- Neutralisation unit
- Backwash unit
- Air-scouring unit
- CIP unit
- Membrane integrity test unit (esp. drinking water application)
- Post treatment (disinfection, RO etc)

COMPONENTS OF AN UF PLANT (2)

PRE-TREATMENT

- Pre-treatment is installed to:
  - Remove particular foulants that UF is susceptible to. (e.g. Mn, Fe, FOG)
  - Reduce size of UF plant by reducing TSS load.

- Typical UF pre-treatment processes:
  - DAF → removal /reduction of FOG, COD and TSS
  - Green sand filter → Mn and Fe removal, reduce TSS
  - Coagulation/Flocculation → Reduce TSS load, remove oxidised Fe and Mn
  - Activated carbon (GAC/PAC) → colour, odour, TOC
  - Oxidation → oxidation of Mn and Fe, reduction of TOC

COMPONENTS OF AN UF PLANT (3)

SCREEN

- A pre-screen is required to remove large particles for membrane protection.

- Specifications:
  - » Surface water → 200 to 300 microns
  - » Sea brackish water → 100 microns
  - » Effluent water → 100 to 300 microns

- Considerations:
  - » UF feed pump should also consider head loss across strainers
  - » For large plants, strainers should be self-cleaning type

COMPONENTS OF AN UF PLANT (4)

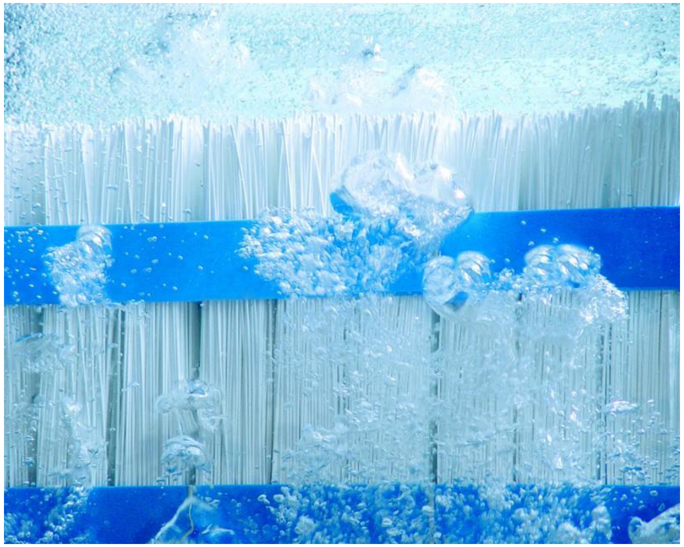
CHEMICAL DOSING UNITS

- For pH adjustment, CEB, in-line coagulant dosing and chemical neutralisation

- Typical dosing sets required:
  - » In-line coagulation: $FeCl_3$, alum, PACl + pH adjustment
  - » CEB: Caustic + NaOCl + acid
  - » Neutralisation: Reducing agent (SBS) + acid/caustic

- Considerations:
  - » Chemical dosing sets should be overdesigned to cater for deterioration in chemical stock concentration and fluctuating water quality

COMPONENTS OF AN UF PLANT (5)



AIR SCOURING/AIR FLUSH UNIT

- Optional, based on membrane design
- Considerations:

  Air quality for scouring should be oil-free.

  Pressure and temperature considerations.

MEMBRANE INTEGRITY TEST UNIT

- To test for leaks in membrane fibers
- Usually a requirement for drinking water applications

CIP UNIT

- Optional for small plants but CIP connections on UF skids recommended.
- RO CIP units can be shared if available.

DESIGNING AN UF SYSTEM (1)

INFORMATION REQUIRED:

- Feed Quality:
  - » Turbidity, TSS, COD, TOC, FOG, dissolved metals, alkalinity, silica, colour etc.)
- Capacity:
  - » Nominal flow
  - » Peak flow
- Required filtrate quality
- Other considerations:
  - » Footprint

DESIGNING AN UF SYSTEM (2)

SIZING UF UNITS:

$$\textit{Required Membrane Area}\ (m^2) = \frac{\textit{Required Capacity}\left(\frac{m^3}{h}\right) \times 1000\left(\frac{L}{m^3}\right)}{\textit{Filtration Flux}\left(\frac{L}{m^2 \cdot h}\right) \times \textit{Percentage of Filtration Time} \times \textit{Recovery}}$$

- Filtration Flux:
  - Dependent on:
    - » Pre-treatment processes
    - » Raw water quality
- Percentage of filtration time:
  - Dependent on:
    - » Raw water quality and filtration flux ➔ affects duration of single filtration cycle.
    - » Performance of CEB, CIP and MIT
- Recovery:
  - Dependent on frequency and volume of filtrate for membrane cleaning.

DESIGNING AN UF SYSTEM (3)

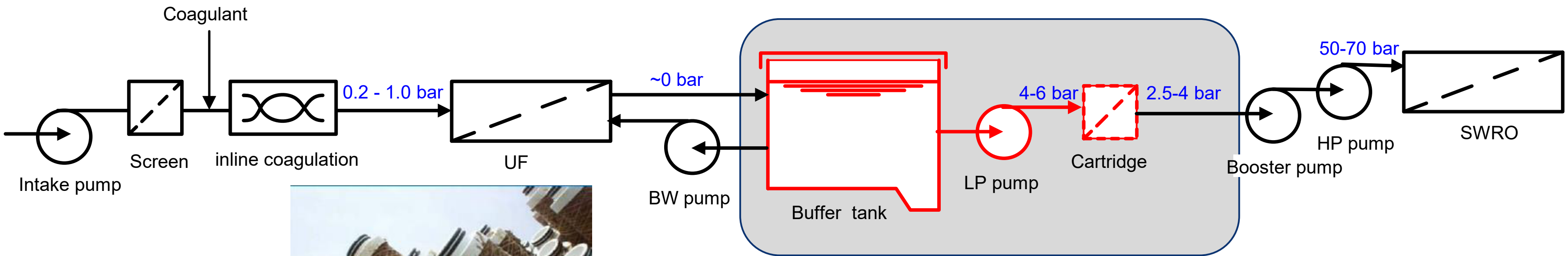
$$\boldsymbol{No.of\ membrane\ elements} = \frac{Required\ Membrane\ Area\ (m^2)}{Unit\ membrane\ element\ area\ (\frac{m^2}{element})}$$

