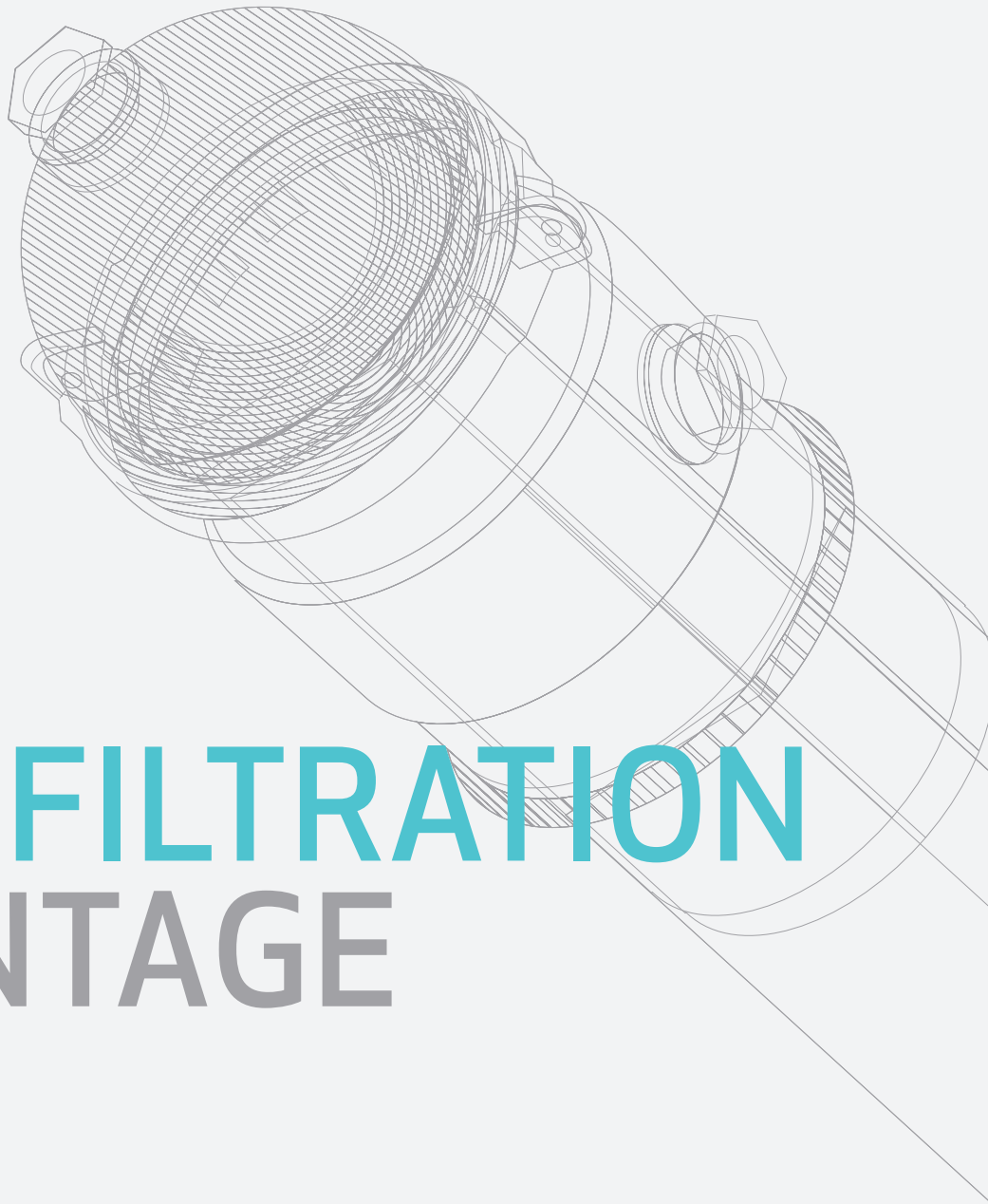


KRISTAL®

THE ULTRAFILTRATION ADVANTAGE

Hyflux®

ENGINEERED FOR CONSISTENT, HIGH WATER QUALITY.

When it comes to filtration, Hyflux's Kristal® polymeric hollow fibre ultrafiltration membranes and systems offer a superior level of performance, efficiency and reliability. Designed with a **cross-flow** and **out-to-in** configuration, Kristal® membranes deliver consistent, high quality product water even in challenging feed water conditions.

Product Features and Benefits

- Enhanced hydrophilic material (PES and PVDF)
- Reduced fouling
- Consistent, high quality permeate
- Enhanced tolerance to cleaning chemicals

Operation Features and Benefits

- Sharp rejection profile
- Long lifespan
- Small footprint
- Automatic backwash function
- Efficient system recovery

Key Applications

- Water treatment/purification
- Pre-treatment filtration
- Wastewater recycling
- Industrial process/waste fluid treatment

KRISTAL® APPLICATIONS

Kristal® membranes may be applied for various uses, including:

Water Treatment/Purification

- Production of potable water from reservoirs, rivers, ground water
- Water purification of municipal supply for hotels, resorts, spas, condominiums
- Mobile water purification systems

Pre-treatment Filtration

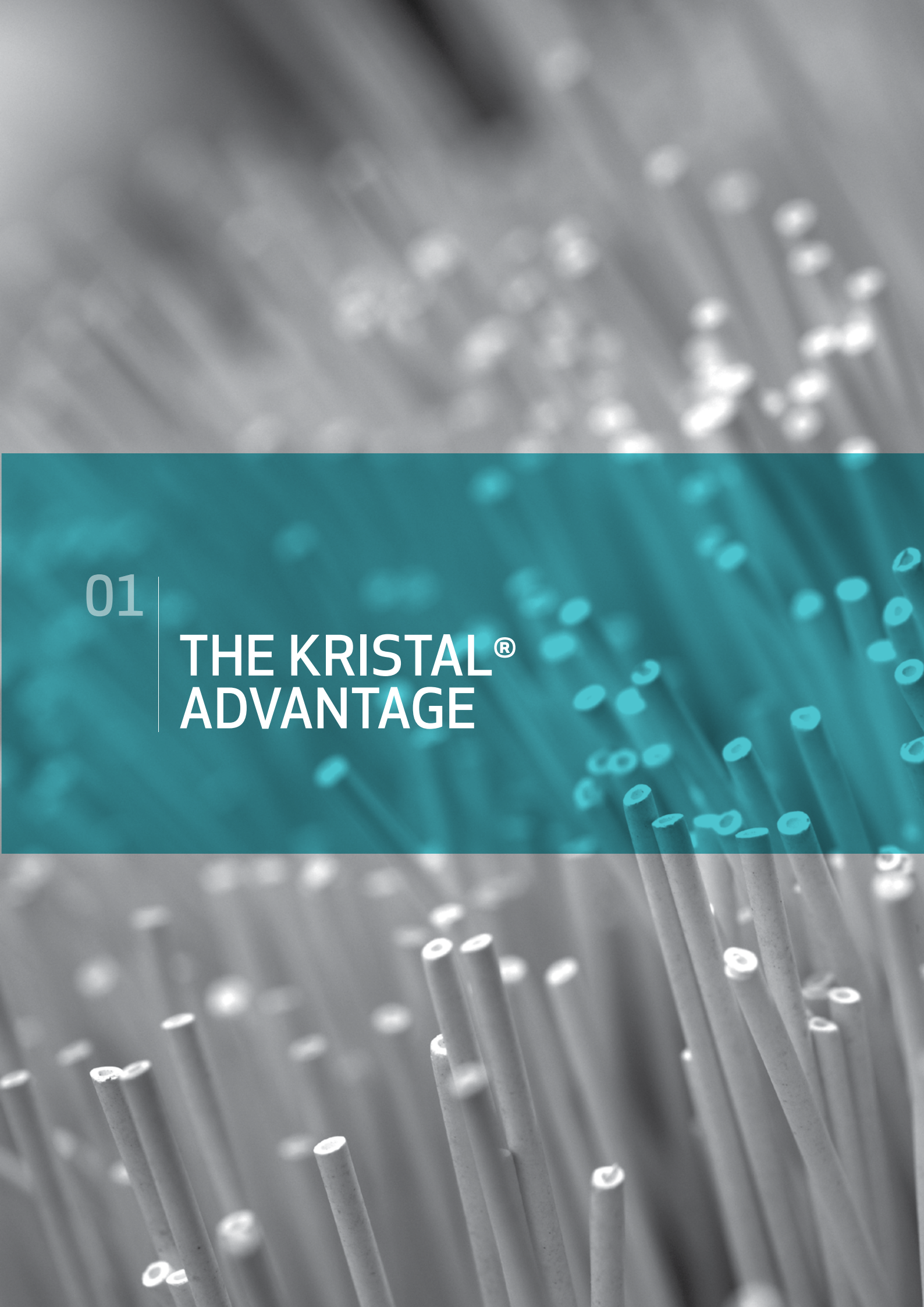
- Seawater desalination reverse osmosis (RO) pre-treatment
- Pre-treatment option before RO or ion exchange system in production of ultra-pure water for power plant, semi-conductor, pharmaceutical industries

Wastewater Recycling

- Municipal wastewater reclamation
- Wastewater recycling for semi-conductor, pulp and paper, textile and dye, and agricultural processes
- Zero discharge of process waste streams

Industrial Process/Waste Fluid Treatment

- Treatment of various aqua-based industrial waste streams
- Recovery of valuable resources from industrial waste streams
- Regeneration of useful process streams by selective removal of contaminants



01

THE KRISTAL® ADVANTAGE

THE KRISTAL® ADVANTAGE

Kristal® has been employed in more than 1,000 installations worldwide, from the largest desalination plants to small and medium-sized water treatment facilities across some 400 locations in Asia, Europe, the Middle East, North Africa and other parts of the world.

Developed, tested and fabricated in Singapore, Kristal® polymeric ultrafiltration (UF) hollow fibre membrane has been one of Hyflux's main product lines since its launch in 1999. Hyflux's technological innovations have taken Kristal® ultrafiltration technology to the next level, and today Kristal® membranes are used in a wide range of applications in water treatment and wastewater recycling.

The development of the Kristal® series has benefited from Hyflux's combined knowledge and experience as a membrane maker, system designer, user and plant operator.

Kristal® membranes have been employed in more than 1,000 installations worldwide, from the largest desalination plants to small and medium-sized water treatment facilities across some 400 locations in Asia, Europe, the Middle East, North Africa and other parts of the world. In fact, the membranes are used in over 40% of seawater reverse osmosis (SWRO) desalination pre-treatment systems worldwide, including China's largest SWRO desalination plant and the world's largest SWRO desalination plant in Algeria.

This is a key testament to the effectiveness and quality of Hyflux's Kristal® membranes, and its widespread use on a global scale. Industries and communities can draw on Hyflux's expertise in the operation and maintenance of Kristal® membranes and the integration of different water technologies, to improve the efficiency and performance of water and wastewater applications.

