Pall MFRO - Fresh Water Generators

The most reliable fresh water production in the toughest water conditions

Pall Corporation

2023

Agenda

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Challenges for fresh water systems with conventional pre-filtration

Depending on water quality, conventional pre-filtration solutions – in most cases utilise a sand filter and cartridge filter to reach the required limits of fresh water system. The lower the quality of the feedwater, the more ineffective and expensive conventional systems are in the long term.

Other Challenges:

- Available space onboard and weight requirements
- High life cycle costs for service and maintenance:
  - System downtime
  - Personnel and Labour costs
  - Cost for replacement parts
- High chemical cleaning requirements
- Consistent fresh water quality and production can only be guaranteed while in open sea, but not in coastal waters, littoral areas, canals / rivers, ports and harbours
- Insufficient bunker water quality
- Mission profiles where operators must remain close to shore

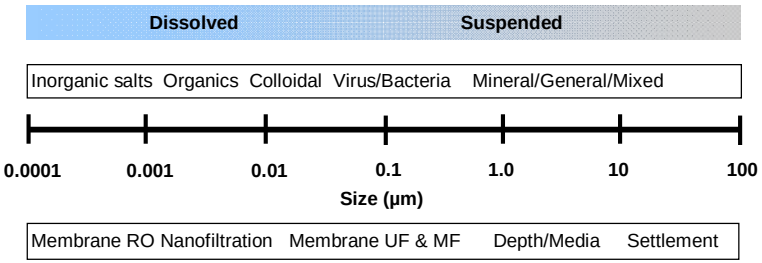
Pall has over 30 years experience in the Marine fresh-water generation industry and has sold over 2000 units worldwide

Our customers include several NATO countries, including Germany, the United Kingdom, New Zealand, Australia, Greece, France, Spain, Portugal etc.

Why Pall is the right partner for you:

Pall Membrane Filtration systems are designed to produce fresh from any (natural) water source, including littoral areas, in rivers and estuaries and harbour basins. Pall introduced these systems to the market in 2006 under the *Operate Anywhere Concept.*

Water contaminants include suspended and solid matter:



Seawater contrains between 30 and 50 g/l of dissolved salt. However, the largest challenge lies in the presence of undissolved solids.

Snapshot of actual water quality during a Pall membrane filtration system trial

Pall‘s expertise in memrbane filtration helps customers around the world meet the most demanding industry-specific requirements:

- Military fresh water production
- Municipal drinking water
- Food Production
- Waste Water treatment
- Sea Water desalination





Fresh Water Generators: Disc Tube Reverse Osmosis (DTRO)

Small footprint systems that meet the highest requirements on military submarines.

- Second and third stage treatment added to make technical and de-ionized water
- Fully customizable and modular

In service extensively, including the following forces:

- UK Royal Navy
- German Navy
- French Navy
- Italian Navy
- Israel Navy
- Royal Australian Navy
- New Zealand Navy
- Hellenic Navy
- South Korean Navy
- Brazilian Navy
- Chilean Navy
- Norwegian Navy

Pall Membrane Filtration (MF) Fresh Water Generators

The "state of the art" freshwater generator for current and future NATO mission profiles.

PALL MF Pre-Filtration Stage

MFRO1014

MFRO3560

MFRO1530

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Pall Membrane Filtration (**MF**) Fresh Water Generators

The most reliable pre-filtration for freshwater production in every application

Pall Corporations industry-leading technology enables onboard water purification from virtually any water source. Locations such as coastal waters, estuaries, rivers and harbours can contain extremely high levels of suspended solids and other contaminants that often discourage vessel operators from producing water in these areas. As the worlds leading provider in filtration solutions, Pall has been a trusted supplier to Governments, Industry and multiple Navies for over 60 years. Pall‘s Engineering Team applies its expertise in process design, membrane science, systems engineering and manufacturing to deliver truly optimised fresh water generators for your needs

PALL MF Pre-Filtration Stage

MFRO1014

MFRO3560

MFRO1530

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Pall Membrane Filtration (**MF**) Fresh Water Generators