SOME DESIGN CONSIDERATIONS:

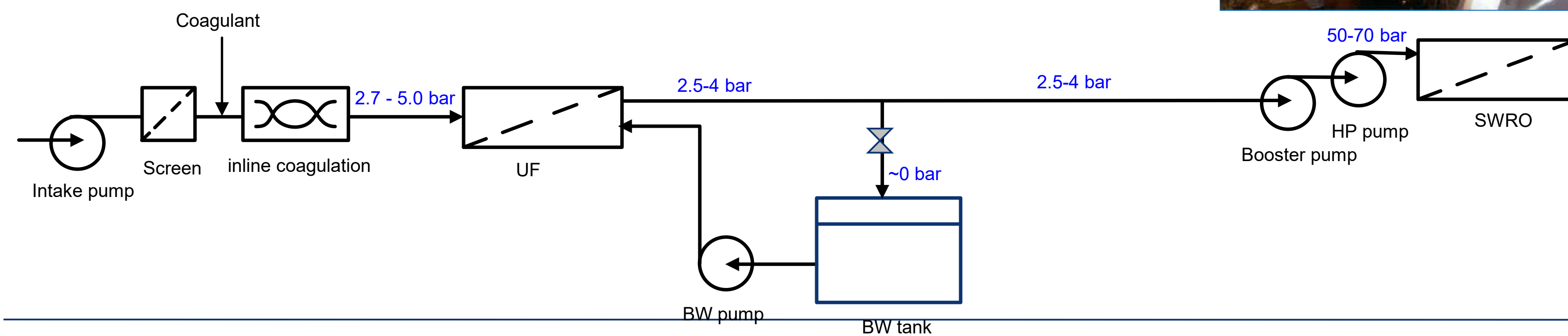
- Is there a downstream RO that requires continuous water supply?
  - » Larger tank required (UF backwash + RO feed) or
  - » Design of UF system for constant flow (in line operation)
- Peak flow occurrences?
  - » Extra UF skids/membranes .
  - » Equalization tank.
- Standby equipment?
  - » Common or dedicated equipment?
  - » Use of standby unit?

NEW DEVELOPMENTS – IN LINE

NORMAL (ATMOSPHERIC) UF – SWRO



Inline (pressurized) UF – SWRO



INLINE UF – SWRO

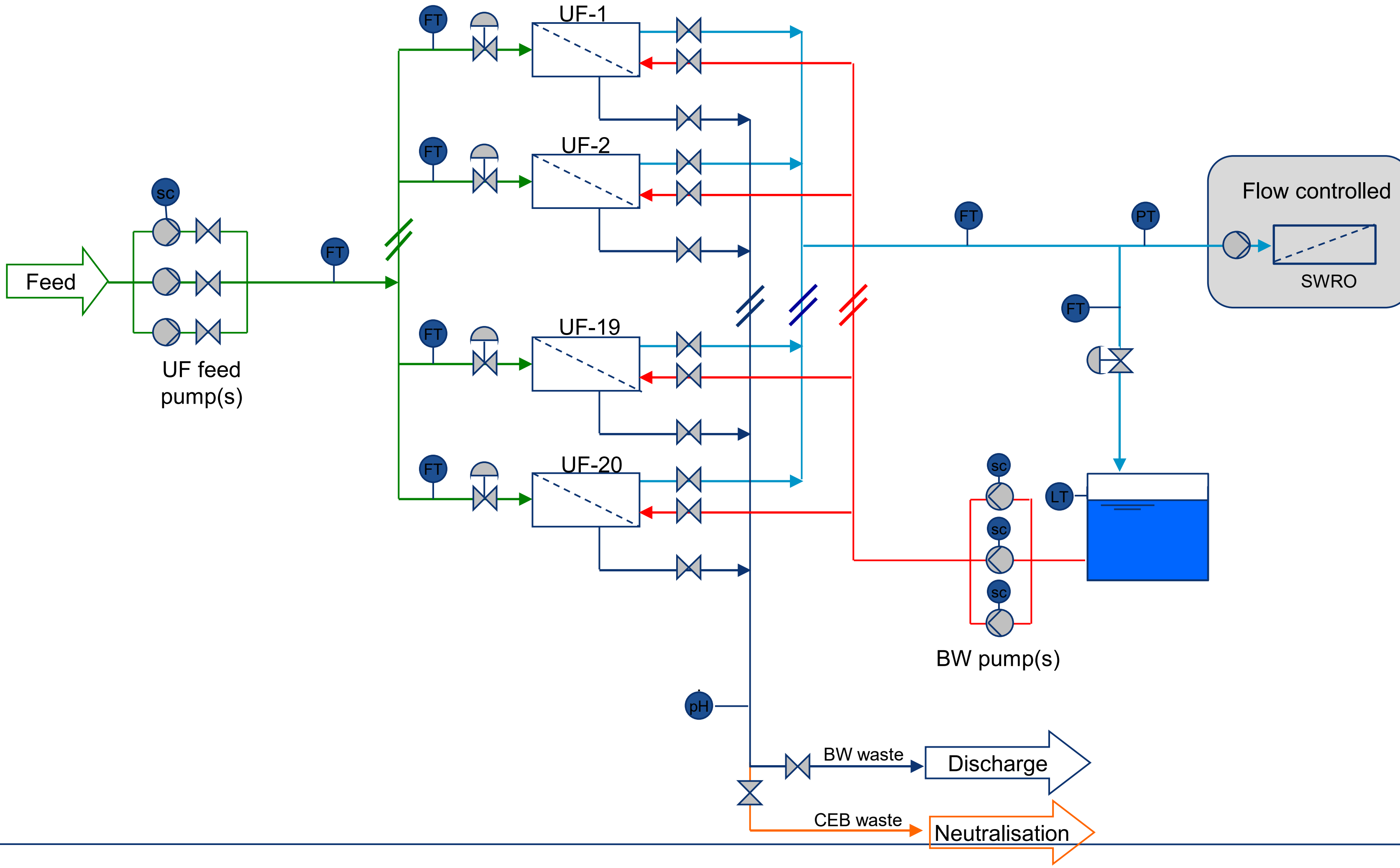
Advantages:

- 1 pumping stage less → Lower Capex / Opex (energy) / smaller footprint
- No cartridge-filters → Lower Capex / Opex (replac.) / smaller footprint
- No buffer tank → Lower Capex / smaller footprint
  No/less biogrowth / RO fouling

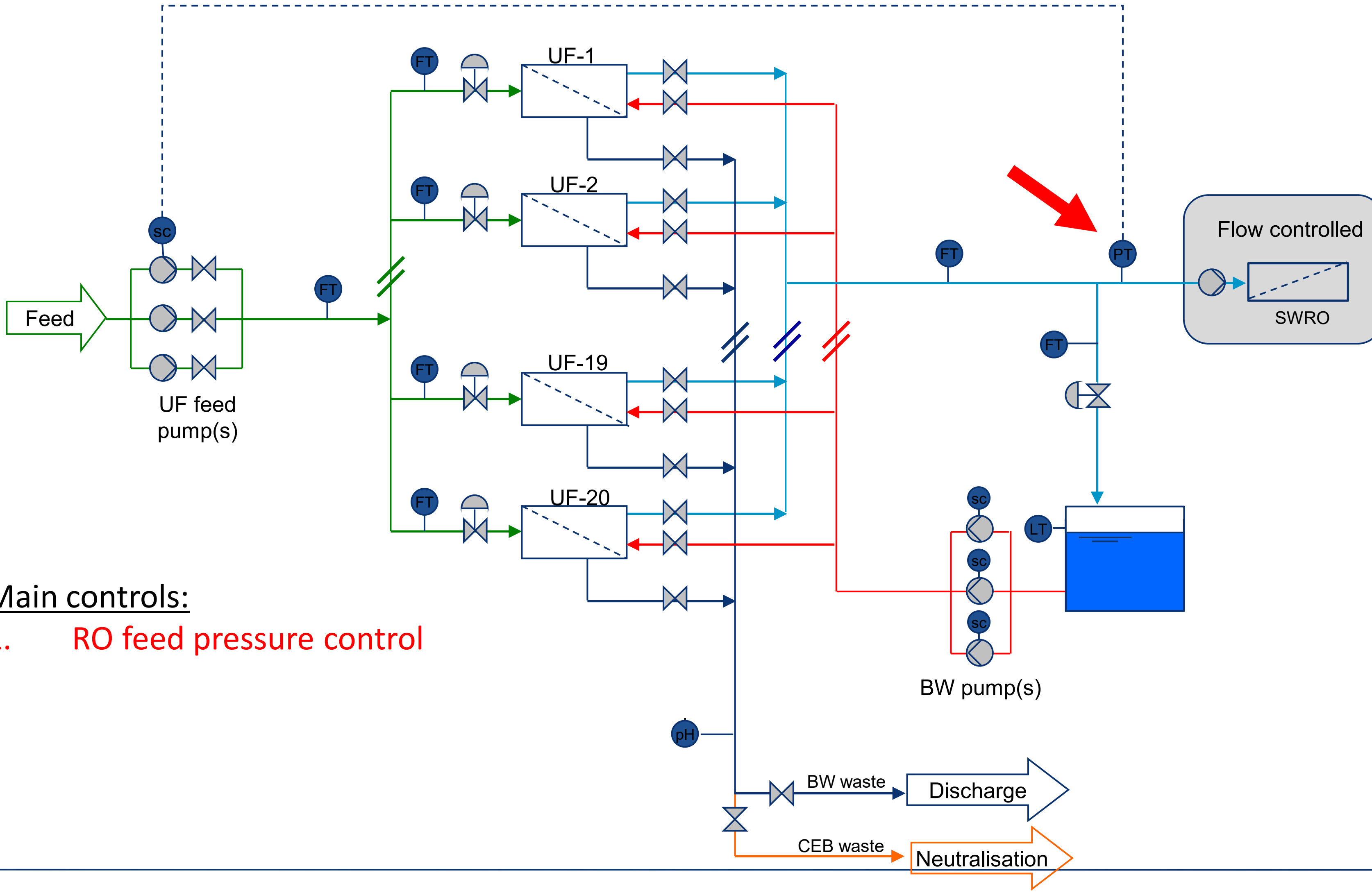
However:

- Higher pressure → Extra attention to be paid to:
  - Design & controls
  - Surge analysis & mitigation

