FLOWSERVE

SEPTEMBER 2022

Application Solutions Guide

DESALINATION

Experience In Motion

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THE GLOBAL DESALINATION LANDSCAPE

MARKET OVERVIEW

The global demand for fresh water is continuously growing, but fresh water sources are limited and not always available where population and industry need them. Only 2.5% of the world's water is fresh, and 70% of this remains frozen in polar ice caps and snow. The remaining 97.5% of the world's water is in the oceans and seas. Desalination allows this large water resource to be tapped for human consumption and many manufacturing processes.

Desalination plants operate in more than 120 countries, but they only provide 1.5% of the world's water supply. Some countries, such as Saudi Arabia and the United Arab Emirates, count on desalination plants for over 70% of their water.

The climate for capital expenditures (CAPEX) in desalination is a good one. The Global Desalination Market report dated February 2022 projected a US$ 32.02 billion global desalination market by 2027. The market forecast is expected to grow at a CARG of 8.8% till 2027 from the USD 19.29 billions of 2021. Middle East and Africa will dominate the regional market in the Global Desalination Industry and have opted for large-scale desalination plant with a capacity greater than 300,000 m^3/d (79,000,000 gpd).

The COVID-19 pandemic resulted in the slow-moving growth of the desalination industry. However, since the beginning of 2021 when the world initiated a return to normalcy, the demand for desalination has grown. This growth was mainly due to large investments in water treatment solutions by the governments of various countries that are trying to address water scarcity issues.

In addition, augmenting measures for providing a safe and reliable water supply amidst the COVID-19 outbreak have driven the demand for water treatment, especially desalination, globally.

Desalination and reuse are proving critical in ensuring the continuity of the drinking water supply worldwide. Spain recorded two of the hottest and driest months ever in summer 2022, reducing reservoir capacities to around 37%.

Saudi Arabia alone has an installed capacity of 9 million cubic meters (317.8 cubic feet) per day. The SWRO installed capacity in Saudi Arabia and UAE is expected to increase by more than 7 million cubic meters (247.2 cubic feet) per day by 2026.

However, the need for new desalination capacity is real and will likely remain a priority in many areas of the world, even with many state budgets under strain. Advances in membrane technology and energy recovery are making desalination more economical. Ground water conservation, a major driver for future demand, will likely remain a priority in growth areas. Finally, CAPEX forecasts for Asia-Pacific and Americas are strong, even though these regions represent a small percentage of the total sum.

IMPORTANT DESALINATION TERMINOLOGY AND ACRONYMS

Seawater and Brackish Water Concentrations

The mineral or salt content of water is defined in terms of total dissolved solids (TDS) using units of mg/l or parts per million (ppm). (1 mg/l equals 1 ppm.) The maximum concentration for potable water is 500 mg/l. Water with TDS from 500 to 15,000 mg/l is generally classified as brackish, while water with higher concentrations is classified as seawater. The salt concentrations in seawater can vary quite significantly. In the Pacific Ocean along the U.S. coast, concentrations vary from 33,000 to 36,000 mg/l, while the Persian Gulf sees concentrations as high as 45,000 mg/l.

Technologies

- **Membrane Desalination**
  - – Seawater Reverse Osmosis – SWRO
  - – Brackish Water Reverse Osmosis – BWRO
- **Thermal Desalination**
  - – Multistage Flash – MSF
  - – Multi-Effect Distillation – MED
  - – Thermal Vapor Compression – TVC *(not covered in this document)*
  - – Mechanical Vapor Compression – MVC *(not covered in this document)*

Market Segmentation by Technology and/or Plant Size

- SWRO <10,000 m^3/d (2,642,000 gpd) >> small and medium
- SWRO <50,000 m^3/d (13,209,000 gpd) >> large
- SWRO >50,000 m^3/d (13,209,000 gpd) >> extra-large
- Thermal > MSF, MED, TVC, MVC
- BWRO and Nanofiltration

A CLOSER LOOK AT DESALINATION TECHNOLOGIES

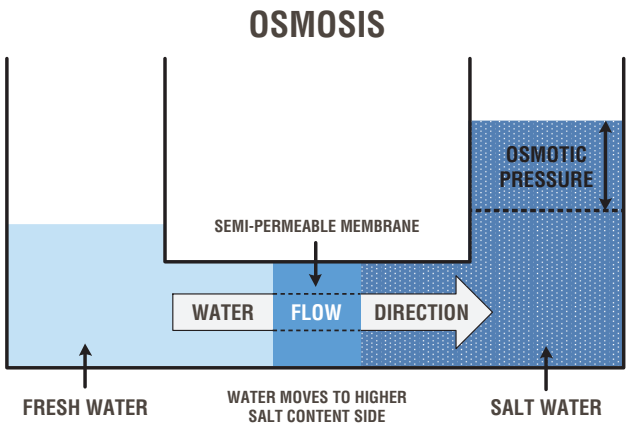
Membrane Desalination

In membrane desalination systems, dissolved minerals are separated from the intake or source water with a semipermeable membrane.