- "Make Water Anywhere" capability that greatly increases your freshwater availability
  - Allows ships to remain "on station" without the need to transit from shore to generate water
    - This leads to a significant saving in fuel costs & greater operational availability of your vessel
  - Reduced dependancy on port authority or bunker water leading to reduced associated costs
    - Bunker water can also be treated by the MF-Stage
- Best in class pre-filtration membranes
  - Low total life-cycle costs thanks to low maintenance and operating costs
  - Made possible by significantly extended RO Membrane life, protected by the industries most robust pre-filtration media
  - Reduced chemical usage – no need to mix, add or adjust pre-treatment chemicals as raw water conditions change
  - Fully regenerable membrane filtration with extended maintenance intervals
  - MF system can be selectively operated while in open sea conditions thus minimising operational time and component wear
  - Ensuring long-term and reliable operation with a treatment process tailored to your raw water characteristics and treatment needs
  - Customised maintenance plans
  - Fully automatic and easy to operate via HMI touch screen panel
  - A 3 Stage System: Freshwater, Technical and De-ionized water
  - Compact design: pre-engineered designs and pre-engineered assembly with a smaller footprint than convential systems
  - The systems can be delivered in modular sections for ease of transport through the vessel for retrofit
- Systems are manufactured to military grade requirements that meet the relevant marine standards for shock, vibration and EMC levels
- Highly beneficial in Disaster and Humanitarian Relief support

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Design of Pall Membrane Filtration Reverse Osmosis Systems

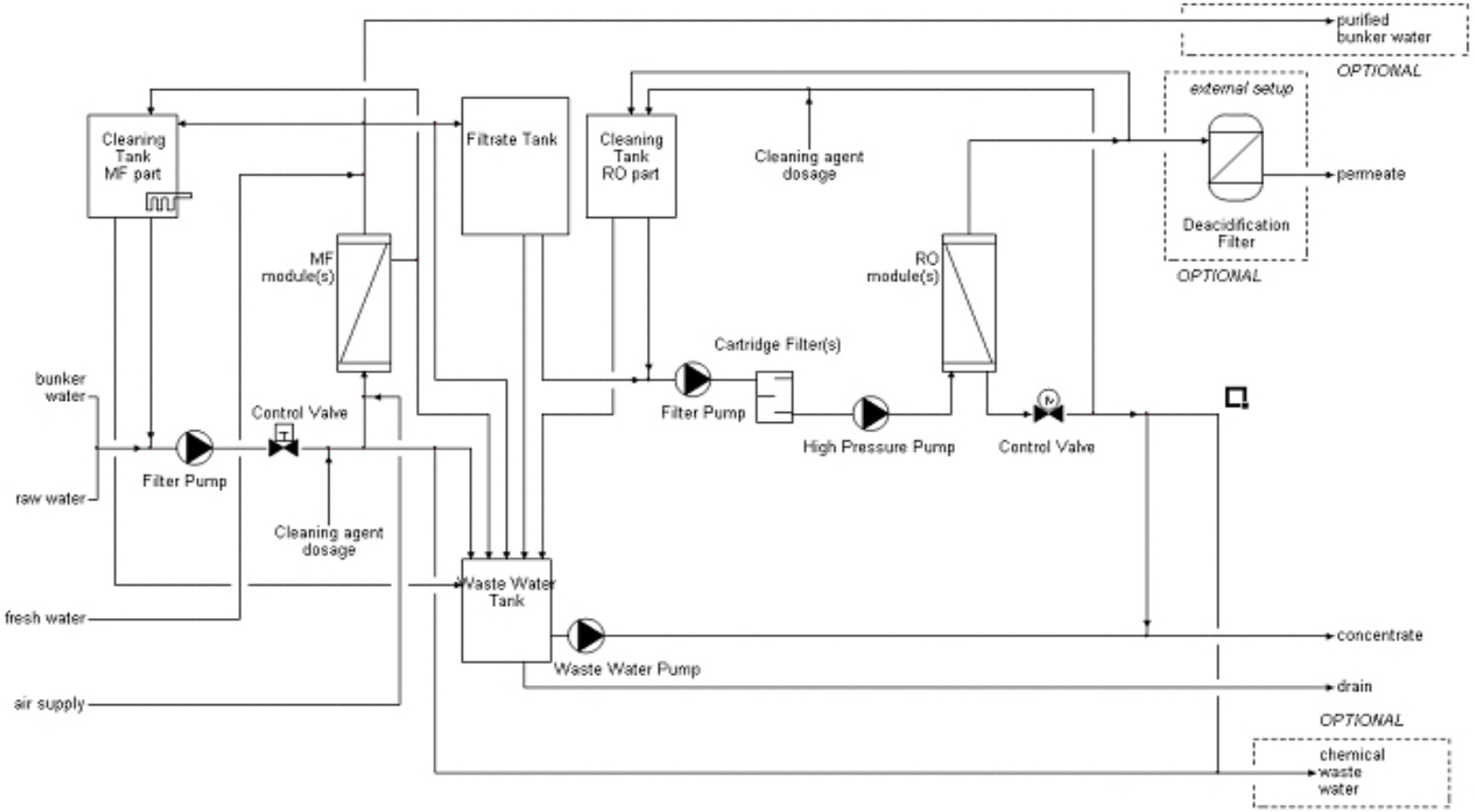
Pall systems consist of the following sections:

- Raw water intake
- Prefiltration (Membrane Filtration)
- Reverse Osmosis (RO)
- Permeate post-treatment
- Cleaning (CIP)
- Plant Control

The systems can also be designed to meet the following requirements:

- Preheating
- CO2 Dosing (Installation between outlet of the RO Modules and deacidification/hardening (“deacidification”)
- pH adjustment
- Second stage RO production of technical water or special specifications

Process of Pall Membrane Filtration Fresh Water Generators

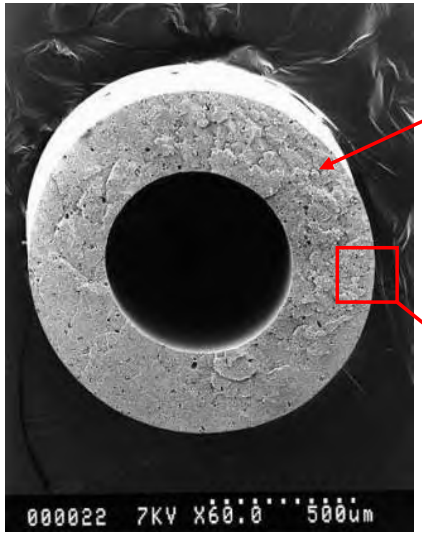


The raw water enters the system through the "Feed" connection point. A centrifugal pump supplies the water to the filtration membranes. The production rate is regulated by a pneumatic control valve at the inlet of the filter stage. The filtrate produced is transported to an intermediate tank, from which the reverse osmosis (RO) stage is supplied with water. The desalinated permeate generated by the RO is optionally further acidified with CO2 and then deacidified in a hardening filter and thus hardened.
Further optional post-treatments are possible at this stage.

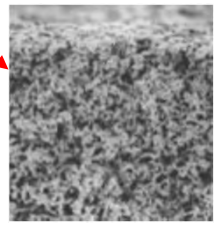
Design of Pall Membrane pre-filtration

- Membrane modules consisting of around 6000 hollow fibres
- Membrane fibres with a retention rate of 0.1µm absolute: stops all solids and bacteria, including legionalla
- Outside-in filtration: contaminants stay on the outside of the PVDF Hollow fibre
- Retained particles are removed from the outside of the fibres during backwashing and flushed out of the module
- Capable of treating inlet water with high turbidity (up to 500 NTU)
- Homogenous fibre material with high mechanical strength

Hollow fibre

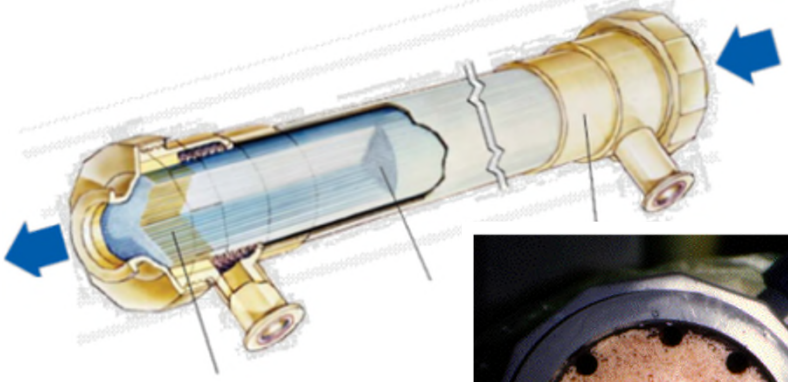


Uniform pore structure throughout the thickness of the polyvinylidene fluoride (PVDF) membrane construction with a unfiform rejection rating of 0,1 µm