NEW DEVELOPMENTS – IN LINE



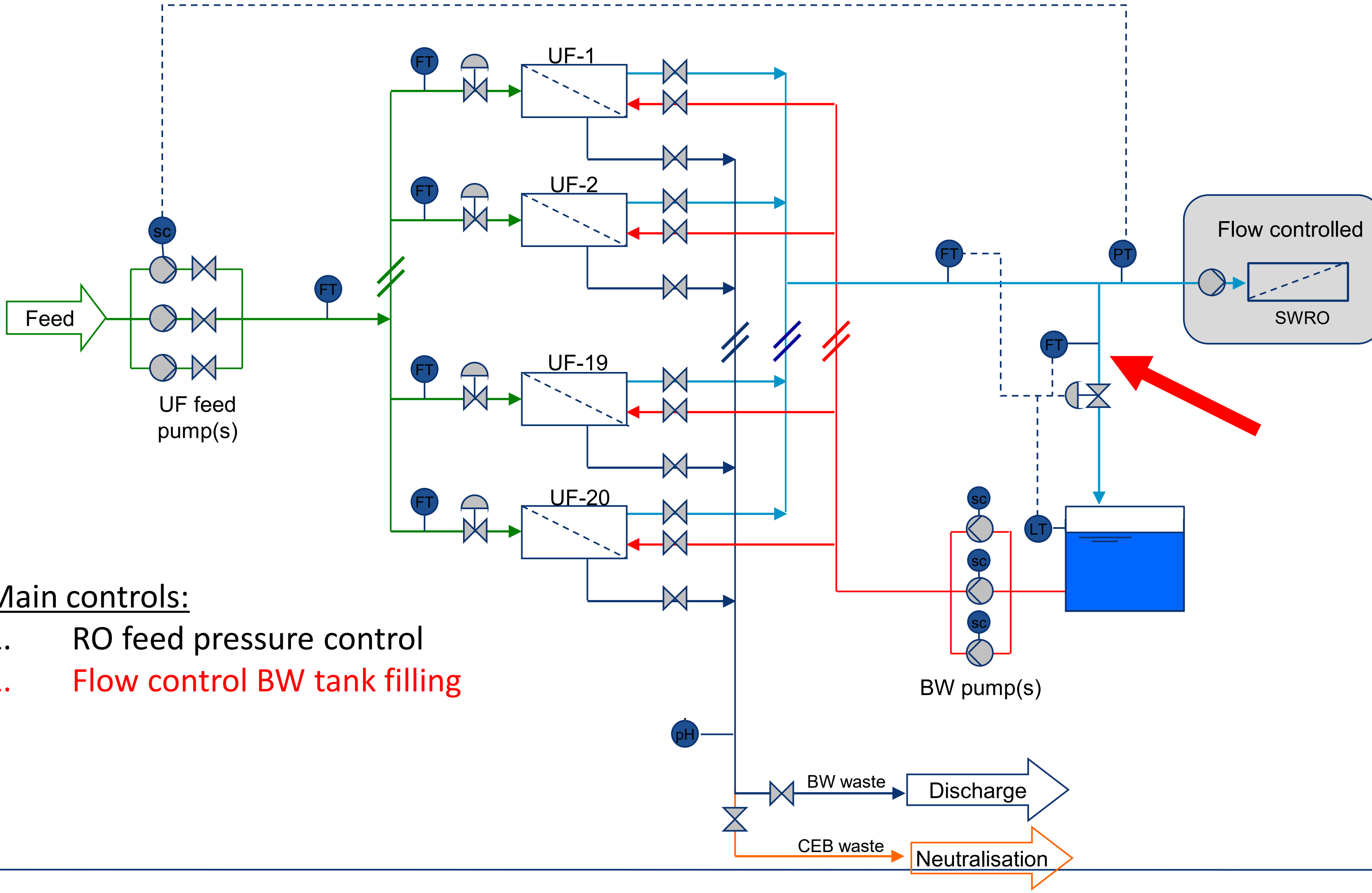
NEW DEVELOPMENTS – IN LINE



Main controls:

1. RO feed pressure control

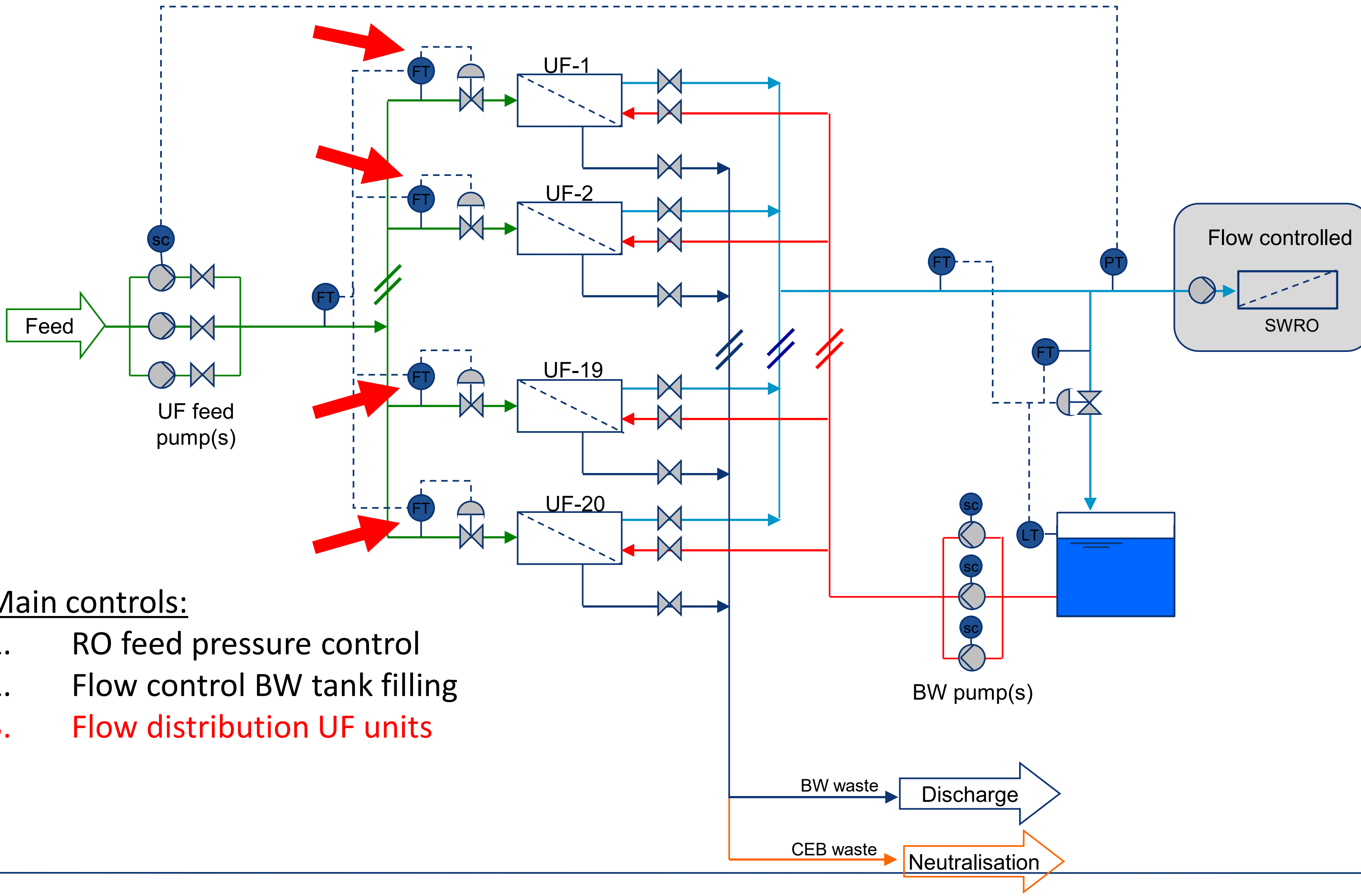
NEW DEVELOPMENTS – IN LINE



Main controls:

1. RO feed pressure control
2. Flow control BW tank filling

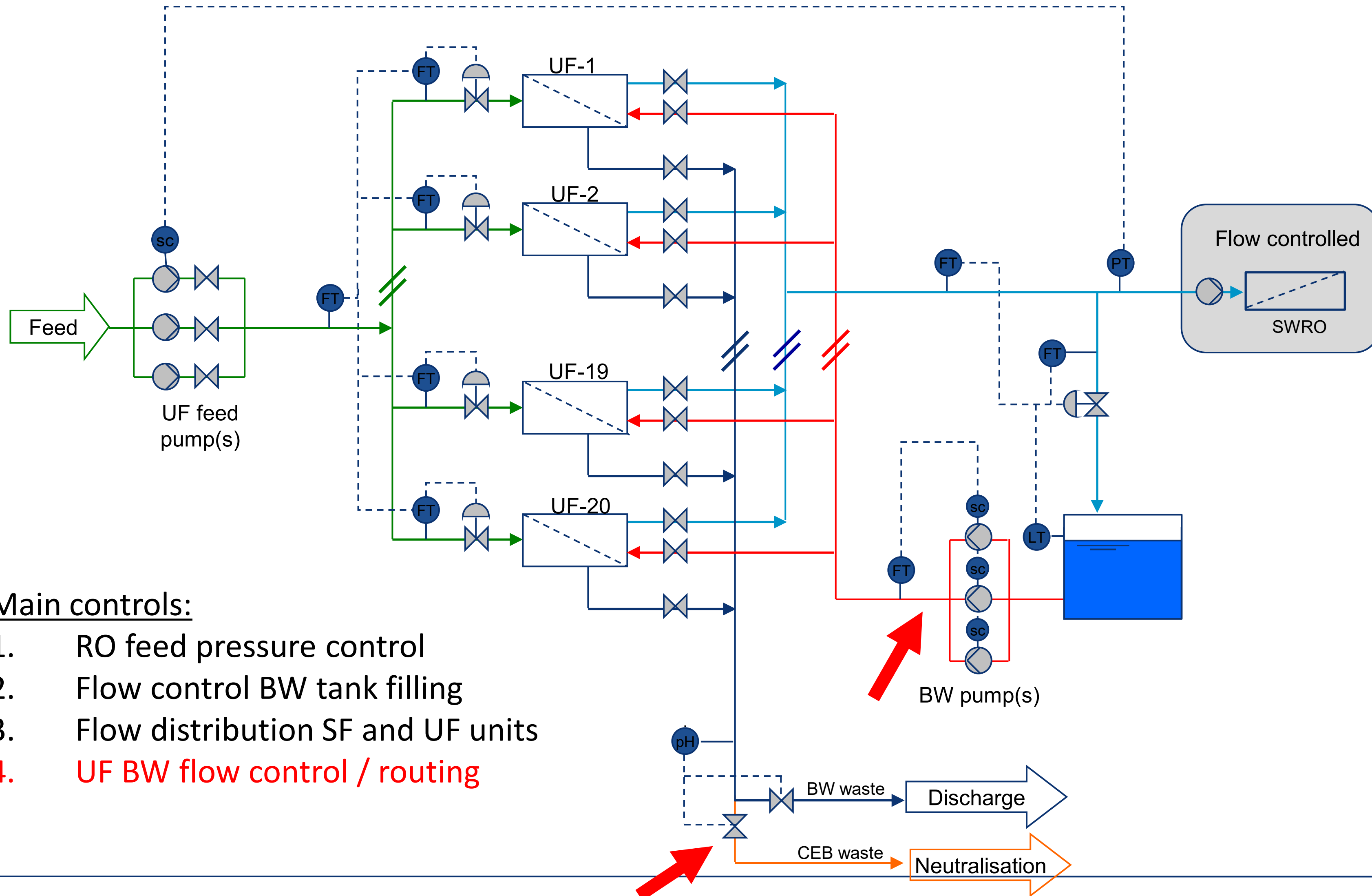
NEW DEVELOPMENTS – IN LINE



<u>Main controls:</u>

1. RO feed pressure control
2. Flow control BW tank filling
3. Flow distribution UF units

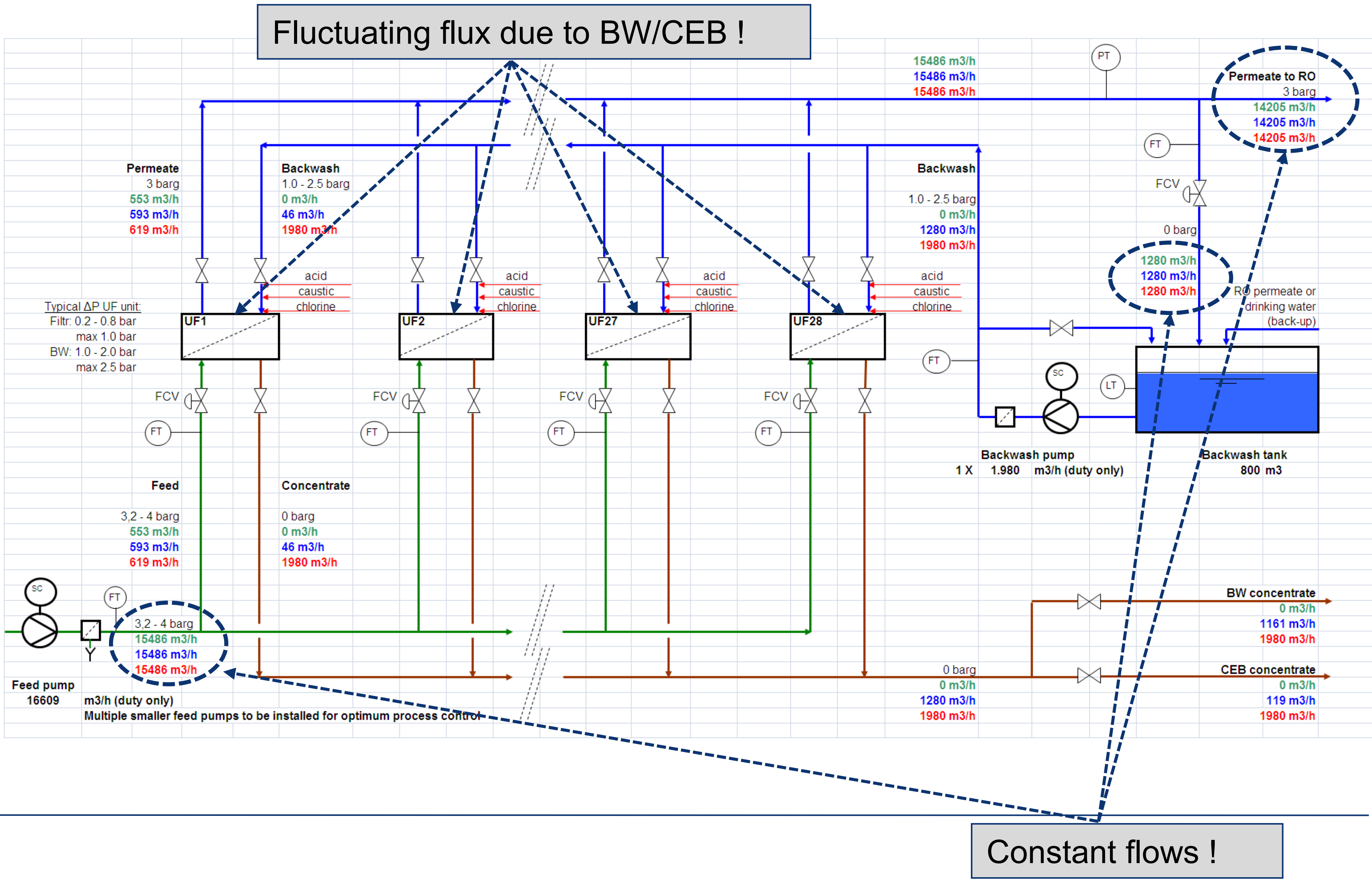
NEW DEVELOPMENTS – IN LINE



Main controls:

1. RO feed pressure control
2. Flow control BW tank filling
3. Flow distribution SF and UF units
4. UF BW flow control / routing

NEW DEVELOPMENTS – IN LINE



NEW DEVELOPMENTS – TIGHT UF

Silica removal
Either stand alone or upstream of reverse osmosis (RO)

Silica is available in three forms

1. Particulate (sand particles)
2. Colloidal or polymerized (silicone dioxide)
3. Reactive (ionized)

- Pretreatment removes particulate silica.
- IX and RO remove reactive silica.
- IX does not remove colloidal silica.
- RO fouls by colloidal silica.

NEW DEVELOPMENTS – TIGHT UF

Colloidal or polymerized (silicone dioxide)

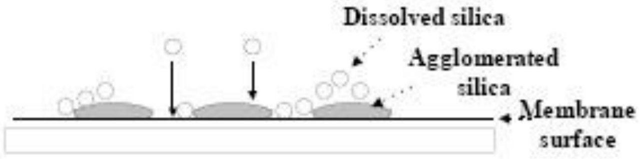
- Complexes with organics
- Agglomerates with deposited silica