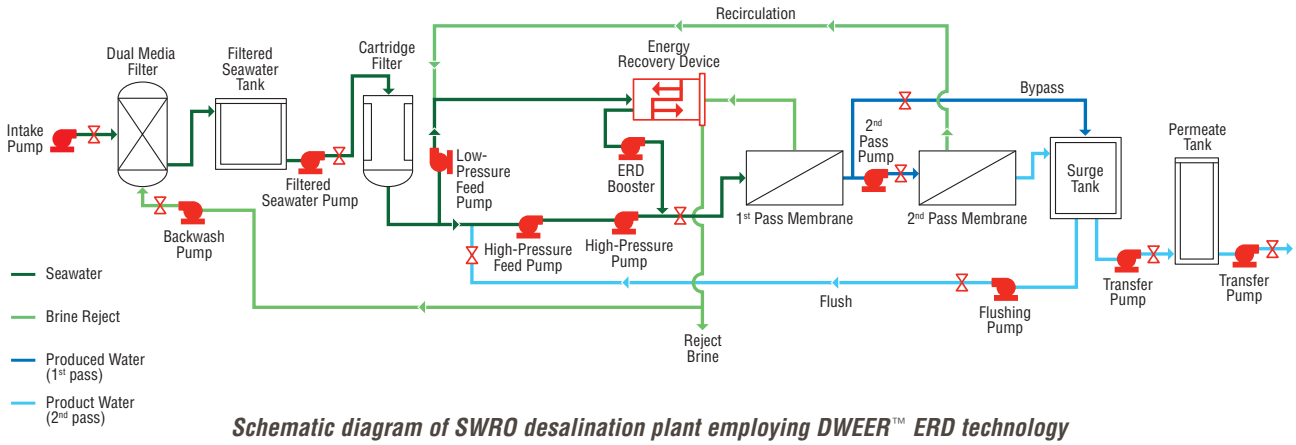
The dominant membrane technology used today is reverse osmosis (RO). If high and low salinity water sources are separated by a semipermeable membrane, water will move from the low salinity side to the high salinity side by a natural process called *osmosis*. The water being transferred exerts a pressure on the membrane known as *osmotic pressure,* which is proportional to the difference in total dissolved solids concentrations on each side of the membrane, and is also dependent on the source water temperature and the nature of the dissolved solids. The osmotic pressure does not depend on the type of membrane used.

This process can be reversed by applying pressure to the salt water side of the membrane. This is the operating principle behind all RO desalination plants.

With its inherently simple design, significantly lower energy consumption and smaller footprint than thermal technologies, the RO process is often the choice for municipal and commercial water supply. This applies to both SWRO and BWRO applications. With its semipermeable membranes,



the RO process requires a pretreatment to ensure all larger particles and suspended solids are removed from the feedwater to protect the membranes. Pressurized feedwater is fed to the membranes where the water stream is split into a high-quality product water stream at lower pressure and a high salinity discharge (reject) stream, which remains at high pressure. Hydraulic energy is recovered from the reject stream with different energy recovery devices (ERDs) to lower the overall energy consumption of the plant. To improve the operational flexibility and minimize downtime, chemical additives are required to prevent scaling and fouling of the membranes.



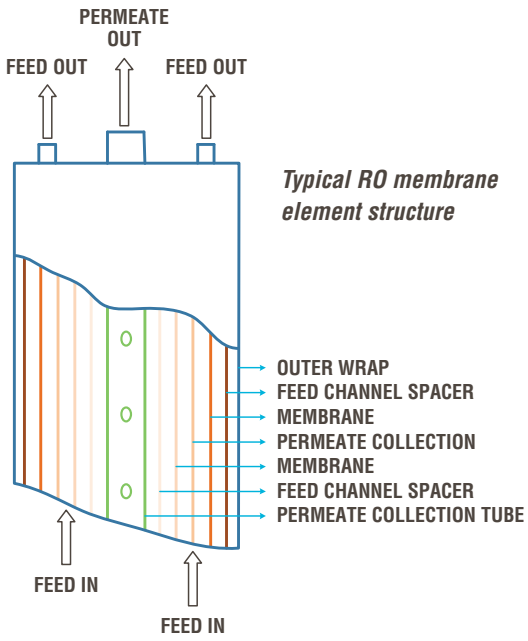
Schematic diagram of SWRO desalination plant employing DWEER™ ERD technology

In electrodialysis (ED) and electrodialysis reversal (EDR) systems, a direct electric current is used to transport the mineral ions across the membrane. ED/EDR systems represent a very small part of the market and are not discussed further in this guide.