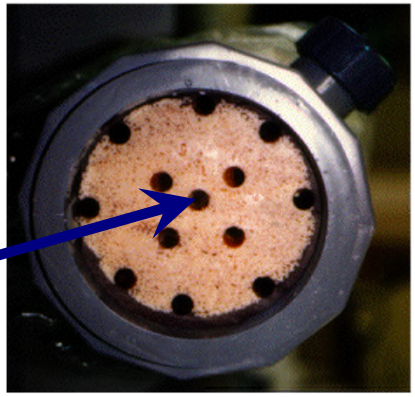


Membrane Modules

Raw Water

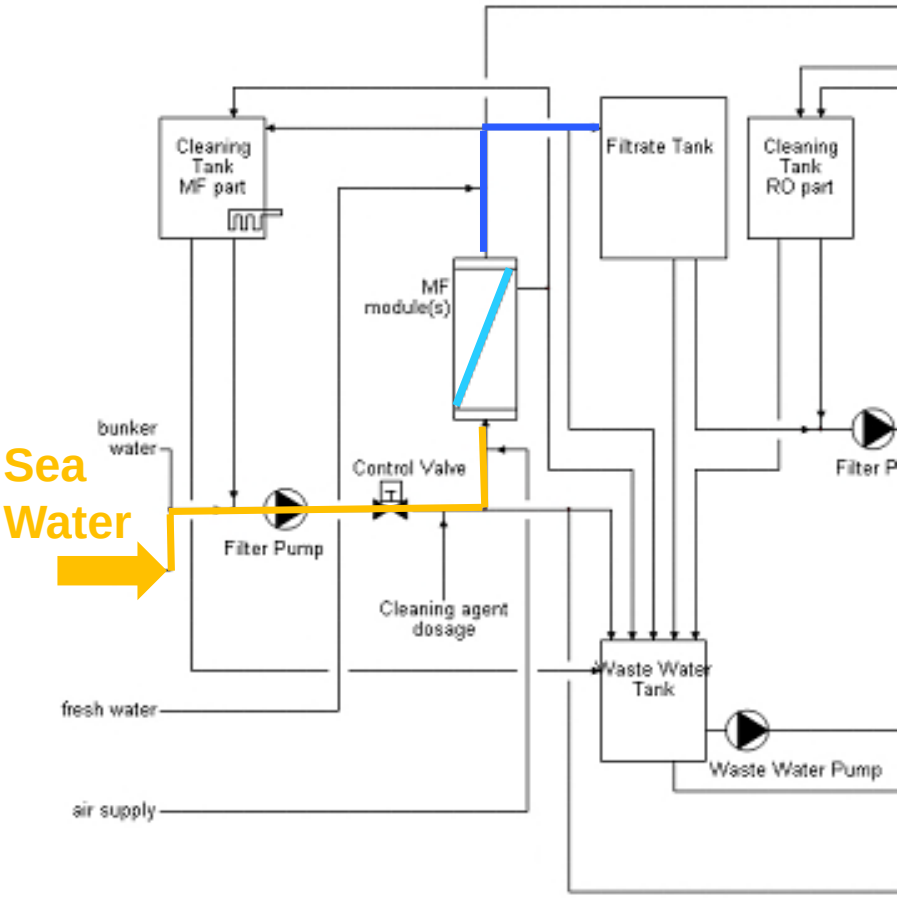


Filtrate



Water absorption

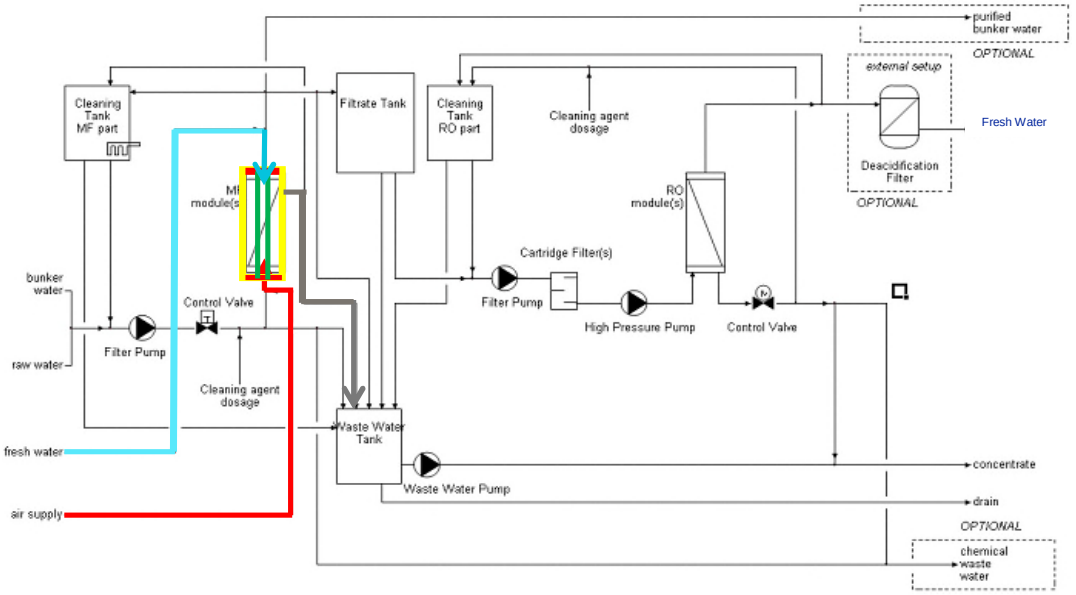
Process of Pall Membrane pre-filtration

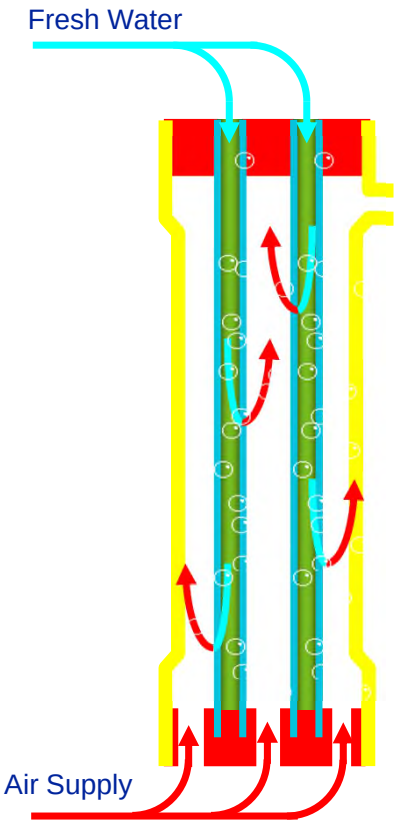


The hollow fibres are sealed on the inlet side. The raw water is introduced between the hollow fibres and flows parallel along the outer surface of the membrane and through the membranes into the inside of the hollow fibres. The water filtered in this way flows from the top of the module into a filtrate tank, which is also the feed tank to the RO.

During the filtration mode, particles settle on the membrane surface, which over time increases the transmembrane pressure of the membrane. Therefore, the flow is kept constant by a control valve.

Efficient and effective cleaning process for long-lasting membranes





Feedwater – Raw SeaWater
RF: Backwash water without air scrubber
AS: Backwash water with air scrubber (shows higher particulate cleaned off fibres with air agitation)