THE KRISTAL® ADVANTAGE

From left to right:

R-type module for 600 series

T-type module for 600, 2000 series

T-type module for Tri-bore series

Kristal® membranes come in three series:

Kristal® 600 series

– Made of specially formulated polyethersulfone (PES)
– Enhanced hydrophilicity reduces fouling and improves flux
– Suitable for applications in desalination, surface and ground water treatment, and wastewater recycling

Kristal® 2000 series

– Made of polyvinylidene diflouride (PVDF)
– Outstanding durability due to high tensile strength and chemical tolerance towards oxidising agents such as chlorine
– Suitable for difficult and challenging conditions such as high solids wastewater recycling

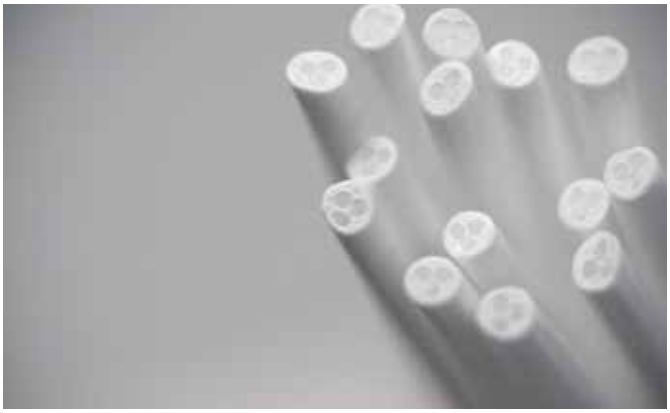
Kristal® Tri-bore series

– Comes in both PES and PVDF
– Latest addition to the Kristal® membrane family
– Tri-bore structure provides even higher tensile strength
– Suitable for extreme water treatment conditions

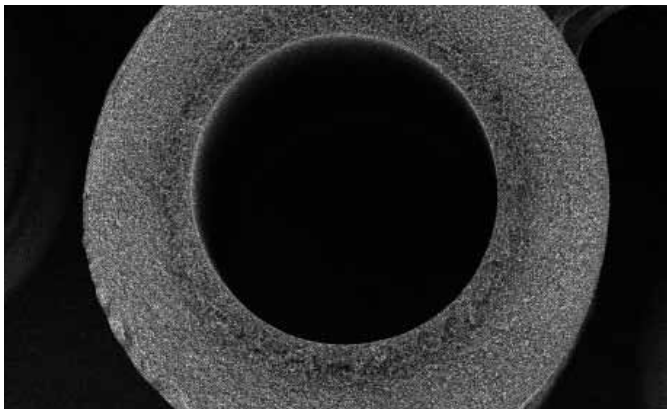
THE KRISTAL® ADVANTAGE

HYDROPHILISED, ENHANCED POLYMERIC MATERIAL

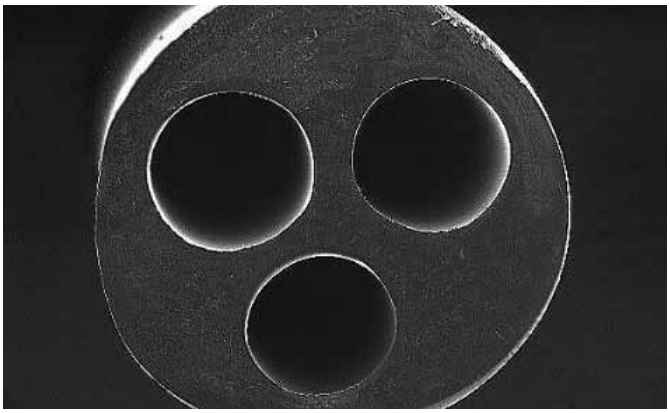
Single bore



Tri-bore



Single bore (SEM photo)



Tri-bore (SEM photo)

Membrane material, surface properties and make-up are crucial to any membrane's performance. Hyflux's Kristal® membranes are made from carefully selected materials which are further enhanced by the modification of its surface properties to achieve high levels of hydrophilicity. The result is high flux rates, low fouling tendencies and enhanced chemical resistance.

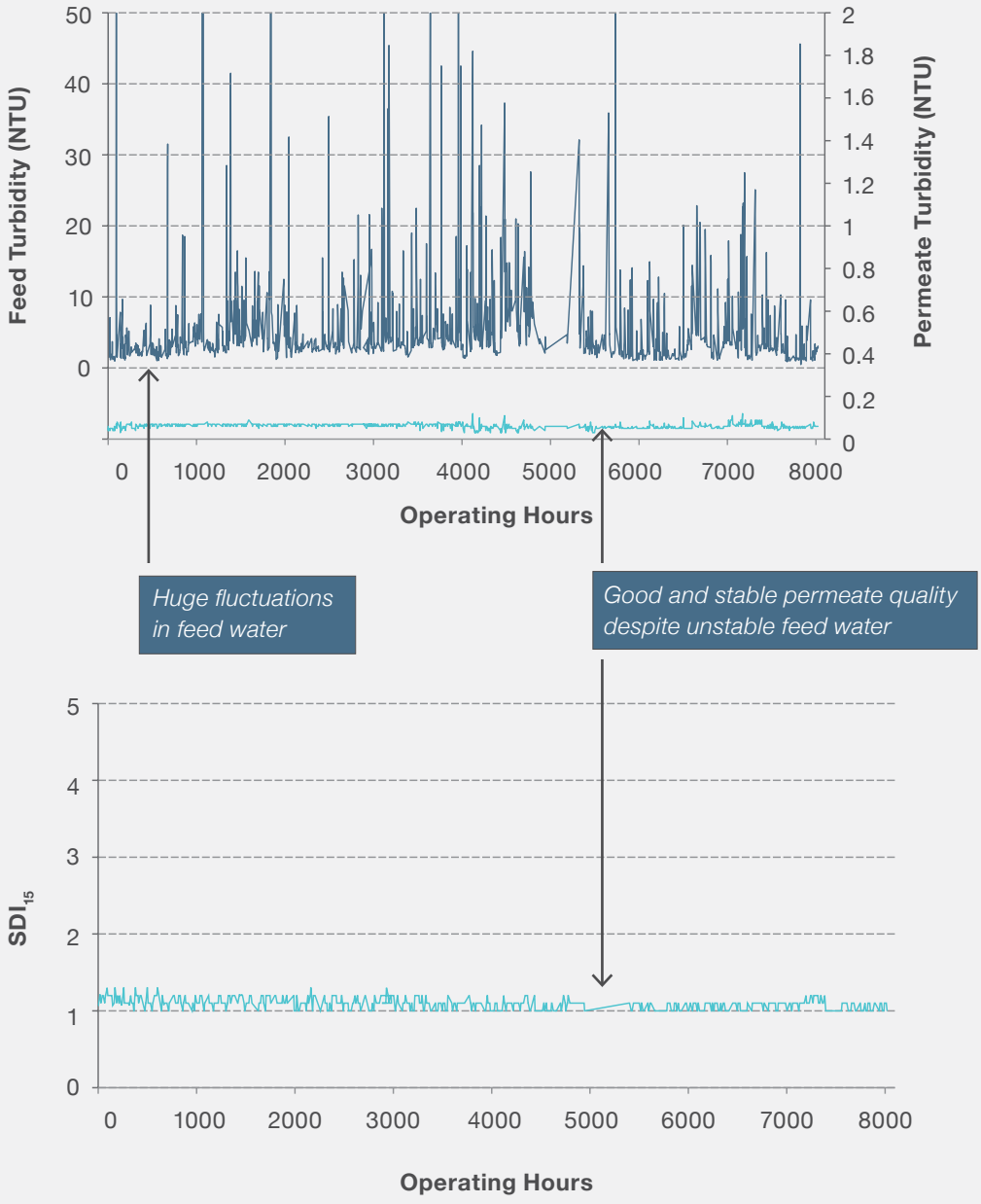
To cater to harsher operating conditions, Hyflux has developed a unique tri-bore membrane. This design not only delivers greater durability and strength that enable the membrane fibres to maintain their integrity, but also the same high level of permeate production as the single bore membrane.

THE KRISTAL® ADVANTAGE

CONSISTENT, HIGH QUALITY PERMEATE

One of the key strengths of the Kristal® membrane is its proven ability to produce **high quality permeate regardless of fluctuations in feed water.**

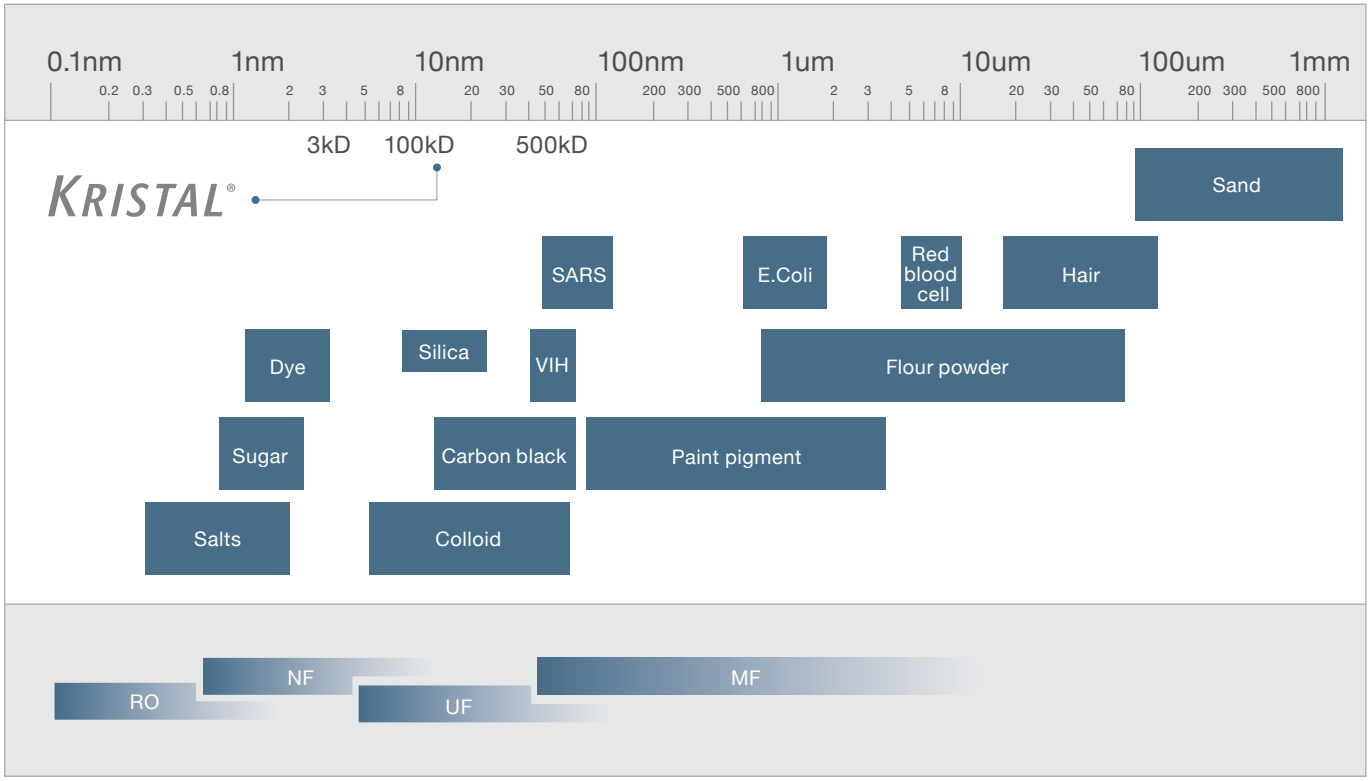
The following graphs illustrate the permeate turbidity and silt density index (SDI) levels of a desalination plant using Kristal® for RO pre-treatment over a year's operation.