Membrane Principles

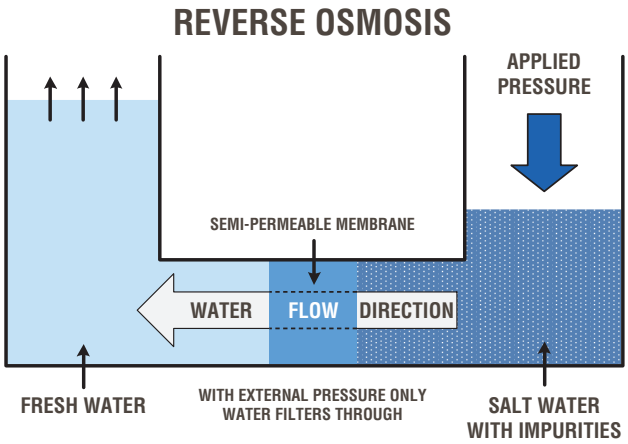
The RO section is one of the most vital steps in the desalination process, as more than 80% of the total energy required by the plant is used in this section. RO membranes are considered the most important equipment in the process.

The membranes used in RO systems are designed to separate dissolved solids and cannot remove or store large amounts of suspended solids. If suspended solids are allowed to enter, the membranes will foul quickly. As a result, RO plants include sophisticated pre-treatment systems to remove suspended solids before the source water is introduced to the membranes.



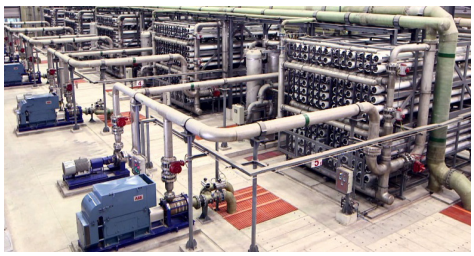
Typical RO membrane element structure

The spiral-wound membrane is the most common type used in the industry today. They are produced in a flat sheet sealed like an envelope and wound in a spiral.



The most common RO elements currently in use are 20 cm (8 in.) diameter and 100 cm (40 in.) long. These are enclosed in a pressure vessel that typically holds about seven elements. In such a configuration, each element produces about 13 to 25 m^3/d (264 to 6,604 gpd) of permeate, and the whole vessel therefore produces 91 to 175 m^3/d (24,040 to 46,230 gpd). Larger 16-, 18- and even 19-inch elements are available but have not gained popularity, partly because they are too heavy to be easily handled by one person.

In large RO plants, 100 to 200 pressure vessels are assembled in parallel into a rack. When combined with the necessary pumps, valves and energy recovery devices, this rack forms an RO train. An extra-large RO plant would consist of several independent trains, each capable of providing a product water flow of 20,000 to 25,000 (5,283,000 to 6,604,000 gpd). The image below shows an installation with five trains, where each train includes a rack of 144 pressure vessels.



Reverse osmosis system with five trains containing 144 pressure vessels per train