Backwashing
The pre-filtration system is programmed in such a way that the modules are mechanically cleaned at a specified interval. The backwash process used enables a reduction in the transmembrane pressure and thus extends the period before chemical cleaning becomes necessary. The fresh water used during backwashing is compensated by additional fresh water generation.

Fresh water enters through the filtrate port of the modules, at the same time air is blown into the module from below. The air in the water moves the hollow fibres so that dirt is shaken off. Light particles are transported laterally out of the module with the air-water flow.

This is followed by a short backwash without air, during which heavy particles are flushed down out of the module. The backwash water is collected in a tank and pumped overboard

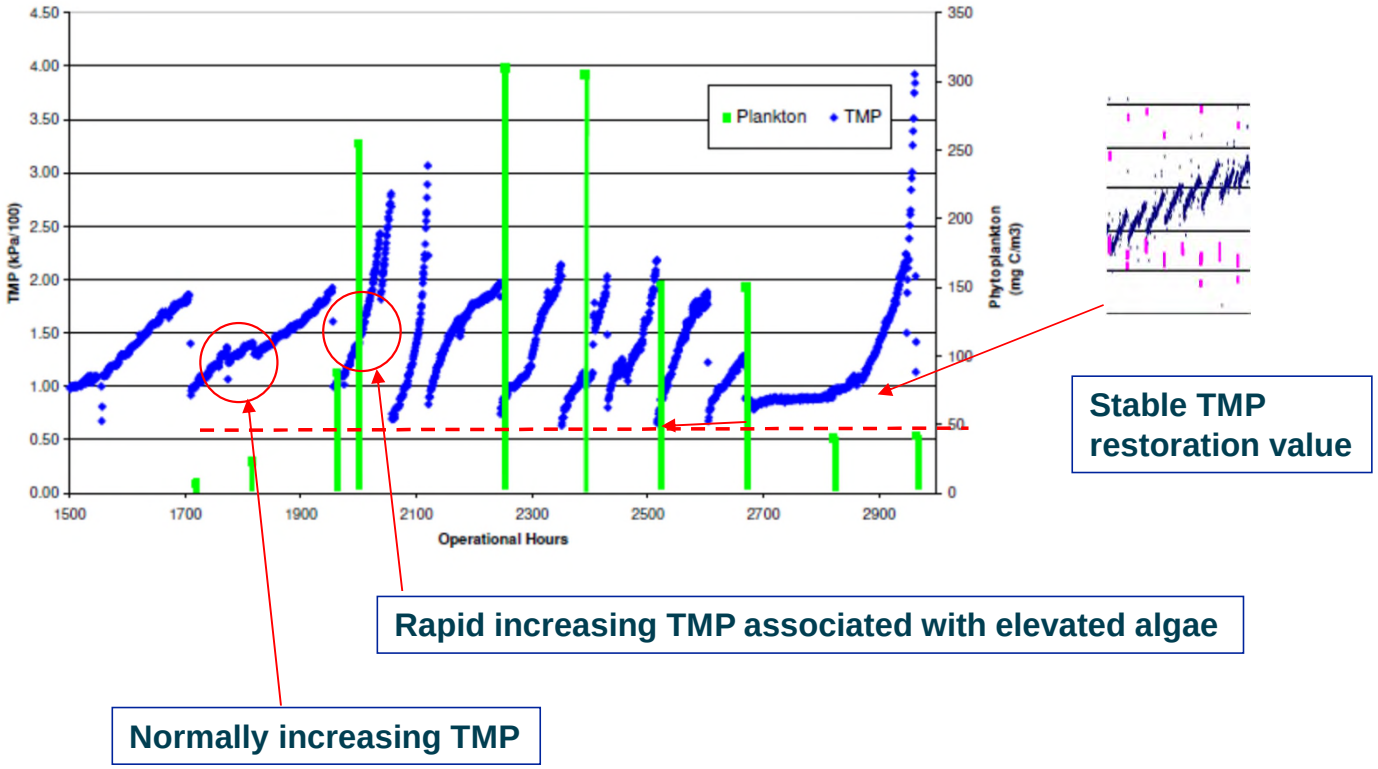
Challenges and requirements of shipboard fresh water generators – MFRO worry-free operation