THE KRISTAL® ADVANTAGE

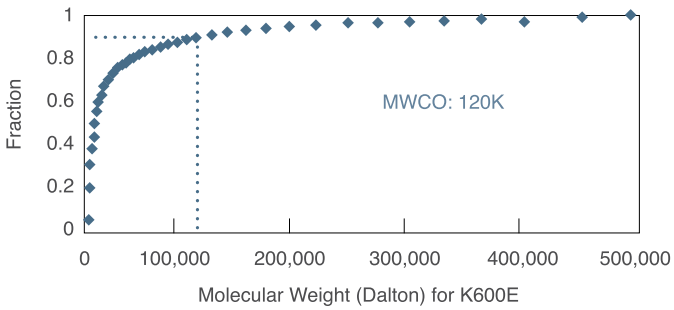
SMALL PORE SIZE AND SHARP REJECTION PROFILE

Kristal® membranes operate on the lower scale of the ultrafiltration spectrum. The consistent, high quality permeate is made possible by Kristal®'s small pore size and sharp rejection profile.

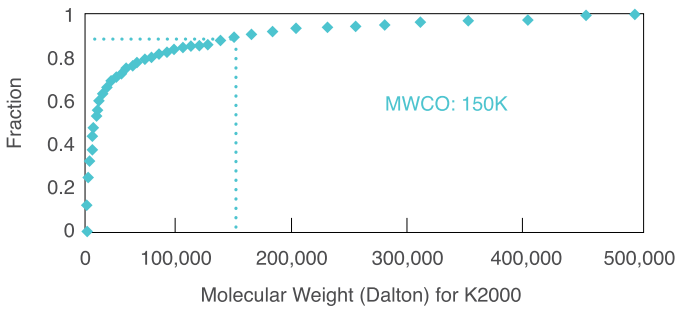


Membrane separation spectrum

Molecular weight cut-off for Kristal® 600E



Molecular weight cut-off for Kristal® 2000



Rejection profiles for Kristal® membranes

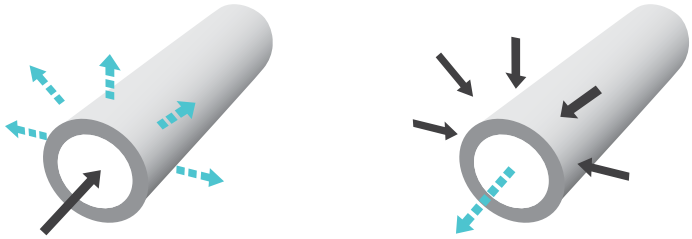
THE KRISTAL® ADVANTAGE

OUTSIDE-IN FLOW MODE

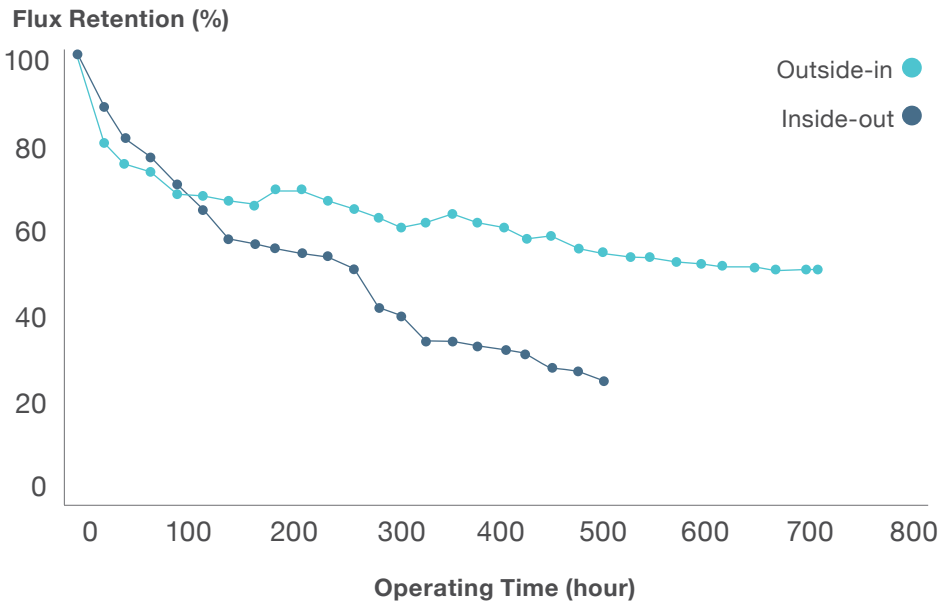
Kristal® membranes operate in an outside-in flow mode. In contrast to inside-out membranes, outside-in membranes tend to be more tolerant towards fouling, minimising the impact on the performance and overall permeate production of the membranes.

Furthermore, the **outside-in flow mode allows for more effective removal of foulants** during backwash with air scouring and chemical cleaning, and prevents the irreversible choking of membrane fibres during surges in feed water quality.

This makes Kristal® membranes suitable even for feed waters with high solids loading such as seawater, river water and treated waste streams.



Cross-section drawing of inside-out and outside-in flow for a hollow fibre membrane



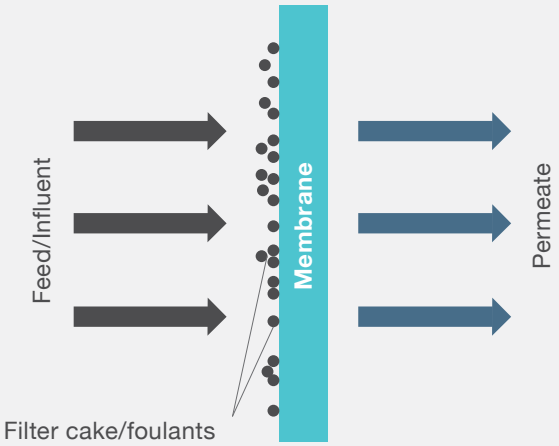
Flux performance graph of outside-in vs inside-out membranes

THE KRISTAL® ADVANTAGE

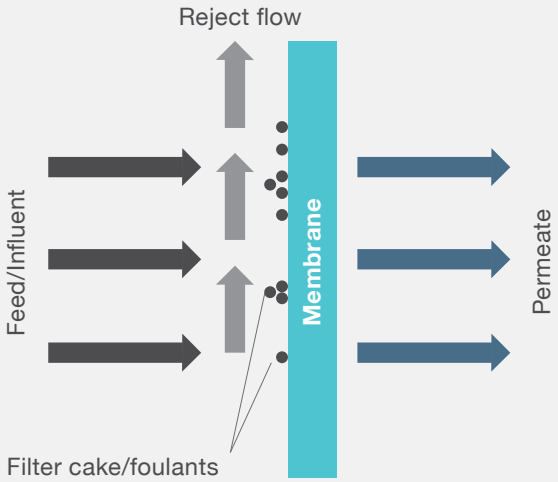
VERSATILE FLOW DESIGN

Kristal® membranes are typically operated in cross-flow recirculation mode. However, the versatility of the Kristal® design allows it to run in other modes of operation as well, including dead-end and bleed, depending on the feed water quality.

Cross-flow operation lets the recirculation/reject stream create a shear force along the surface of the membrane. This prevents the accumulation of solids on the surface. Slower fouling rates will in turn reduce operational costs and downtime (mainly for cleaning purposes). In instances of very poor feed water quality, bleeding may be employed in place of recirculation to prevent the buildup of solids in the UF feed tank.



Dead-end filtration



Cross-flow filtration

THIRD PARTY CERTIFICATION

Users of Kristal® membranes can be assured of the commitment of Hyflux to the quality of its products which have received certification from international organisations, government agencies as well as consultants.

Kristal® membranes are manufactured according to ISO standards and undergo independent testing by NSF International, a widely respected and recognised global third-party testing and certification organisation.

Kristal® is the first UF membrane to achieve certification to the NSF Public Drinking Water Equipment Performance Certification Programme, which tests and certifies the performance of water treatment products. Kristal® has been certified to effectively remove cryptosporidium in drinking water.

In addition, Kristal® is certified to the NSF/ANSI Standard 61 Drinking Water System Components - Health Effects.


NSF International
HYFLUX LIMITED
SINGAPORE

NSF certification


Certificate of Registration

ISO certification

Chinese Ministry of Health certificate for drinking water applications in China


FICHTNER (ASIA) Consulting Pte Ltd

To Whom It May Concern

PERFORMANCE OF HYFLUX AND KRISTAL IN SINGAPORE

Fichtner Consulting certificate

CASE FOR MEMBRANE PRE-TREATMENT IN SEAWATER DESALINATION

SWRO desalination is a membrane-based process using semi-permeable membranes and pressure to separate salts from the water. While conventional pre-treatment for SWRO desalination has been the norm for years, the introduction of UF membranes in the pre-treatment process has yielded various advantages over conventional pre-treatment.

With the growing scale and technological advancements in membrane development, the cost advantage of UF membranes will widen, making the case of membrane technology in the pre-treatment stage of SWRO desalination even more compelling.

UF Membrane Pre-treatment	Conventional Pre-treatment
Provides a physical barrier to particles, thereby giving consistently high quality and reliable feed water to the RO.	Removes a proportion of particles but produces poor and inconsistent feed quality to the downstream RO. Operational and feed-dosing problems as well as backwashing operation of sand filters can result in long periods of poor RO feed quality.
Good quality feed to RO means lower frequency of RO cleaning and therefore extended on-stream time.	More frequent RO cleaning required due to poor feed quality, resulting in downtime.
Lifespan of RO membranes is extended, hence RO replacement cost is lower.	RO membranes may need to be replaced more regularly, resulting in higher operational cost.
Lower requirements for chemical dosing and for RO cleaning, resulting in lower chemical costs.	Chemical dosing is required in conventional pre-treatment and with more frequent RO cleaning, more chemicals are also used.
Lower environmental impact.	Extensive use of concrete, large footprint, higher energy use and high chemical waste disposal.

REFERENCES

Through the years, Hyflux has established its dominance in the UF membrane market, particularly in the SWRO pre-treatment segment where it is acknowledged as a market leader.

While recognised internationally for its role in large-scale municipal water projects, Hyflux has also demonstrated its experience in customising water treatment plants of varying sizes for industries such as cement, electronics, petrochemical, semiconductor, steel, textile as well as the production of boiler water for power plants. The following table shows a selection of projects that has benefited from Kristal®.