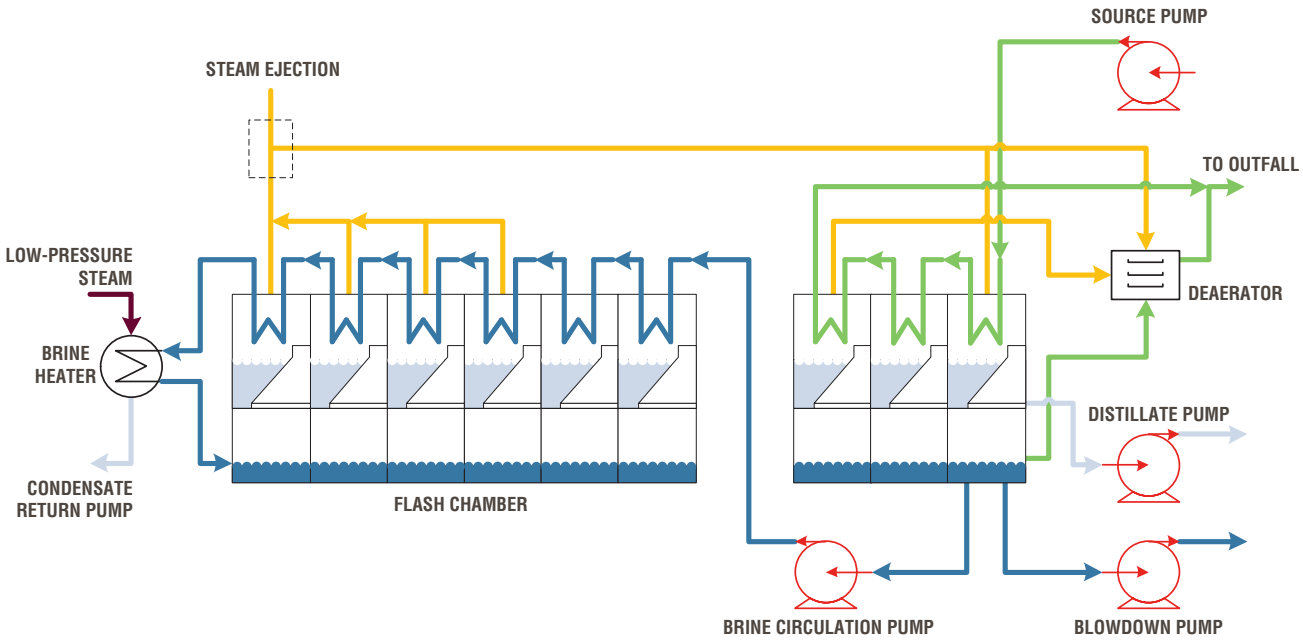
Thermal Desalination

Multistage Flash Distillation

The first large commercial scale desalination plants used the MSF process to produce potable water. In this process, seawater is heated to 90°C to 115°C (194°F to 239°F) by steam provided from a co-located power plant. The heated seawater enters a chamber (called a *stage* or *effect*), which is maintained at a lower pressure, causing some of the seawater to flash to steam. This pure distillate is condensed on tubes that are cooled by the incoming seawater and collected in trays to be transferred to product water storage tanks.

The remaining brine concentrate passes through several more effects, each operated at a lower pressure, causing more seawater to flash. Each stage produces about 1% of the total plant product water volume. Commercial MSF plants typically have 19 to 28 stages. As a result, the recovery rate of an MSF plant (finished product, or permeate, divided by seawater intake) is typically in the range of 19 to 29%

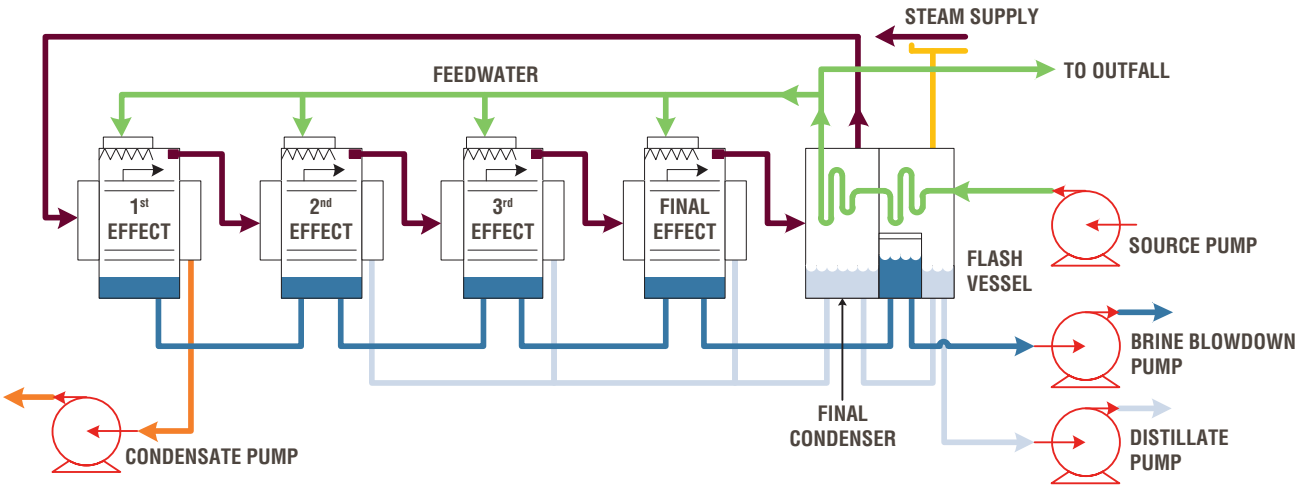
After the last stage, a portion of the brine is recirculated back into the source water stream, reducing the total intake water requirements and improving the thermal efficiency of the process.



Schematic diagram of an MSF desalination plant

Multi-Effect Distillation

Able to operate at temperatures as low as 62°C (144°F), MED plants require less heat input and lower pumping power (0.8 to 1.4 kWh/m^3) than MSF plants. The main difference between MED and MSF systems is that in MSF systems the vapor is created by flashing, while in MED systems the source water is evaporated by heat transfer from steam in condenser tubes.