- Sustainable operation of the MFRO – constant performance even after heavy contamination

The graphic shown shows the pressure curve of membrane filtration during the difficult conditions of an algae bloom

The increase in TMP follows the blocking effect of the algae bloom. The automated mechanical cleaning of the modules (air-assisted backwashing) leads to a stable “baseline” of the pressure curve, even after the critical event of the algae

Transmembrane pressure (TMP) trends in heavily contaminated feed water



Challenges and requirements of shipboard fresh water generators – MFRO worry-free operation

- The pre-treatment stage can be extremely demanding given the variability of raw water conditions
- As membrane filtration retains solids, it shows an increase in transmembrane pressure (TMP)
- To ensure constant operation, the rise in TMP must be fully recoverable
- This is achieved thanks to physical and chemical cleaning regimes
- The membrane pre-filtration significantly reduces the cleaning effort of the downstream reverse osmosis modules, as membrane fouling is avoided and scaling is significantly minimised

Consequences of inadequate pre-filtration

Formation of a covering layer of dirt/fouling on the RO leads to reduced quality of fresh water

Blocked RO membrane due to inorganic and biological fouling

Conventional pre-filtration:

"…more problematic to our operation was the presence of particles passing the filter cartridge (candle filters) in our pre-treatment with a size of 5-10 µm. When analysing the Reverse Osmosis modules we detected significant amounts of silt (2-63 µm) and algae components. The presence of these particulates can destabilise RO membranes which has led to blockage and subsequent malfunction of the system, preventing consistent drinking water production onboard."*

***Military EU NATO Member**

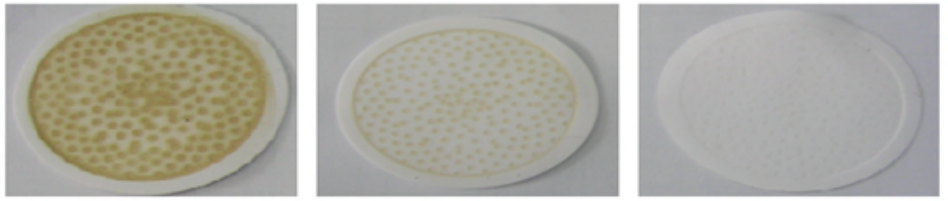
Clean RO element after Pall MF-Pre-treatment

Excerpt from a test report on Pall MFRO:

"The Pall membrane pre-filtration system connected to the RO system has been running for three years without any problems, the RO Modules are receiving a particulate free feedwater… the system has operated fully automatically so that the production of drinking water has been guaranteed even during the backwashing process*."

***Military EU NATO Member**

The following image illustrates the effect of MF filtration (test filter after SDI measurement)



Raw Water | After conventional pre-filtration | After Pall Membrane Filtration

Membrane Filtration – Advantages over conventional filtration

Features / Performance Evaluation	Sand Filter / MMF/DMF	Membrane MF	Benefit of Pall MF
Protection of potential RO	+	++++	0.1 µm rating removes particulate fines (colloids and oxidized metals eg. Fe, Mn, As) & micro organisms
Silt Density Index (SDI)	+	++++	Filtrate with SDI <3
Turbidity	++	++++	Filtrate with turbidity < 0.1 NTU
Microbial removal	+	++++	6 log removal of microorganism and pathogens
Consistency in performance	+	++++	Continuous
Integrity testable	-	++++	Assurance of safe potable water supply
Flexibility to cope with variable feeds and hydraulic loads	++	++++	Broad operation range, handles upsets
Reliability & longevity	++	++++	Superior strength of HC-PVDF membranes
Modular & expandable	+	++++	Future needs, by modules or banks
Waste minimization	+	+++	Unique Air-scrub-feature for high recovery
Footprint and weight	+	+++	Compact design, small footprint
Response to oil in feed	++	+++	CIP will clean membranes while SF blocks