Application	Country	Kristal® UF Capacity (m^3/d)	Completion/ Estimated Completion
Seawater desalination pre-treatment for production of potable water	Algeria	1,125,000	2012
Seawater desalination pre-treatment for production of potable water	Singapore	745,000	2013
Seawater desalination pre-treatment for production of potable water	Algeria	450,000	2011
Seawater desalination pre-treatment for production of high-grade industrial water	China	220,000	2009
Seawater desalination pre-treatment for production of industrial water	China	88,000	2006
Municipal wastewater recycling	Singapore	48,000	2004
Seawater desalination pre-treatment for boiler feed water	Turkey	47,520	2009
Water treatment	Namibia	37,647	2002
River water clarification	Malaysia	31,680	2005
Industrial wastewater recycling for production of boiler feed water	China	22,000	2004
Water treatment	China	22,000	2006
Industrial water production	China	22,000	2007
Seawater desalination pre-treatment for boiler feed water	Philippines	17,028	2011
Seawater desalination pre-treatment for production of boiler feed water	Indonesia	8,300	2010
Wastewater recycling for industrial use	India	5,000	2010
Brewery effluent recovery	India	360	2011
Textile wastewater recovery	Colombia	2,000	2010

CASE STUDIES

SEAWATER DESALINATION TO PRODUCE HIGH-GRADE INDUSTRIAL WATER

Location:
Tianjin Dagang, China

UF Capacity:
Approximately 220,000 m^3/d

Commissioned In:
2009

Background

Tianjin, situated in north China, is home to a fast expanding petrochemical industry. Competing demands for water for agricultural, industrial and municipal purposes have exerted strains on the depleting water resources. The lack of water is also becoming a bottleneck for industrial development. Thus, the government has to look at non-traditional sources of water, including desalination, to tackle the situation.

Hyflux was invited to develop a seawater desalination plant in the Dagang district of Tianjin. At 100,000 m^3/d, the Tianjin Dagang Desalination Plant is currently the largest SWRO plant in China and one of the world's northern-most large-scale desalination plants.

The feed water quality presented a challenge because the water had to be drawn from the discharge canal of a neighbouring power plant's cooling water system instead of directly from the sea. Not only did turbidity levels fluctuate between 20 to 200 NTU in a short period of time, the TOC also tended to be in a relatively high range of 8 to 14 mg/L.

To optimise the performance of the RO system downstream and protect the membranes from fouling, an effective pre-treatment was required.

CASE STUDIES

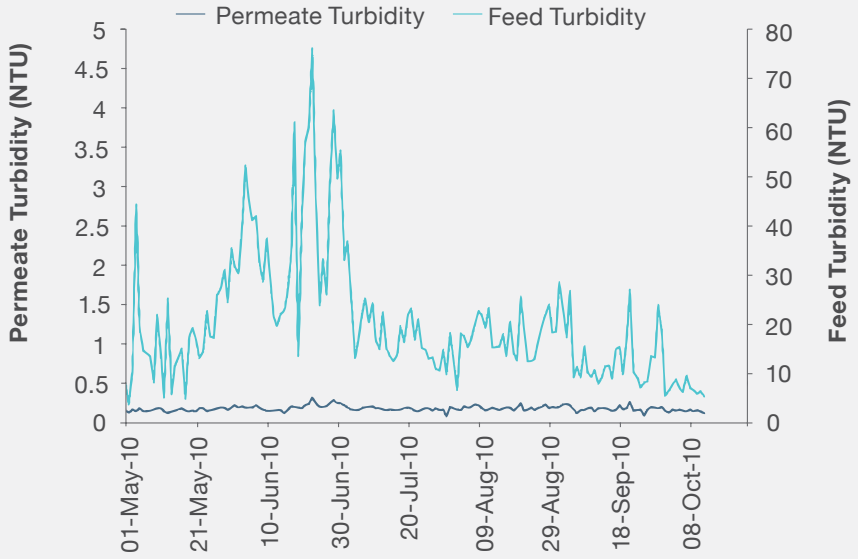
SEAWATER DESALINATION TO PRODUCE HIGH-GRADE INDUSTRIAL WATER

Hyflux's Kristal® membranes act as an effective barrier to suspended solids and microorganisms, thereby enhancing the performance and extending the lifespan of the RO membrane system downstream.

Solution

As Hyflux's Kristal® membranes can effectively produce a consistent stream of high quality permeate even in challenging feed water conditions, the membranes were selected for the pre-treatment process at Tianjin Dagang Desalination Plant.

A pilot test was conducted to observe Kristal®'s performance over a six-month period. The test showed that while feed turbidity at Tianjin Dagang Desalination Plant could spike up to 80 NTU as a result of wastewater discharge into the canal, the permeate turbidity remained consistently low at approximately 0.1 NTU. The pilot plant also experienced minimal differential pressure drop throughout the UF pre-treatment process. The effectiveness of the performance of the Kristal® membranes is evident at the actual plant, where the RO membranes have been operating optimally since start up in 2009.



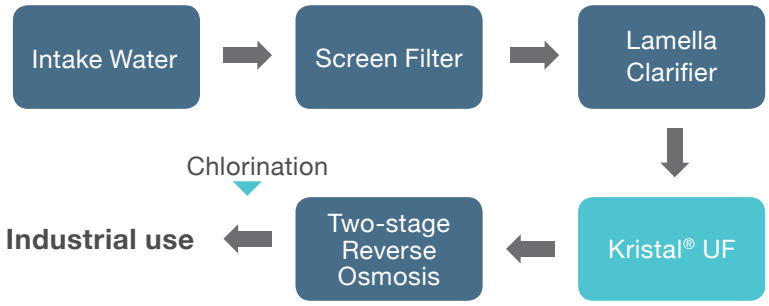
Graph of feed and permeate turbidity over 6 months

CASE STUDIES

SEAWATER DESALINATION TO PRODUCE HIGH-GRADE INDUSTRIAL WATER

By acting as an effective barrier to suspended solids and microorganisms, Hyflux's Kristal® membranes ensure stable, high quality feed water is delivered to the RO membranes, thereby enhancing the performance and extending the lifespan of the RO system downstream.

Tianjin Dagang Desalination Plant won a highly commended mention at the GWI Global Water Awards 2010 for Desalination Plant of the Year.



Simplified process flow diagram for Tianjin Dagang Desalination Plant

CASE STUDIES

RECYCLING SEWAGE TO HIGH-GRADE INDUSTRIAL WATER

With the improved BWRO feed water quality, the feed pressure as well as the cleaning frequency is lower. This translates to savings on chemical and electricity costs, and a longer lifespan for the BWRO membranes.

Location:
India

UF Capacity:
Approximately 5,000 m^3/d

Commissioned In:
2010

Background
A government-linked company in India relied on high-grade industrial water produced from a sewage recycling plant for its production processes.

The sewage recycling plant used a conventional pre-treatment system with the most advanced water recycling technologies at the time. It comprised clarification, gravity filtration and multi-grade filtration to reduce the amount of suspended solids from the secondary treated effluent before the permeate was fed to a brackish water reverse osmosis (BWRO) system to further eliminate dissolved solids.

While the BWRO membranes were able to produce high quality product water for the company's production needs, the high levels of suspended solids in the BWRO feed affected the system's effectiveness and ultimately, the membranes' lifespan.

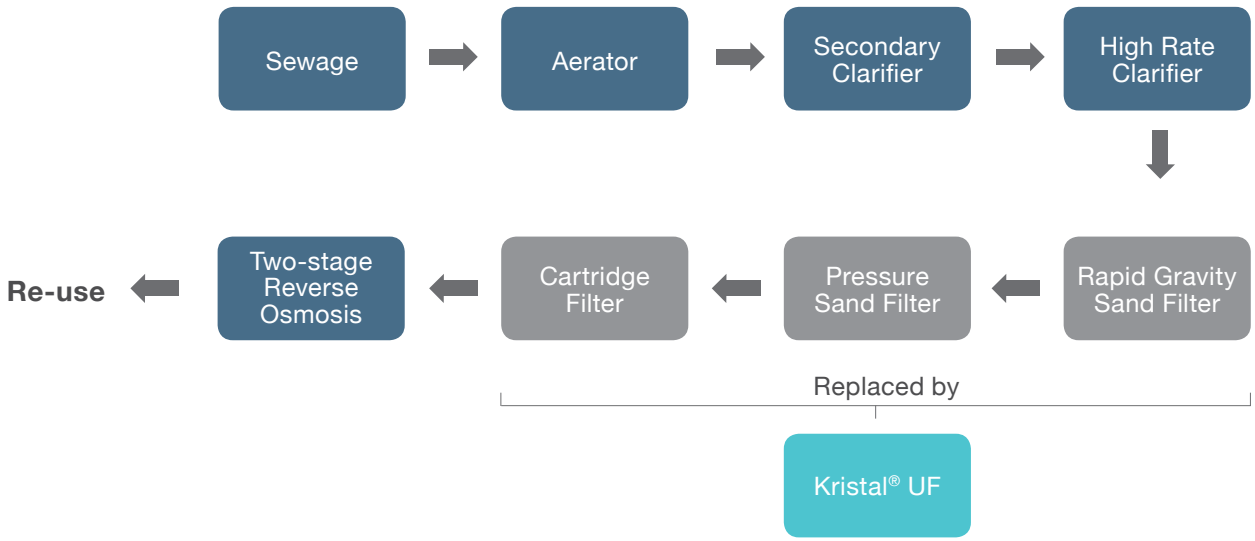
Solution
A more effective pre-treatment system was needed to optimise the performance of the BWRO system and protect them from fouling. The solution rested in the introduction of Hyflux's Kristal® membranes as a replacement for the current conventional pre-treatment system.

Once installed, the Kristal® UF system effectively removed suspended solids, silicates, colloids, organics, bacteria and other microorganisms. The SDI of the permeate was reduced from 5 to less than 3, and the fouling rate dropped significantly.

With the improved BWRO feed water quality, the feed pressure as well as the cleaning frequency is lower. This translates to savings on chemical and electricity costs, and a longer lifespan for the BWRO membranes.

CASE STUDIES

RECYCLING SEWAGE TO HIGH-GRADE INDUSTRIAL WATER



Process flowchart for sewage recycling plant

Pre-treatment Permeate Water	Conventional System	Contractual Obligations	Kristal® UF System
SDI	≥ 5	< 3	< 1*
Turbidity (NTU)	≥ 1	< 0.2	< 0.1*
TSS (ppm)	3 - 5	Nil	Nil
Stability when source water quality changes	Fluctuating	-	Stable

**SDI and turbidity depend on feed quality. The values shown in the table are for reference.*

Comparison of permeate water quality between conventional and Kristal® UF systems

CASE STUDIES

SEAWATER DESALINATION TO PRODUCE POTABLE WATER

Location:
Tlemcen, Algeria

UF Capacity:
Approximately 450,000 m^3/d

Commissioned In:
2011

Background

Algeria, in North Africa, has embarked on an extensive desalination programme to address its water needs. With some 80% of its land surface in desert zones and little rainfall, the perennial water crisis is an impediment to economic development, and water security remained one of the key concerns for the country's future. The vast Mediterranean Sea to the country's north is seen as a source of life for the country.

Hyflux was contracted to develop a 200,000 m^3/d SWRO desalination plant in the northwest of the country on a design-build-own-operate model with a 25-year concession to operate and maintain the plant. The water produced is for potable use.

One of the key challenges of the plant was the high degree of variation of turbidity in the feed water from the Mediterranean Sea. During the rainy season, it was common for turbidity to spike to 100 NTU.

Solution

Ultrafiltration, using Kristal® membranes, was chosen as the preferred technology for pre-treatment over conventional media filtration as the former was able to achieve sustainable operating cost efficiency.