Schematic diagram of an MED desalination plant

As with MSF plants, MED plants require a large source of steam and are therefore always co-located with a thermal power plant.

In the past, thermal desalination has been economically advantageous where water salinity is very high, because the energy required for separation is practically independent of the salinity of the source water. As a result, MSF and MED have been particularly popular in the Arabian Peninsula, which is bound by water bodies with the highest salinity in the world and demand for power and potable water has historically grown at a compatible pace. Approximately 85% of the global thermal desalination capacity is located in the Arabian Peninsula, with 70% of that in Saudi Arabia and the UAE.

There are new technology developments in thermal desalination, including hybrid systems that may bring about a revival in thermal plant construction. For example, approaches that combine desalination with concentrated solar heat and electricity production are advancing. Longer term, this could be an opportunity for Flowserve due to its combined experience in desalination and concentrated solar power. These technologies are not covered in this document.

Note that because of significant improvements in membrane and isobaric energy recovery technology, most near-term growth in desalination will take place in SWRO at the expense of thermal desalination. Accordingly, this document focuses mostly on SWRO.

DESALINATION PROJECT MODELS

Desalination plants are built under a variety of commercial models involving different influencers and decision makers. This section summarizes the primary project models, the key players in each model and current trends.

Fixed Engineering Procurement and Commissioning (EPC) Projects

This conventional approach to plant construction still represents 50% of the market. While every project has its own nuances, these projects generally involve the following scenario:

- The plant owner (government or private entity) uses a design engineer (consulting and specifying engineer) to handle the initial technology selection and plant design.
- The plant owner engages with multiple engineering and procurement contractors for bids on engineering, purchasing and construction of the plant.
- These are generally price-driven scenarios based on an agreed-upon cost per cubic meter of desalinated water produced.

Build-Own-Operate (BOO) and Build-Own-Operate-Transfer (BOOT) Projects

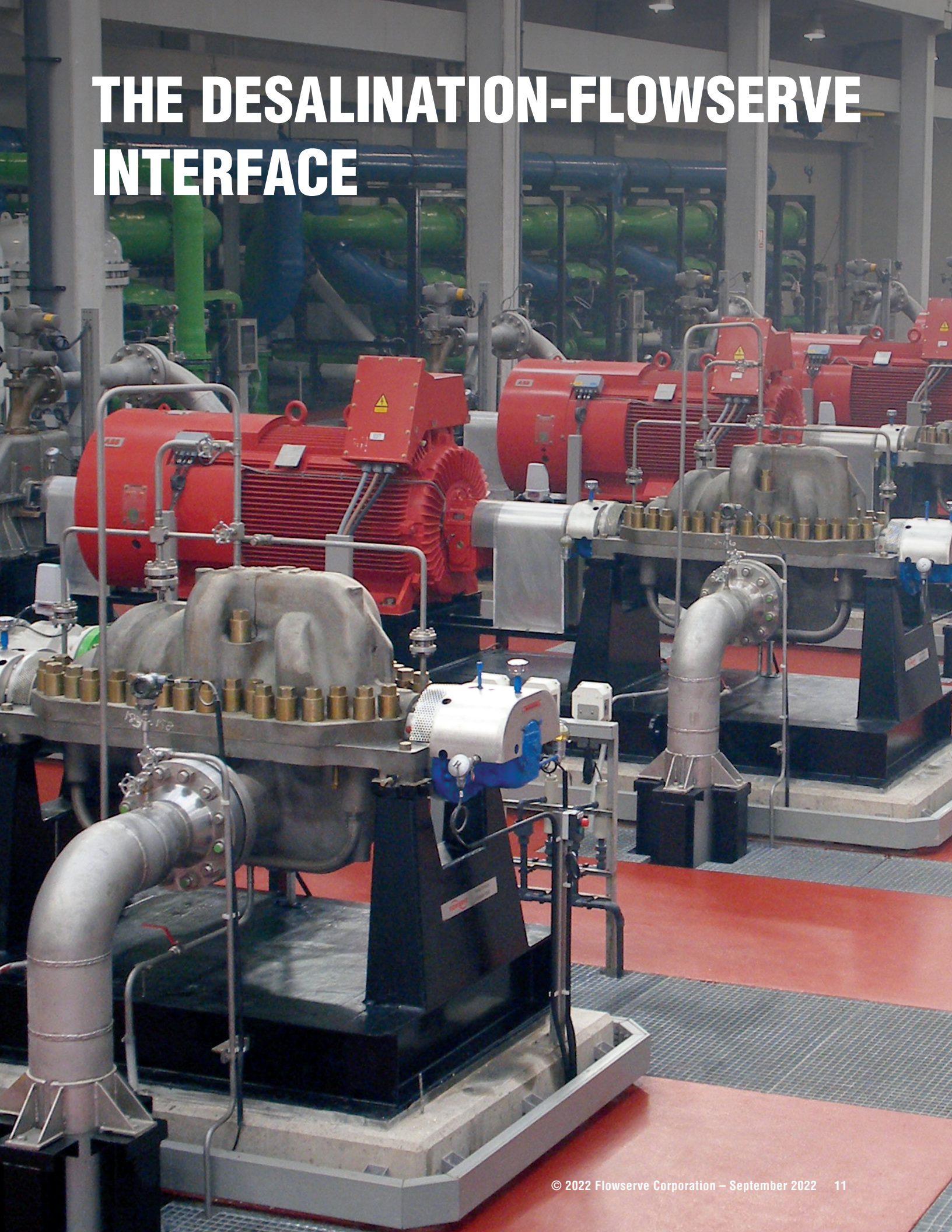
These privately financed ventures are becoming more prevalent in the global desalination market, especially for RO projects >50,000 m^3/d (13,209,000 gpd). These projects typically involve a BOO(T) contractor who will own and operate the plant for a period of time after they complete construction. In some models, an independent developer who sells water (and sometimes power) to the owner plays the role of owner/operator. In cases where a power plant is also involved, you may see the terminology *Independent Water* and *Power Project (IWPP)* used.