++++ : excellent **+++ : good** **++ : fair** **+ : poor** **- : not available**

MAINTAINERS FEEDBACK REPORT

MAINTAINERS FEEDBACK REPORT
Operational Performance Details (Six Months, Jan – Jul 12)
Table 1: Comparison of performance between legacy plant and MFRO
Planned Maintenance

Approximate Values	MFRO Plant	Legacy RO Plant (per plant)
Cartridge Filter Usage	20	80
Bag Filter Usage	0	50
Chemical 1 (Litres) Acid	40	65
Chemical 2 (Litres) Alkaline	10	30
Chemical 3 (Litres) Biocide	20	30
Chemicals for MF (Litres)	30	0
Average Fresh Water Quality	500µS	850µS
Average FW Production	1.60m^3/hr	1.1m^3/hr
Maximum FW Production rate	1.75m^3/hr	1.5m^3/hr
Run alongside/within littoral	Yes	No
Hours unavailable (defects)	10	30

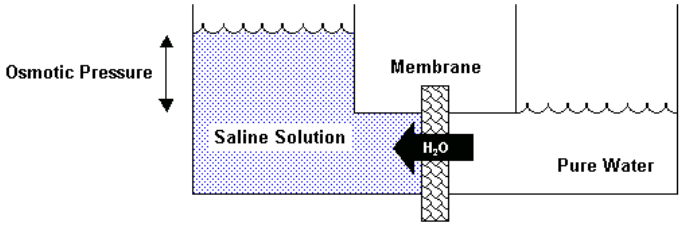
Conclusion

Ship's Staff have ensured that the MFRO Plant has remained the first preferred RO Plant throughout the deployment, and it has now accumulated 2775 hours to date. It has proved to be very capable of operating in the harsh environment of the Suez Canal, alongside in Mumbai Harbour, and in the high operating temperatures of the Arabian Gulf. In comparison to the other RO Plants fitted, it outperforms them in all areas. Ships Staff are very encouraged by both its performance and high level of availability.

Overview of the Reverse Osmosis process:

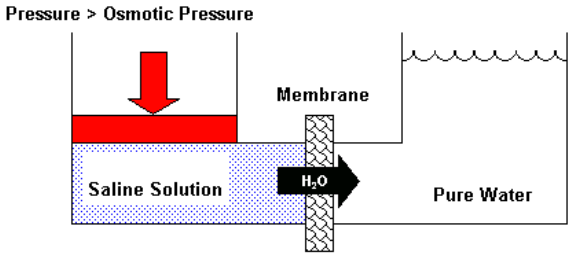
The Principal of Natural Osmosis

If two saline liquids are separated from each other by a semi permeable membrane, the less saline liquid will permeate through the membrane until the salinity equalizes. This process is called natural osmosis. Salt ions cannot pass the membrane, so if one of these liquids is salt water and the other is pure water, the pure water molecules will diffuse through the membrane into the salt water to dilute it. During this process, a certain pressure (resulting in different levels of the fluids) develops in the system. It is called the Osmotic Pressure.



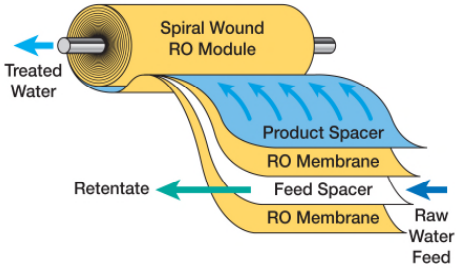
Reverse Osmosis

For water desalination, this process is reversed by pressurising the salt water to a pressure level higher than osmotic pressure. This forces the water molecules to permeate through the membrane in reverse direction. The majority of the dissolved salts, organic material, bacteria and suspended solids are physically rejected by the membrane and remain on the salt water side. The raw water is thus divided into pure water and brine with a higher salt concentration than the initial solution. In the practical application of the reverse osmosis process, the pure water and the concentrate are discharged continuously.