6,480 Kristal® modules were employed and set on 45 membrane trains. Each train had 144 modules.

The Kristal® pre-treatment system proved to be an effective barrier to the suspended solids and colloids in the intake water and has been able to produce consistently high quality permeate for the RO process despite fluctuations in the feed water turbidity.

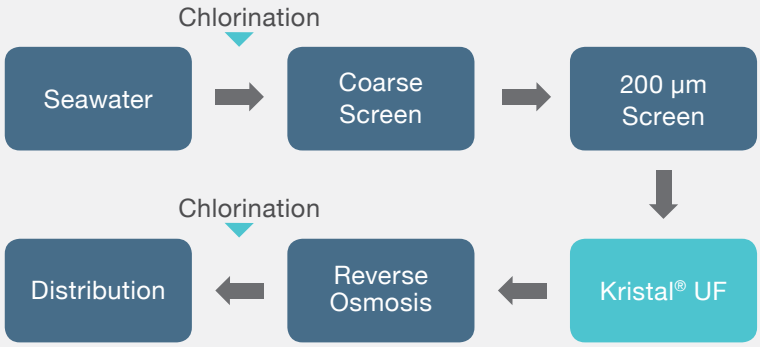
CASE STUDIES

SEAWATER DESALINATION TO PRODUCE POTABLE WATER

The Kristal® pre-treatment system has been able to produce consistently high quality permeate for the RO process despite fluctuations in the feed water turbidity.

Intake feed water turbidity may fluctuate between 5 to 25 NTU, but the permeate quality from the Kristal® membranes has constantly remained below 0.08 NTU.

Since its commissioning, the water produced by the plant has consistently met the standards set by the World Health Organisation and the EU guidelines for drinking water. With the Kristal® UF membrane system, the plant will continue to provide a reliable and drought-proof supply of water to meet the residential and industrial needs of the surrounding areas.



Process flow chart for SWRO desalination plant

CASE STUDIES

TEXTILE WASTEWATER RECOVERY

With the help of Kristal®, the textile company has been able to achieve significant savings by cutting down on water and energy consumption as well as wastewater discharge fees imposed by the government.

Location:
Bogota, Colombia

UF Capacity:
Approximately 2,000 m^3/d

Commissioned In:
2011

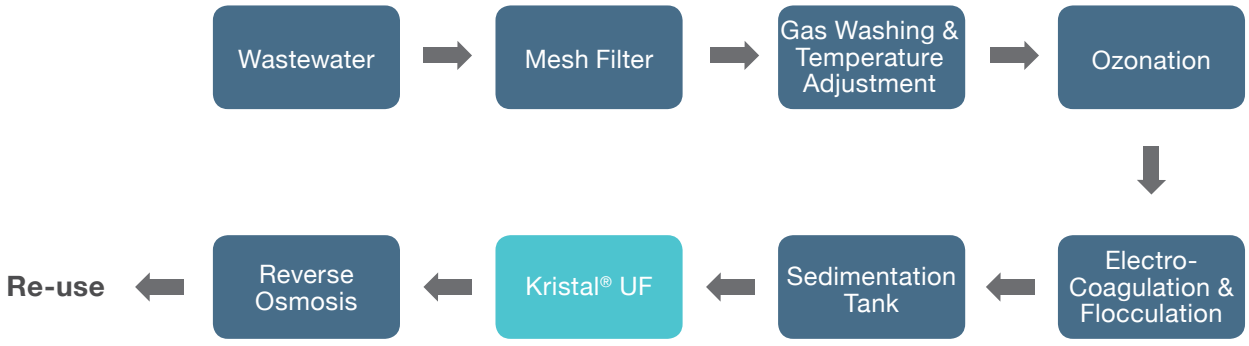
Background

A textile company in Colombia was keen to improve the quality of the wastewater discharge from one of its factories while lowering water consumption. To reclaim the wastewater, a combined UF and RO wastewater treatment was required. The entire treatment process involved a number of steps to first remove lint, chemicals, colour and large suspended solids before the wastewater was fed into the UF-RO system.

Solution

Hyflux's proprietary Kristal® membranes were selected for the UF pre-treatment. A total of 30 Kristal® modules were installed, producing close to 2,000 m^3/d of UF permeate to be fed into the RO system. The UF system has been operating at a recovery rate of close to 93% while the UF-RO plant's overall recovery rate is about 85%.

With the help of Kristal®, the textile company has been able to achieve significant savings by cutting down on water and energy consumption as well as wastewater discharge fees imposed by the government. In addition, the high quality permeate from the UF membranes ensures a longer lifespan for the RO membranes, resulting in savings from RO membrane replacement.



Process flow chart for textile wastewater recycling plant

CASE STUDIES

SEAWATER DESALINATION TO PRODUCE BOILER FEED WATER

Location:
Sumatra, Indonesia

UF Capacity:
Approximately 8,300 m^3/day

Commissioned In:
2010

Background

A crude palm oil refinery situated in a rural part of Sumatra depended on deep well water or trucked surface water from other provinces to supply clean water to its refinery boilers. At times, it was a challenge to maintain a steady supply from these sources.

The refinery needed a reliable supply of water to ensure operations would not be disrupted. As the facility was located near the coast, it hoped to tap on seawater desalination for a sustainable source of water to meet its needs. However, the turbidity of the seawater could fluctuate widely between 30 to 151 NTU because the sea was near a zone of peat swamps and had been badly polluted by poorly treated discharge from surrounding factories.

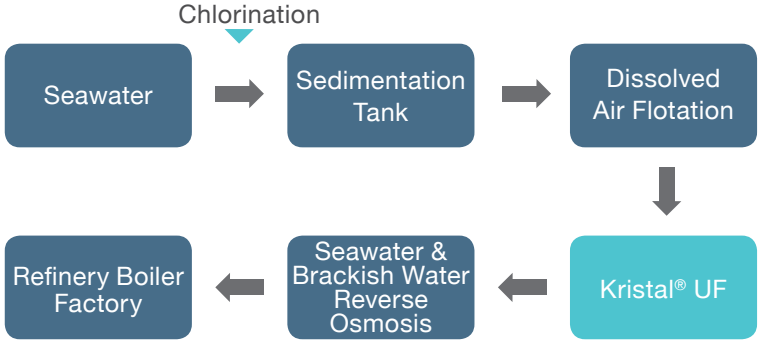
For seawater desalination to be feasible, a combined UF and double-pass RO system was required.

Solution

Hyflux was approached to supply a system that would incorporate its proprietary Kristal® ultrafiltration membranes for pre-treatment, to make the seawater suitable as a source for the boiler feed water. 144 Kristal® modules were installed to remove suspended solids and colloids in the turbid water. It has been able to produce close to 8,300 m^3/day of UF permeate water with low turbidity values of 0.02 to 0.13 NTU which is then fed into the RO system. The overall production capacity of the combined system is 2,400 m^3/day.

The Kristal® membranes optimise the performance of the RO system and protect it from the variable seawater quality. This ensures a constant supply of consistent, high quality feed water for the refinery's boilers.

By using Hyflux's proprietary ultrafiltration technology, the refinery is able to draw on the sea for a cost-effective, reliable water solution that does not leave it vulnerable to supply disruptions. It can now operate round the clock with improved efficiency and productivity.



Process flow chart for refinery desalination plant

02

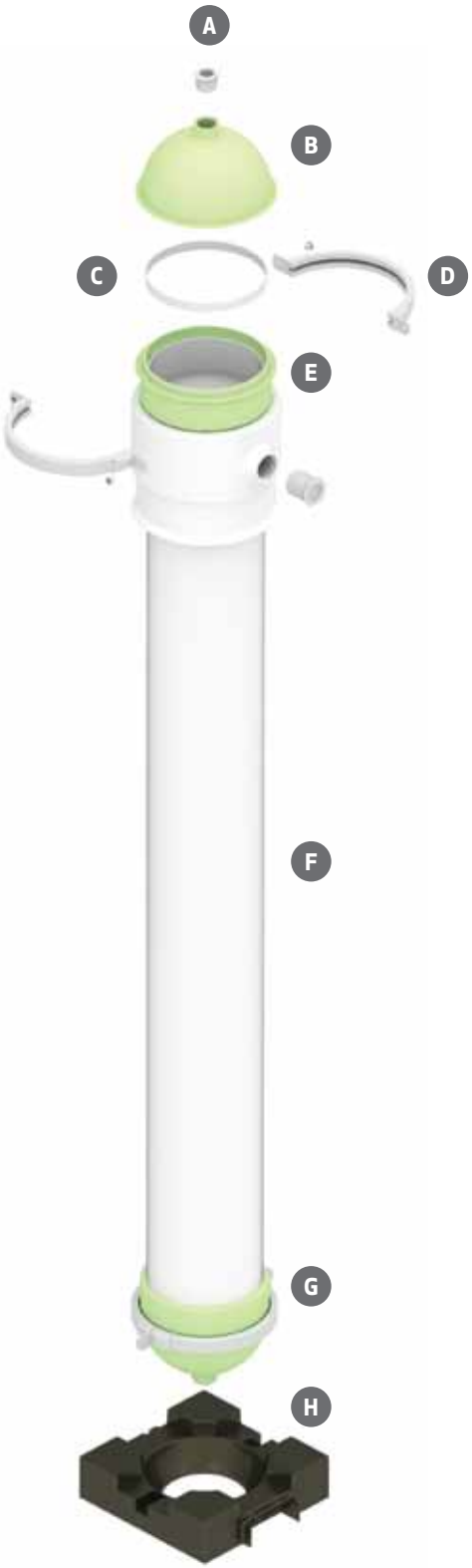
TECHNICAL SPECIFICATIONS

KRISTAL® SPECIFICATIONS

Kristal® Membrane Specifications						
Membrane type	K600ER	K600ETN	K600ET	K600ET3	K2000T	K2000T3
Structure	Asymmetric			Asymmetric tri-bore	Asymmetric	Asymmetric tri-bore
Material	Modified PES				Modified PVDF	
Outer diameter (mm/inch)	1.35 / 0.053			2 / 0.075	1.2 / 0.047	2.1 / 0.083
Inner diameter (mm/inch)	0.7 / 0.028			0.6 / 0.024		
Wall thickness (mm/inch)	0.33 / 0.013			0.25 / 0.010	0.30 / 0.012	0.3 / 0.012
Nominal molecular weight cut-off (Dalton)	120,000			150,000		200,000
Bacteria rejection (%)	> 99.9999*					
Tensile force (N)	> 3			≥ 6	3	> 5
Kristal® Module Specifications						
Overall dimensions: diameter x length (mm/inch)	257.8 x 2,130 / 10.2 x 83.9	344 x 1,190 / 13.5 x 46.9	344 x 2,340 / 13.5 x 92.1			
Nominal membrane area (m^2/ft^2)	60 / 646	23 / 248	60 / 646	50 / 538	60 / 646	50 / 538
Feed inlet (inch)	1.5 NPT					
Permeate outlet (inch)	1.5 NPT					
Reject outlet (inch)	1.0 NPT	1.5 NPT				
Dry weight (kg/lbs)	55 / 121	35 / 77	60 / 132		55 / 121	60 / 132
Wet weight (kg/lbs)	100 / 220	60 / 132	100 / 220		95 / 209	100 / 220
Housing shell	PVC					
End caps	PVC					
Sealant	Hyflux proprietary composite potting material					
Operating Parameters						
Flow type	Outside-in					
Operating temperature (°C)	5 - 40					
Clean water flux at 30°C (LMH/GFD)	170 / 100	200 / 118	170 / 100	190 / 112	140 / 82	200 / 118
Operating pH range	2 - 10					
Cleaning pH range	2 - 11					
Max. NaOCl – cleaning (ppm)	500				2,000	
Max. NaOCl – continuous (ppm)	10				20	
Operating TMP (bar)	0.2 - 1.5					
Max. feed pressure (bar)	2.5					
Max. backwash TMP (bar)	2.0					
Max. cleaning TMP (bar)	2.0					