In these cases, roles are as follows:

- The BOO(T) contractor handles engineering, purchasing and construction of the plant. The BOO(T) contractor owns and operates the plant instead of the end user government or private entity, selling water (and power) to the end user. In Transfer (T) scenarios, ownership is transferred after the defined contract duration, typically 25 years.
- In some cases, a private developer serves as the owner/operator. They engage directly with an EPC for plant construction.

The extent to which the end user is involved in equipment specification is dependent upon their role in the project. Very often, the end user involves a consultant to prepare specifications.

THE DESALINATION-FLOWSERVE INTERFACE



BUSINESS IMPACT AND FOCUS

The Big Picture

According to the 2022 Global Desalination Market report, fast population growth coupled with climate change and environmental degradation are causing regions like the Middle East and Africa, North America, South America, Europe and the Asia Pacific to face increasing uncertainty in providing ample, safe and sustainable sources of potable water. As per their analysis, the Middle East and Africa dominate the regional market in the global desalination industry. Moreover, the Middle East and Africa have opted for large-scale desalination to reduce dependence on increasingly expensive imported water. The stable, efficient supplies of urban and industrial water that desalination provides are helping governments to manage a range of economic, social and political risks.

The Flowserve Fit in SWRO

Due to advances in membrane and energy recovery technologies, SWRO will claim the lion's share of CAPEX for the foreseeable future. Because Flowserve has a strong portfolio of pumps, ERDs and services that align perfectly with SWRO, this market segment is a critical focus area. Our experience in power generation and oil and gas is extremely relevant, as our pump portfolio is regarded as one of the most efficient and reliable in the world. Our expertise in ERDs is critically and integrally important to this fastest-growing segment of desalination.

Finally, our extensive investment in aftermarket services and supporting infrastructure is extremely important, especially with the emergence of BOO and BOOT commercial models where contractors and developers are assuming operational risks. Turnkey maintenance contracts, local service capability and equipment monitoring services are all in high demand from owners and operators of these massive plants.

Desalination Center of Excellence

With more than 50 years of experience in desalination, we bring extensive industry knowledge, system expertise, and testing and R&D resources to help desalination plant owners and operators achieve their business objectives.

Watch the video!

PRODUCTS FOR DESALINATION — AT-A-GLANCE

There are many different technologies and project scales for desalination plants. Accordingly, the products Flowserve typically delivers for desalination projects will vary. A high-level discussion of our desalination offerings follows.

A detailed entry on specific Flowserve products for key applications in thermal and SWRO plants can be found in the next section.

Pumps

Desalination applications for pumps run the gamut, from source water intake and pressure boosting to various feed and chemical applications. Therefore, numerous configurations of pump products can be applied in desalination. Key among them:

- Vertical wet- and dry-pit configurations VCT, VTP, LNNV, SUBM)
- Between bearings, single-stage (DVSH-RO, LNN, LR)
- Vertical inline process pumps (LNNV)
- Horizontal, overhung process pumps (DS-RO, HHPX, PolyChem S-Series, Z Series)
- Between bearings, multistage (DMX-RO, CSX, MS)

The project opportunity for pumps varies by size, of course, but typical expenditures for pumps on a new construction SWRO plant are always in the millions of U.S. dollars, with pump costs exceeding US$15 million for some mega projects. *Note: costs include mechanical seals.*

Energy Recovery Devices

Energy is generally the biggest cost driver in any SWRO desalination facility, thereby making energy recovery equipment critical to the process. Flowserve is a world leader in the manufacture and supply of the most efficient energy recovery devices for the SWRO desalination process.