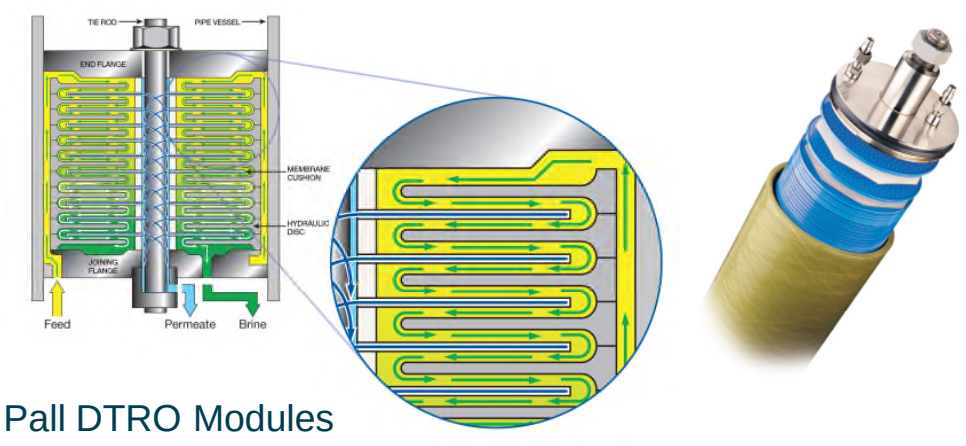
Pall Filter Modules for Reverse Osmosis

Spiral Wound RO modules perform the same function as DT modules but are typically used in larger applications – at flow rates above 50 m3/day. These modules are characterized by an extremely high ratio of membrane surface area to holding volume. Raw water pre-treated by membrane filtration which enables spiral wound modules to provide excellent reliability with the greatest potable water output in the smallest of spaces and minimal energy consumption.



Pall Spiral Wound modules for Reverse Osmosis

Pall Disc Tube Reverse Osmosis Modules are used to remove dissolved salts contained in sea or brackish water. Membrane technology enables dissolved salts to be reduced by over 98.5%. The Pall Disc Tube (DT) with its short, channel-like flow paths imparts turbulent flow to the raw water to minimize concentration polarization, thereby reducing membrane fouling. The compact and flexible design ensure long membrane life, these can be repaired on-site by simple exchange of single membrane cushions to reduce through life cost and minimize system downtime.



Pall DTRO Modules

Customer Feedback

- *"…Pall's significant contribution made to implementing this innovative solution on Type 45 destroyer before the ship was deployed to the Gulf, and the noticeable difference the MFRO has made to the ship's fresh water supplies in that challenging area, and during transit through the Suez Canal"*

- *"The additional capabilities provided by the MFRO unit is a fantastic evolution in fresh water production technology. As shown by the humanitarian assistance provided following a hurricane in the Philippines, it is a true 'make water anywhere' solution, and should set the standard for all future water generating installations.*

- *[…] if I had my way we would have this unit fitted to every ship in the fleet!"* Gareth Pritchard - Type 45 ADTA Warship Technical Authority

MFRO Systems for different system capacities

Technical Specification	
Dimensions (LxWxH)	2820 x 995 x 1700 mm 111 x 38 x 67 (in)
Section Dimensions	< 700 x 1000 x 750 mm (each)
Weight	1300 Kg (2866 lb)
Power	440V / 60 Hz or 400V / 50 Hz, both 3 phase
Control	Fully automatic
Technology	3 Microfiltration MF modules 3-4 DT modules

Desalination Capacity: 10 to 14 m³/day

Based on water with <500ppm TDS

Technical Specification	
Dimensions (LxWxH)	1445 x 1200 x 2100 mm 57 x 47 x 83 (in) plus DT section
Section Dimensions	Optional for retrofit max 1100 x 1000 x 1500 mm
Weight	1780 Kg (3924 lb)
Power	440V / 60 Hz or 400V / 50 Hz, both 3 phase
Control	Fully automatic
Technology	4 Microfiltration MF modules 4-7 DT modules

Desalination Capacity: 15 to 30 m³/day

Based on water with <500ppm TDS

Technical Specification	
Dimensions (LxWxH)	Process section: 4080 x 1718 x 19339 mm DT (RO) section: 1320 x 540 x 1820 mm
Weight	1700 Kg
Power	440V / 60 Hz or 400V / 50 Hz, both 3 phase
Control	Fully automatic
Technology	9 Microfiltration MF modules 8-14 DT modules

Filtration Capacity: 35 to 60 m3/day*

*output to RO Stage

Pall Marine Systems Quality Assurance

Pall Marine Fresh Water Generating systems are built in accordance with the major shipboard notified bodies:

- Lloyd's Register of Shipping
- BV (Bureau Veritas)
- ABS (American Bureau of Shipping)
- DNV (Det Norsk Veritas, former DNV GL)

Additional Specifications are considered as well- e.g.

- STANAG
- Registro Italiano Navale (RINA)
- ISO 9001
- Specific type approval upon request

PALL CORPORATION

Thank you.