**Verified by accredited third-party laboratory*

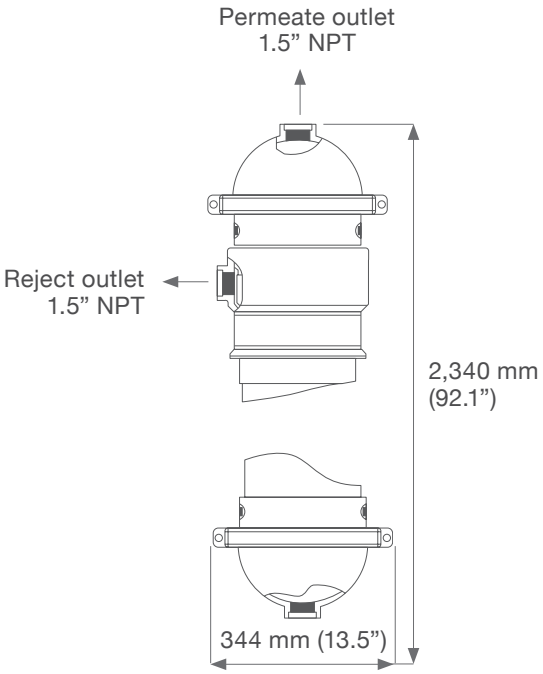
KRISTAL® MODULES



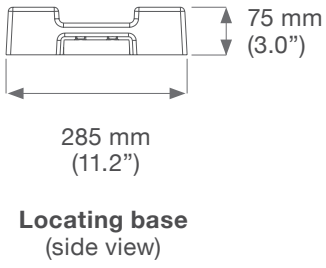
Each Kristal® module is a collection of thousands of Kristal® UF hollow fibres secured on both ends by a proprietary composite potting material and enclosed in a compact PVC housing.

Every Kristal® module goes through a membrane integrity test before it is delivered to customers.

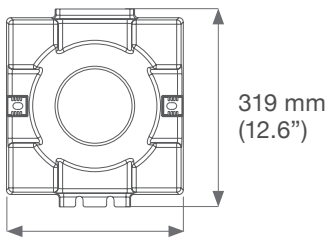
Item	Description	Material
A	Permeate port	PVC
B	Permeate end cap	PVC
C	O-ring (permeate side)	EPDM
D	Clamps (permeate side)	POM
E	Reject chamber/port	PVC
F	Housing	PVC
G	Feed end cap	PVC
H	Locating base	ABS



Module
(side view)



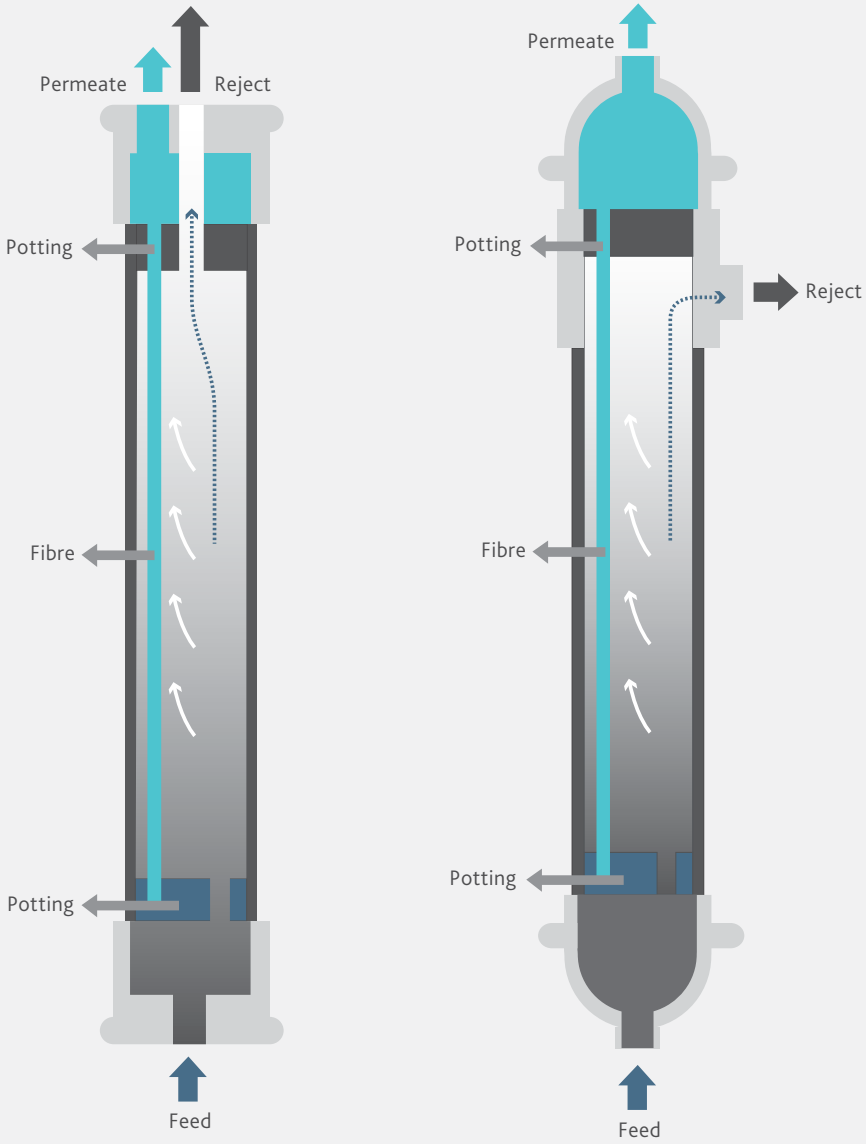
Locating base
(side view)



Locating base
(top view)

KRISTAL® FILTRATION PROCESS

The Kristal® module operates in a pressurised mode to drive filtration through the membrane fibres. Feed water enters the bottom of the module, and the filtered water is channelled through the top permeate line into a collection tank. A reject port allows for recirculation or discharge of the feed.

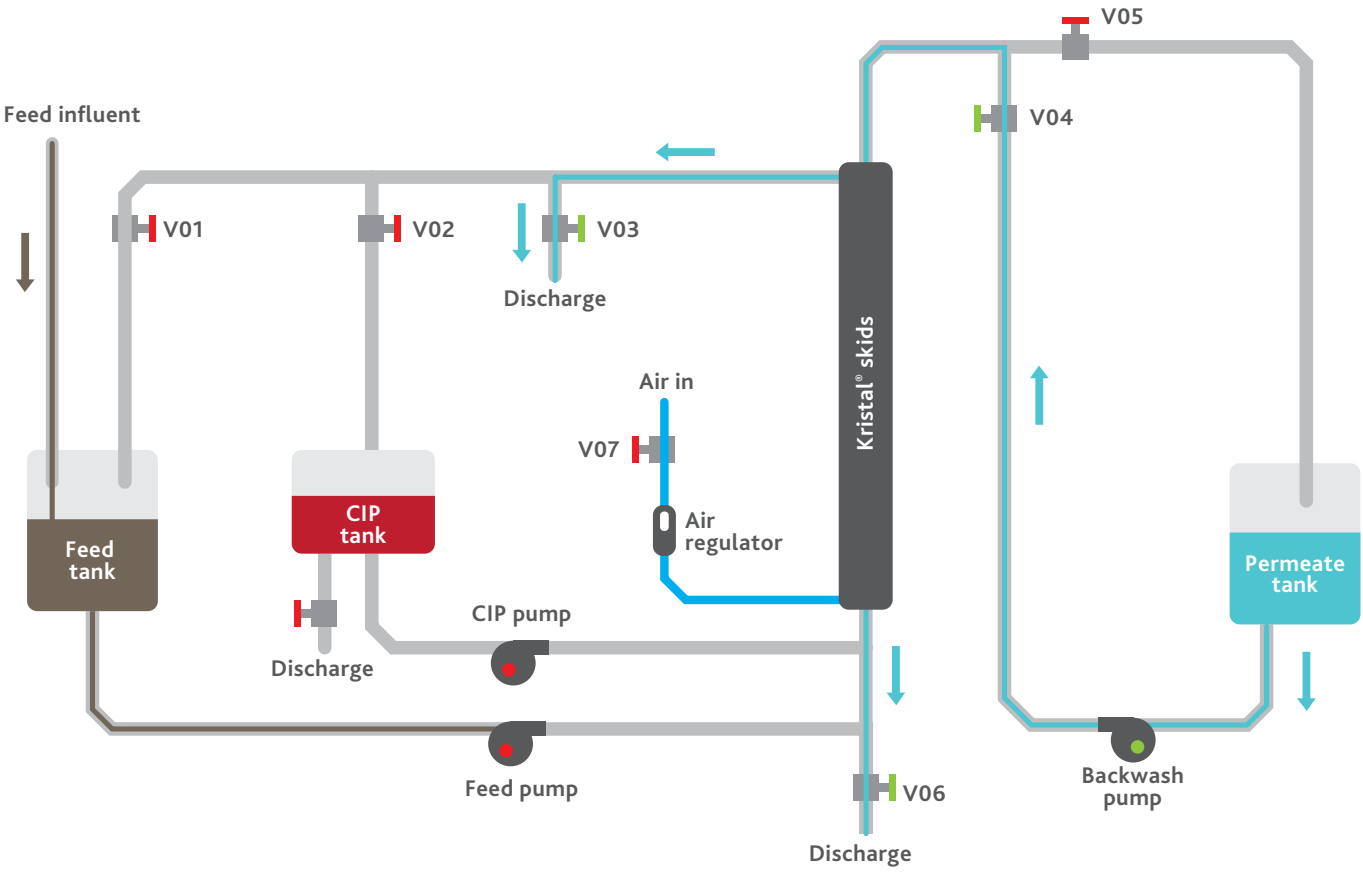


BASIC CONFIGURATION

Kristal® modules are commonly arranged in parallel rows and connected through headers to form a train. The entire train is operated, backwashed, cleaned and integrity tested as a single entity. Kristal® modules can be installed in trains of varying sizes to cater to different plant capacities.

Before entering the Kristal® UF system, the intake water is pumped through a set of screen filters to remove any debris and large objects. The water is then circulated in the UF membrane system. This filtered water is stored temporarily in a collection tank and can be directly used or sent for further treatment, such as nanofiltration or reverse osmosis.