Flowserve offers the following leading technologies for energy recovery:

- **Flowserve FLEX™ pressure exchanger –** a next-generation compact isobaric recovery device that recovers more than 98% of the hydraulic energy and the highest capacity per unit of the market
- **Dual Work Exchanger Energy Recovery (DWEER) –** an isobaric energy recovery device capable of recovering up to 98% of the energy in the brine waste stream
- **Energy Recovery Turbines –** capable of recovering as much as 90% of the hydraulic energy in the brine waste stream

Note that SWRO is trending toward isobaric energy recovery devices due to increasing energy costs. Energy recovery turbines remain common in BWRO and small SWRO plants where there is more sensitivity to capital costs.

INSTALLATIONS AND EXPERIENCE

Flowserve pumps or energy recovery devices are installed in some of the biggest desalination plants in the world. In fact, more than two-thirds of mega SWRO projects use Flowserve pumps and ERDs. Our customers include some of the world's most important desalination EPCs, contractors, developers and end users. The table below includes a partial list of Flowserve customers and end user locations.

FLOWSERVE CUSTOMERS AND END USER LOCATIONS (PARTIAL LISTING)

Customers
ABB UK
Abeinsa
Abengoa
Acciona Agua
Aguas Antofagasta
Alfatah Water & Power
Aqualia
Aquatech
Cadagua
Cameron System, Ltd.
Cargill S.L.U.
Clyde Union
Degremont
Doosan
Emalsa
Fisia Italimpianti
Global Environmental Solutions Ltd.
GS Inima
Hyflux
IDE Technologies
Inalsa
International Water Treatment
Italveco SRL
IVM (Minrav Sadyt)
Mekorot
MHI
Osmoflo International FZE
Repsol Exploracion
Southern Seawater JV
Suez Degremont
Tecton Engineering
Tedagua
Va Tech Wabag
Valoriza Agua/Sadyt
Vasilikos SWRO
Veolia (OTV)
Via Maris
Wabag
Wetico

End Users	Country
AAN	Chile
Abaqua	Spain
Abu Dhabi Water & Electricity Authority	UAE
Acuamed	Spain
ACWA Power	Saudi Arabia
ADWEA	Abu Dhabi
Aguas Antofagasta	Chile
Algerienne des Eaux	Algeria
Aqualectra	Curacao
Aquamarine	Scotland, UK
ATLL	Spain
BHP	Chile
Cargill	Spain
CCMC	Chile
DEWA	Abu Dhabi
EAC	Cyprus
Emalsa	Spain
Federal Electricity & Water Authority	UAE
H2 Oil & Gas, Ltd.	Saudi Arabia
Haileah	USA
Inalsa	Spain
KNEW	Kuwait
KWS	Saudi Arabia
M&G Resins	USA
M.N. Larnaca	Cyprus
Mekorot Israel National Water Co.	Israel
Minera Escondida	Chile
NLC	India
OCP	Morocco
Oman Power and Water Procurement Co.	Oman
Peregrino	Brazil
Poseiden Resources Corporation	USA
Public Utilities Board Singapore	Singapore
Punj Lloyd, Ltd.	Qatar
Pupuk	Indonesia
Reliance Industries	India
Repsol	Algeria
Salalah	Oman
Saline Water Conversion Corporation (SWCC)	Saudi Arabia
SMN Barka Power Company SAOC	Oman
Sorek	Israel
Via Maris	Israel
Water Corporation	Australia
ZADCO	Abu Dhabi