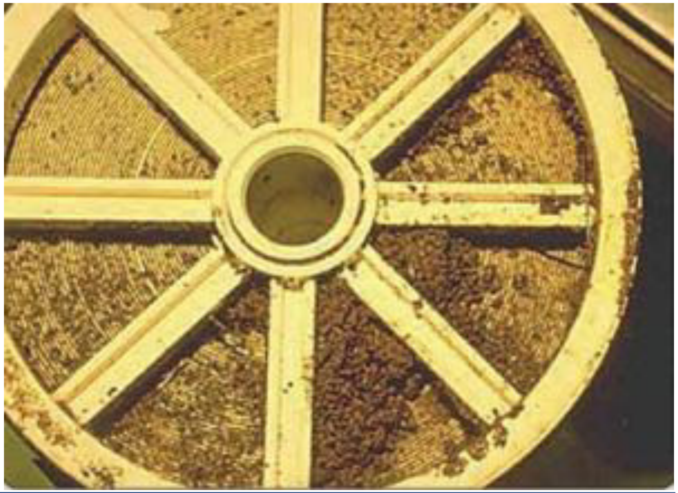
Reactive silica

- Forms colloidal silica

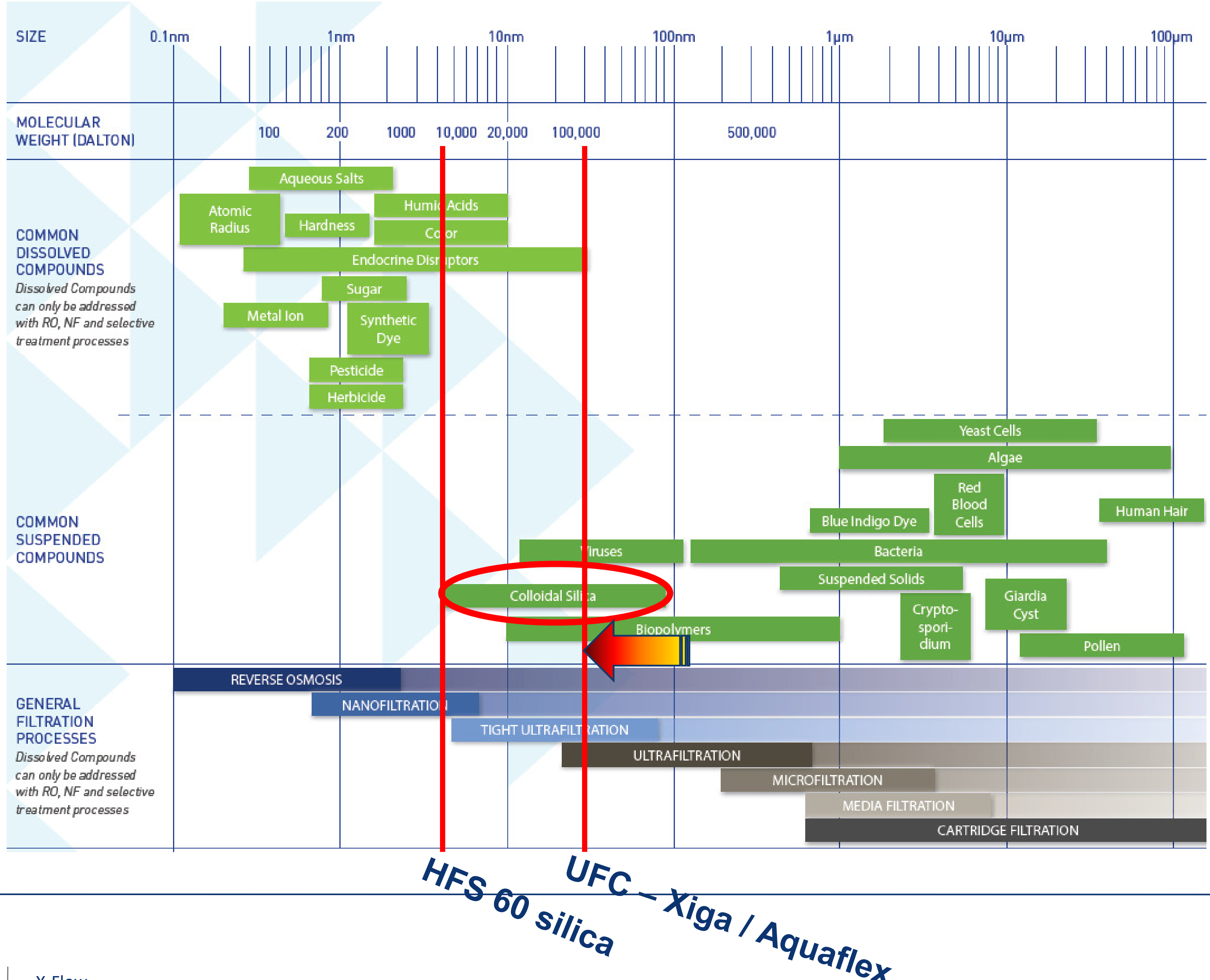
Silica fouling on RO membranes

- High ph cleaning
  RO membranes sensitive to caustic
- If combined with inorganic fouling
  calcium carbonate requires acid





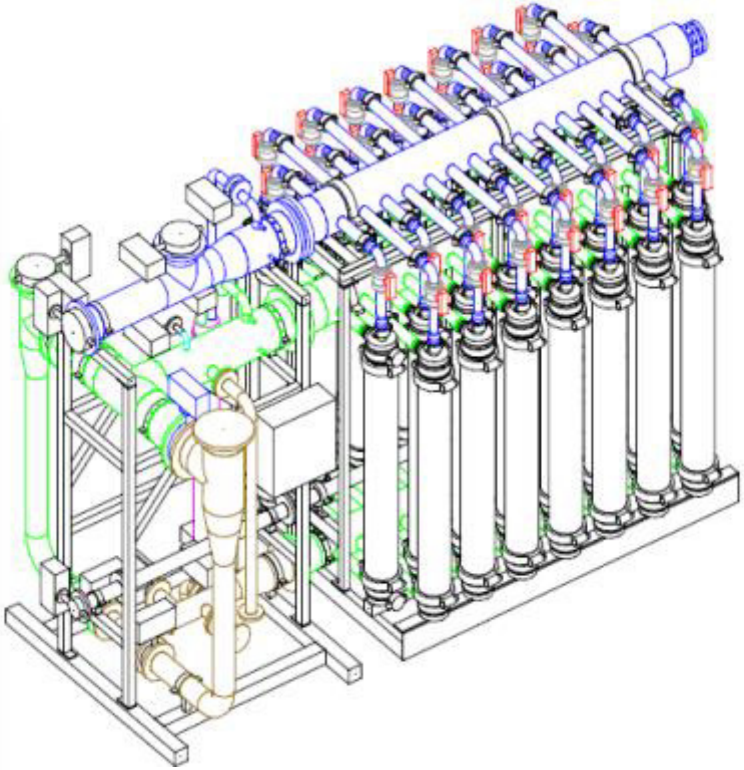
NEW DEVELOPMENTS – TIGHT UF



NEW DEVELOPMENTS – TIGHT UF

Aquaflex or X-Line skids

- Standardized design
  From 10 to 120 membrane modules per skid
- Dead end operation
- Chemically enhanced backwash



NEW DEVELOPMENTS – TIGHT UF

HFS 60 Silica for boilerfeed applications

- Jaypee Nigrie Super Thermal Power Project in Singrauli, Madhya Pradesh, India
  Electrical output: 2 X 660 MW
  Boilerfeed: 3,840 m^3/day

- J.K. Paper plant in Rayagada, Chhattisgarh, India
  Paper production: 260,000 tonnes per annum
  Pulp production: 200,000 tonnes per annum
  Electrical output: 48.5 MW
  Boiler feed: 6,000 m^3/day

NEW DEVELOPMENTS – TIGHT UF

- Lanco Mahagenco, India
  Water production: 7,200 m^3/day (X-Line)

- Hindustan Coca Cola, India