BACKWASH & CLEAN-IN-PLACE



In a Kristal® UF system, backwashing is a necessary part of normal operation to maintain membrane permeability. Backwashing uses a reverse flow of clean water to 'unplug' the solids accumulated on the membrane surface during filtration. Air scouring is performed concurrently to provide extra mechanical force and enhance the effectiveness of the backwash.

Backwashing is usually carried out after every 30 to 40 minutes of operation.

While backwashing can remove most contaminants from the membrane, periodic chemical cleaning is necessary to remove stubborn foulants that are not easily displaced by physical methods. This cleaning-in-place (CIP) involves the use of both alkaline and acid solutions.

CIP is considered a part of a membrane maintenance routine and is performed after about 120 hours of operation. CIP is also recommended every time the Kristal® module shows evidence of fouling.

DESIGN OPERATING PARAMETERS

Parameters		Drinking Water	Ground Water	Surface Water			Seawater		Municipal Wastewater	Industrial Wastewater
Water properties	Turbidity (NTU)	< 1	< 5	20 - 40	5 - 20	< 5	10 - 25	< 10	< 20	< 20
	TOC (mg/L)	< 1	< 5	< 10	< 5				< 15	< 10
Operating flux at 25°C (LMH)		90 - 110	70 - 90	50 - 65	55 - 70	60 - 75	55 - 70	60 - 75	50 - 65	50 - 60
Pre-filtration (µm)		100 - 200								
Backwash Cycle										
Frequency (min)		45 - 60	40	30	30	40	30 - 40	30 - 40	30	20 - 30
Duration (sec)		90 - 120								
Backwash flux at 25°C (LMH)		75 - 100		90 - 125					90 - 130	
Air scouring	Recommended pressure (bar)	1 bar max. (0.5 bar max. for K600ETN)								
	Air flow (Nm^3/h)	2.3 - 3.4 (1.1 - 1.6 for K600ETN)								
	Duration (sec)	60 - 80								
	Air quality	Oil free								
Maintenance Cleaning										
Frequency (day)		30 - 60	10 - 15	3 - 5	5 - 7	7 - 10	5 - 7	7 - 10	5 - 7	3 - 5
Duration (hour)		1		1 - 2						
NaOCl dosage (ppm)		60 - 400								
Solution pH		10 - 11								
Solution flow (m^3/h)		3 - 6 per module (1.1 - 3.2 per K600ETN module)								
Solution temperature (°C)		25 - 35								
Recovery Cleaning										
Frequency (day)		300	20 - 50	20 - 50	20 - 50	20 - 50	20 - 50	20 - 50	20 - 50	20 - 50
Duration (hour)		1 - 2		2 - 5						
NaOCl dosage (ppm) NaOCl solution pH Solution temperature (°C)		200 - 500 10 - 11 25 - 35								
HCl dosage (ppm) HCl solution pH Solution temperature (°C)		0 - 500 2 - 3 25 - 35								
Solution flow (m^3/h)		3 - 6 (1.6 - 3.2 for K600ETN)								

The table above is provided as a guide. Please contact Hyflux's Technical Support to assist you for your application.

FEED & PERMEATE PARAMETERS

FEED WATER CONDITIONS FOR LONG-TERM OPERATIONS

Feed Water Parameters	Unit	Recommended	Maximum	Allowance Limit for Short-term ≤ 2 h/month
TOC	ppm	< 10	< 20	50
COD	ppm	< 30	< 60	150
Turbidity	NTU	< 20	< 120	600
TSS	ppm	< 10	< 100	250
Total oil & grease	ppm	0	< 1	1
Temperature	°C	25 - 30	5 - 40	0 - 45
pH (continuous)	-	6 - 9	6 - 9	2 - 10
Chlorine (continuous)	ppm	0	< 5	10 (K600E) 20 (K2000)

The table above is provided as a guide. Please contact Hyflux's Technical Support to assist you for your application.

PERMEATE QUALITY

Permeate Parameters	Unit	Specifications
Turbidity	NTU	< 0.2
SDI	-	< 3

The table above is provided as a guide. Please contact Hyflux's Technical Support to assist you for your application.

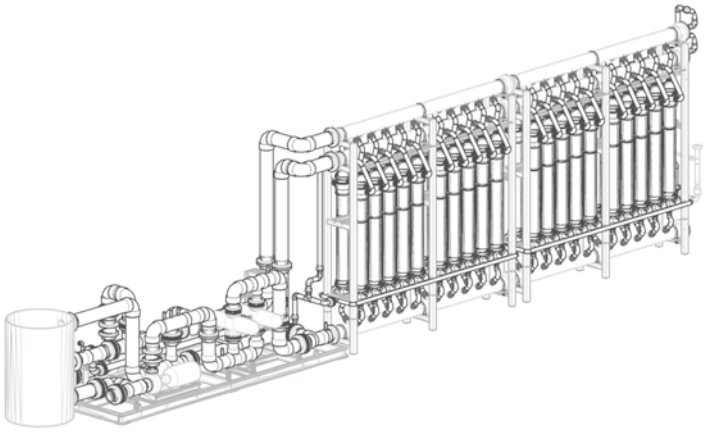
03

STANDARDISED KRISTAL® UF SYSTEMS

KRISTAL® STANDARD UF SYSTEMS

INTRODUCTION

Kristal® Standard UF Systems are designed specifically for the end-user who values economy, convenience and efficiency in a small water treatment system.



Kristal® Standard UF Systems bring together Hyflux's proven technology and processes in some of the world's largest and most cost effective seawater desalination plants and water treatment facilities. Designed specifically for the end-user who values economy, convenience and efficiency in a small water treatment system, it is an easy-to-use, plug-and-play system capable of treating water from a wide range of sources for various applications by industries and small communities. The system can be used as a stand-alone plant, or as a pre-treatment option to reverse osmosis or other technologies.

Benefits

- Low capital and operating costs
- Easy to install
- Easy to operate and maintain
- Compact and small footprint
- Consistent, high quality product water
- Efficient, reliable operation with minimum downtime
- Low chemical usage
- Wide range of treatment capacities available

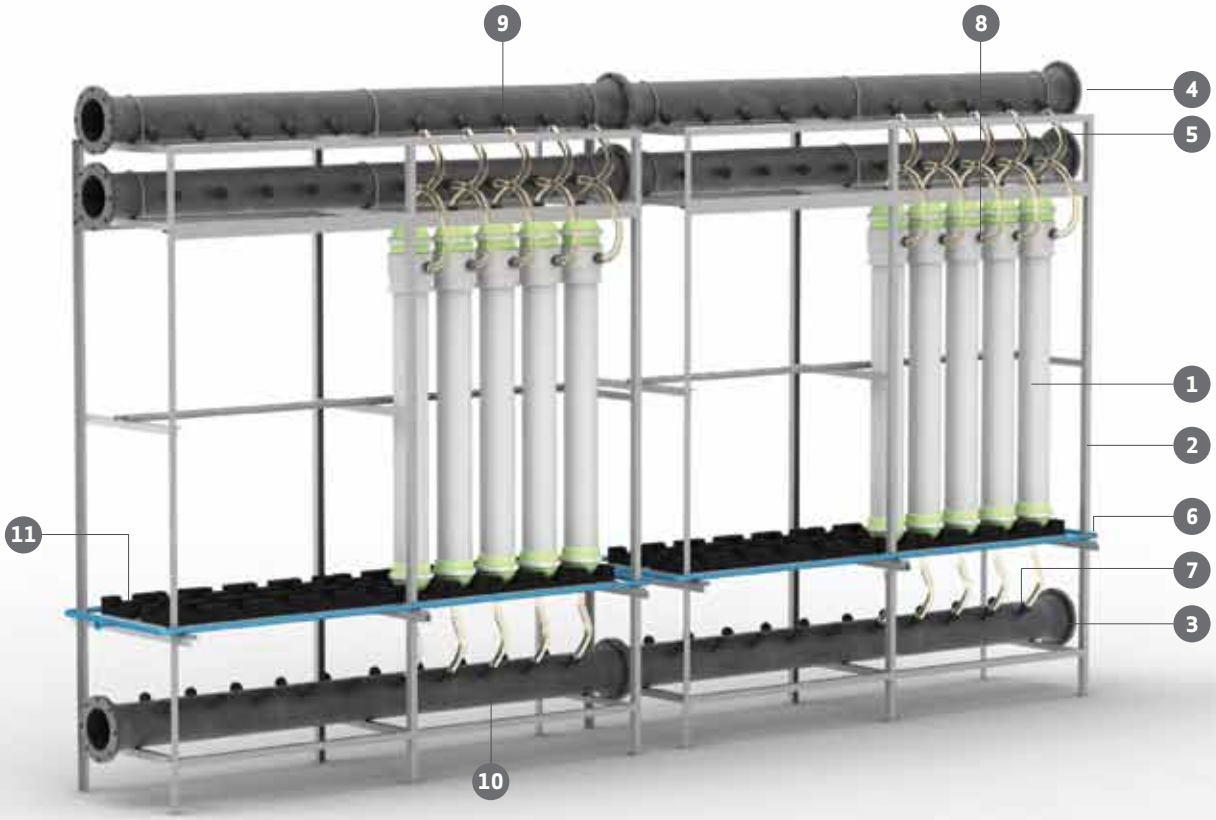
Kristal® Standard UF Systems are available in four configurations:

Model	Treatment Capacity* (litres/day)
MK-4	0.30 million
MK-10	0.75 million
MK-20	1.50 million
MK-40	3.00 million

**Dependent on feed water quality*

KRISTAL® STANDARD UF SYSTEMS

SKID PARTS LIST



Item	Description
1	Kristal® module
2	Steel frame
3	Feed header
4	Permeate header
5	Reject header
6	Air header
7 - 10	Connector assembly
11	Locating base

KRISTAL® STANDARD UF SYSTEMS

PROCESS EQUIPMENT SPECIFICATIONS

Tanks

Item	Quantity	Capacity
Intake tank (optional)	1	Dependent on system capacity
Filtered water tank (optional)	1	MK-4: 2 m^3
		MK-10: 5 m^3
		MK-20: 10 m^3
		MK-40: 20 m^3
CIP tank	1	MK-4: 0.5 m^3
		MK-10: 1 m^3
		MK-20: 2 m^3
		MK-40: 4 m^3

Pumps

Item	Quantity	Capacity
Feed pump	1	MK-4: 15 - 21 m^3/h
		MK-10: 38 - 52.5 m^3/h
		MK-20: 75 - 105 m^3/h
		MK-40: 150 - 210 m^3/h
Backwash pump	1	MK-4: 24 m^3/h
		MK-10: 60 m^3/h
		MK-20: 120 m^3/h
		MK-40: 240 m^3/h

Other Equipment

Item	Remarks
Pre-filter	200-micron screen
Programmable logic control (PLC) panel	Includes all automatic controls and instrumentation relays
Motor control centre (MCC) panel	Includes all automatic controls and instrumentation relays
Level switches and sensors	1 set each for: intake tank, filtered water tank, CIP tank
Pressure indicator (feed)	1 set
Pressure indicator (filtered water)	1 set (optional)
Flow indicator (feed)	1 set (optional)
Flow indicator (filtered water)	1 set
Turbidity sensor (feed)	1 set (optional)
Turbidity sensor (filtered water)	1 set (optional)
pH sensor (feed)	1 set (optional)