  Water production: 1,000 m^3/day (<20 kDalton requirement)

- Euraqua, UK
  Water production: 1,300 m^3/day (<20 kDalton requirement)

- Bushan Steel, India
  Water production: 3,000 m^3/day

- Giza Power Plant, Egypt
  Water production: 12,000 m^3/day

- Banha Power Plant, Egypt
  Water production: 11,000 m^3/day

PENTAIR

CASE STUDY

COMPARISON OF CONVENTIONAL FILTRATION AND ULTRAFILTRATION

CASE STUDY

Small scale desalination using membrane pretreatment

Independent electricity producer in Antofagasta

GASATACAMA

Main customers

- Municipalities & industries (through distributor)
- Mining (90% of consumption)

CASE STUDY

Water needed for

- Boiler feed
- Cooling of gas turbines
- Supply of potable water
- Fire fighting

Existing desalination plants:

- Thermal: 2 X 700 m^3/day
  High energy consumption
- Reverse Osmosis: 2 X 500 m^3/day
  Insufficient pretreatment
- Total capacity: 2,400 m^3/day

Expansion needed:

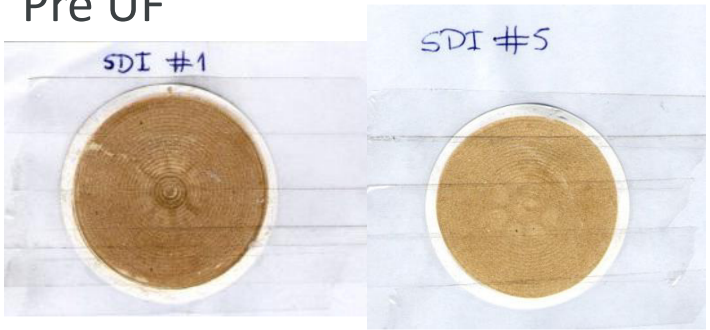
- Total capacity: 2,590 m^3/day (3 X 863 m^3/day)
- Lower energy consumption
- Lower chemical consumption
- Lower waste production

CASE STUDY

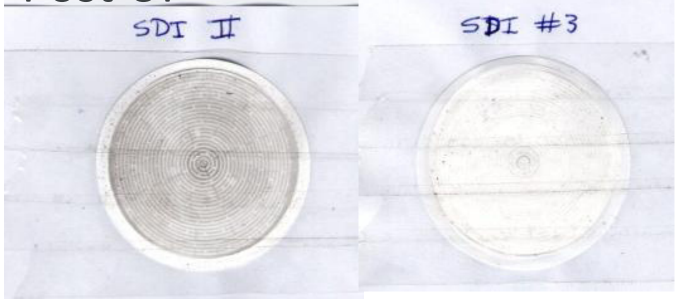
Design for compact and robust system

- Open intake (- 5 meters)
- Automatic strainers 200 micron
- Seaguard ultrafiltration
- Buffertank
- Reverse osmosis

Pre UF



Post UF



CASE STUDY

Comparison existing DAF + MMF versus new UF plant

	DAF + MMF	Seaguard UF
Chemical consumption	25 ppm coag + polymer	1 ppm coag, no polymer
SWRO CIP	1 – 2 X /month	none
5 micron cartridge filter replacement	1 – 2 X / month	none

PENTAIR X-FLOW

MEMBRANES FOR WATER & WASTEWATER TREATMENT

X-FLOW HISTORY

- 1984 — Membrane Technology X-Flow
- 1985 — Separation University Twente
- 1995 — Launching customer PWN
- 1997 — Acquisition Norit
- 2011 — Water Technology Company of the Year (GWI)
- 2011 — Acquisition Pentair

WATER & WASTEWATER TREATMENT

POTABLE / PROCESS WATER

- Clean & safe water
- Reliable barrier for bacteria & viruses
- High performance & integrity

DESALINATION PRETREATMENT

- Optimum pre-treatment for RO
- Removal of fine silt & turbidity
- High fluxes
- Small plant design

MUNICIPAL WASTEWATER

- Fully enclosed, robust system
- Limited energy consumption
- Safe working environment
- Compact & flexible design

INDUSTRIAL WASTEWATER

- Primary treatment
- Secondary treatment
- Robust & reliable
- Clean & dry systems

XIGA – FINAL BARRIER POTABLE WATER

Clay Lane - London (UK)
6,700 m^3/h

South West - Moscow (RUS)
10,000 m^3/h

XIGA – POTABLE WATER FROM SURFACEWATER

Minneapolis (USA)
11,000 m^3/h

Roetgen (Germany)
6,000 m^3/h

XIGA – MUNICIPAL EFFLUENT POLISHING

Al Wathba (Abu Dhabi)
1125 m^3/h

Sulaibiya (Kuwait)
15,600 m^3/h

XIGA/AQUAFLEX – PROCESS WATER

Mosenergo, PP Russia
250 m3/h

Zaynskaya PP, Russia
600 m3/h

SEAGUARD - SEAWATER PRE-TREATMENT

Jubail (KSA)
10,000 m^3/h

Palm Jumeirah (UAE)
7,667 m^3/h

MBR – MUNICIPAL WASTEWATER TREATMENT

King Faisal Hospital (KSA)
XX m3/h

WRD, Ootmarsum (NL)
150 m3/h

MBR – INDUSTRIAL WASTEWATER TREATMENT

Russky Solod, Russia
1600 m^3/day

Obolon, Ukraine
2000 m^3/day

ULTRAFILTRATION
DRINKING WATER PRODUCTION

CLAYLANE WTW, UK

Design UF product flow rate 162.000m^3/d

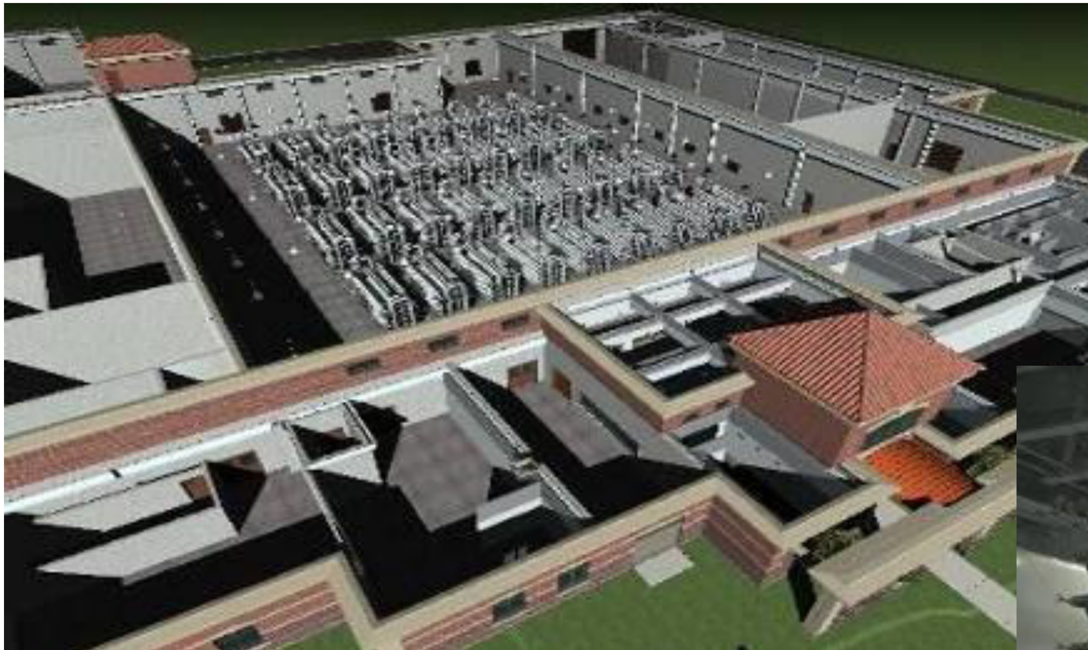
PWN HEEMSKERK, NETHERLANDS

Design UF product flow rate 65.000m^3/d

ROETGEN, GERMANY

Design UF product flow rate 145.000 m^3/d

MINNEAPOLIS, USA



Design UF product flow rate   265.000 m^3/d

MOSCOW SOUTH WEST, RUSSIA

Design UF product flow rate 250.000 m^3/d

THANK YOU FOR YOUR ATTENTION!