KRISTAL® STANDARD UF SYSTEMS

MK-4: 4-MODULE SYSTEM

Overall footprint (m^2):	1.0 - 1.5 (approx.)
Skid dimensions (mm):	1135(L) x 1280(W) x 4223(H)
Design permeate flow rate* (m^3/h):	12 - 17

Connection	Type	Size	Material
Feed header pipe	Flanged	4-inch, DN100	PE
Permeate header pipe	Flanged	4-inch, DN100	PE
Reject header pipe	Flanged	4-inch, DN100	PE
Reject recirculation pipe	Flanged	2-inch, DN50	PE
Backwash header pipe	Flanged	4-inch, DN100	PE
CIP header pipe	Flanged	4-inch, DN100	PE
Air line		1-inch, DN25	PE

Process Parameters*	UOM	Specifications
Feed flow rate	m^3/h	15 - 21
Permeate flow rate	m^3/h	12 - 17
Recirculation flow rate	m^3/h	3 - 4
Backwash flow rate	m^3/h	24
CIP flow rate	m^3/h	15 - 21
Air flow rate	Nm^3/h	8.5 - 11
Backwash frequency	mins	30 - 45
Maintenance cleaning frequency	days	3 - 10
Recovery cleaning frequency	days	20 - 50

**Dependent on feed water conditions*

KRISTAL® STANDARD UF SYSTEMS

MK-10: 10-MODULE SYSTEM

Overall footprint (m^2):	2.5 - 3.6 (approx.)
Skid dimensions (mm):	2110(L) x 1280(W) x 4223(H)
Design permeate flow rate* (m^3/h):	30 - 42

Connection	Type	Size	Material
Feed header pipe	Flanged	4-inch, DN100	PE
Permeate header pipe	Flanged	4-inch, DN100	PE
Reject header pipe	Flanged	4-inch, DN100	PE
Reject recirculation pipe	Flanged	2-inch, DN50	PE
Backwash header pipe	Flanged	4-inch, DN100	PE
CIP header pipe	Flanged	4-inch, DN100	PE
Air line		1-inch, DN25	PE

Process Parameters*	UOM	Specifications
Feed flow rate	m^3/h	38 - 53
Permeate flow rate	m^3/h	30 - 42
Recirculation flow rate	m^3/h	7.5 - 10.5
Backwash flow rate	m^3/h	60
CIP flow rate	m^3/h	38 - 52.5
Air flow rate	Nm^3/h	20 - 27.5
Backwash frequency	mins	30 - 45
Maintenance cleaning frequency	days	3 - 10
Recovery cleaning frequency	days	20 - 50

**Dependent on feed water conditions*

KRISTAL® STANDARD UF SYSTEMS

MK-20: 20-MODULE SYSTEM

Overall footprint (m^2):	5.5 - 7.0 (approx.)
Skid dimensions (mm):	3860(L) x 1280(W) x 4223(H)
Design permeate flow rate* (m^3/h):	60 - 84

Connection	Type	Size	Material
Feed header pipe	Flanged	6-inch, DN150	PE
Permeate header pipe	Flanged	6-inch, DN150	PE
Reject header pipe	Flanged	6-inch, DN150	PE
Reject recirculation pipe	Flanged	3-inch, DN75	PE
Backwash header pipe	Flanged	6-inch, DN150	PE
CIP header pipe	Flanged	6-inch, DN150	PE
Air line		1.5-inch, DN40	PE

Process Parameters*	UOM	Specifications
Feed flow rate	m^3/h	75 - 105
Permeate flow rate	m^3/h	60 - 84
Recirculation flow rate	m^3/h	15 - 21
Backwash flow rate	m^3/h	120
CIP flow rate	m^3/h	75 - 105
Air flow rate	Nm^3/h	40 - 55
Backwash frequency	mins	30 - 45
Maintenance cleaning frequency	days	3 - 10
Recovery cleaning frequency	days	20 - 50

**Dependent on feed water conditions*

KRISTAL® STANDARD UF SYSTEMS

MK-40: 40-MODULE SYSTEM

Overall footprint (m^2):	10.5 - 14 (approx.)
Skid dimensions (mm):	7723(L) x 1280(W) x 4223(H)
Design permeate flow rate* (m^3/h):	120 - 168

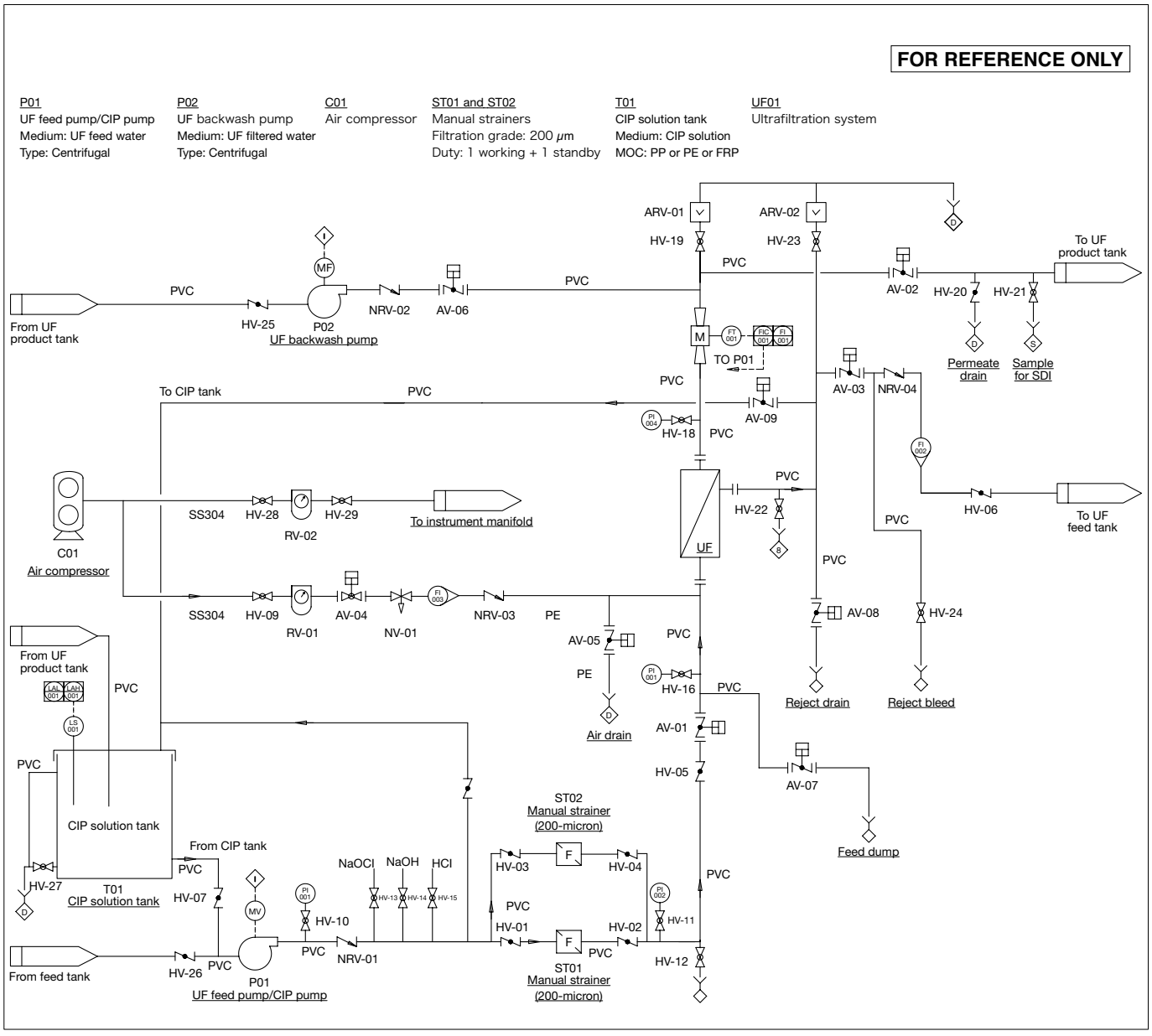
Connection	Type	Size	Material
Feed header pipe	Flanged	8-inch, DN200	PE
Permeate header pipe	Flanged	8-inch, DN200	PE
Reject header pipe	Flanged	8-inch, DN200	PE
Reject recirculation pipe	Flanged	4-inch, DN100	PE
Backwash header pipe	Flanged	8-inch, DN200	PE
CIP header pipe	Flanged	8-inch, DN200	PE
Air line		2-inch, DN50	PE

Process Parameters*	UOM	Specifications
Feed flow rate	m^3/h	150 - 210
Permeate flow rate	m^3/h	120 - 168
Recirculation flow rate	m^3/h	30 - 42
Backwash flow rate	m^3/h	240
CIP flow rate	m^3/h	150 - 210
Air flow rate	Nm^3/h	85 - 110
Backwash frequency	mins	30 - 45
Maintenance cleaning frequency	days	3 - 10
Recovery cleaning frequency	days	20 - 50

**Dependent on feed water conditions*

KRISTAL® STANDARD UF SYSTEMS

P&ID



LEGEND

Valve symbols

- Ball valve
- Butterfly valve
- Auto on-off valve
- Check valve
- Air release valve
- Needle valve

Equipment symbols

- Centrifugal pump
- Air filter regulator
- Manual strainer

Primary element symbols

- Rotameter
- Electromagnetic flowmeter

Uppercase letter	First position (Measured or indicated variable)	Second position (Modifier)	Succeeding letters (Output function/ modifier)
A	Analysis	Alarm	
C			Control
E		Element	
F	Flow		
H			High
I		Indicator	
L	Level		Low
P	Pressure		
S			Switch
T	Temperature		Transmitter

ABOUT HYFLUX

At the core of Hyflux's business is its membrane innovation that is focused on the development of membranes, membrane applications, and the design and development of membrane-based plants to deliver solutions for a wide range of applications in water treatment and industrial manufacturing processes.

Founded in 1989, Hyflux has successfully transformed itself into a global fully-integrated water solutions company and one of the top desalination plant suppliers in the world.

Hyflux offers sustainable solutions in the areas of membrane-based desalination, water recycling, wastewater treatment including membrane bioreactor technology, and potable water treatment. Its projects and operations span across South East Asia, China, India, Europe, the Middle East and North Africa, and include landmark projects such as the world's largest seawater reverse osmosis (SWRO) desalination plant in Magtaa, Algeria.

Hyflux is distinctive in its ability to address the challenges at every point of the entire value chain of the water industry – from R&D in membrane technology, component manufacturing, process engineering, engineering, procurement and construction (EPC), to operations and maintenance (O&M), in addition to arranging for project financing of large-scale municipal water projects.

At the core of Hyflux's business is its membrane innovation that is focused on the development of membranes, membrane applications, and the design and development of membrane-based plants to deliver solutions for a wide range of applications in water treatment and industrial manufacturing processes. Today, Hyflux's membrane systems have been installed in more than 1,000 plants in over 400 locations worldwide.

Through its projects across the world, Hyflux has left an indelible imprint on the communities that it serves, driven by its commitment to deliver water that is clean, safe and affordable.