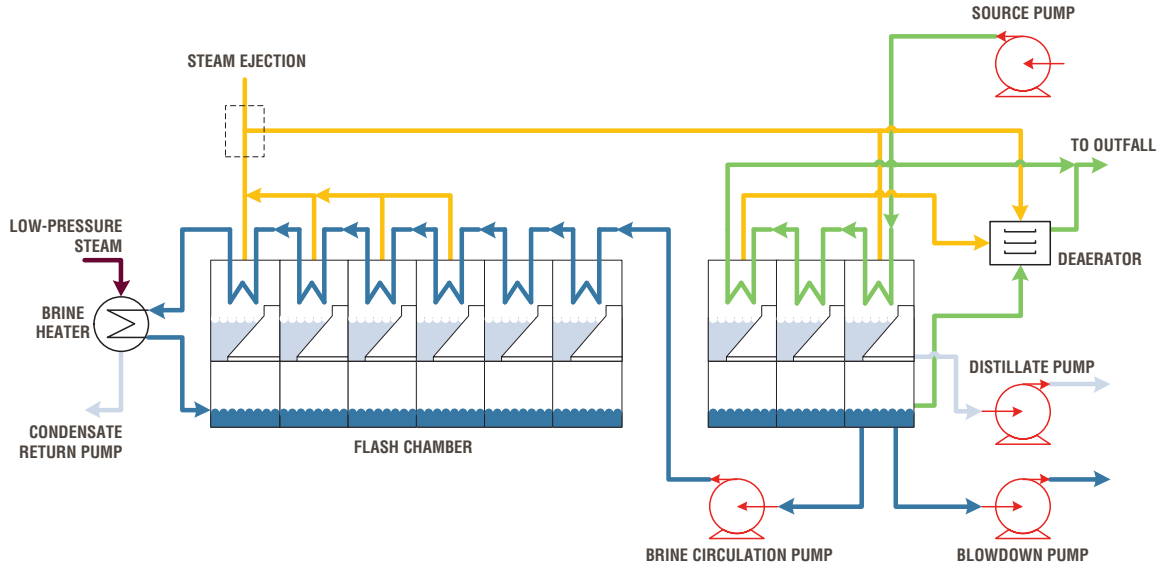
FLOWSERVE SOLUTIONS FOR DESALINATION — PRODUCTS AND CAPABILITIES

OVERVIEW

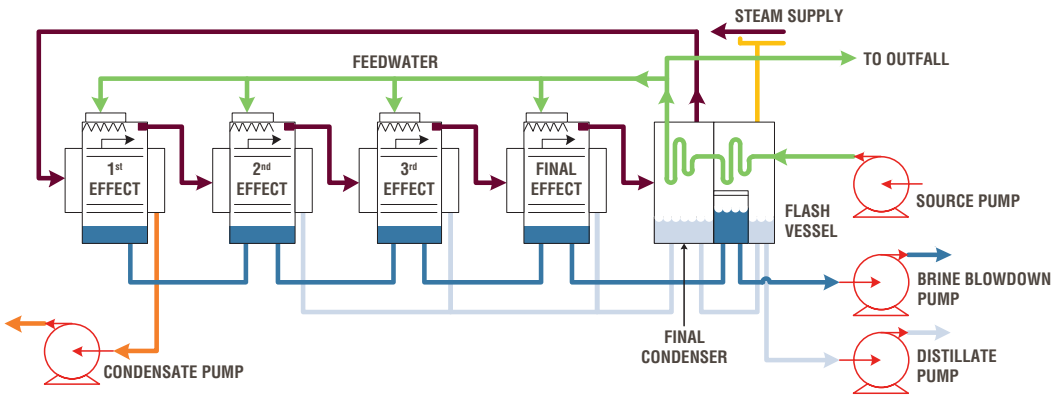
In this section you'll find a detailed listing and description of the key products and capabilities Flowserve offers for desalination plants. Because the market has shifted primarily to SWRO, the emphasis of this section is on SWRO technology. But first, a quick summary of our product offerings for thermal desalination technologies.

Flowserve Products in Thermal Desalination – MSF and MED

The diagrams below provide basic schematics of multistage flash distillation and multi-effect distillation. The pump symbols in red provide a snapshot of the key applications for which Flowserve has an offering.



Multistage flash distillation process diagram

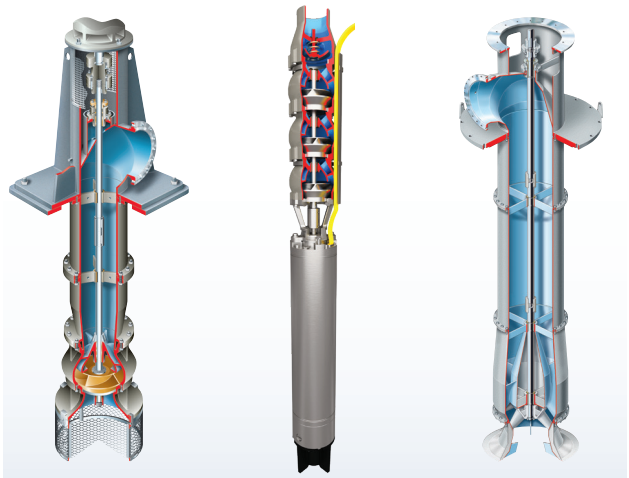


Multi-effect distillation process diagram

Seawater Intake Service

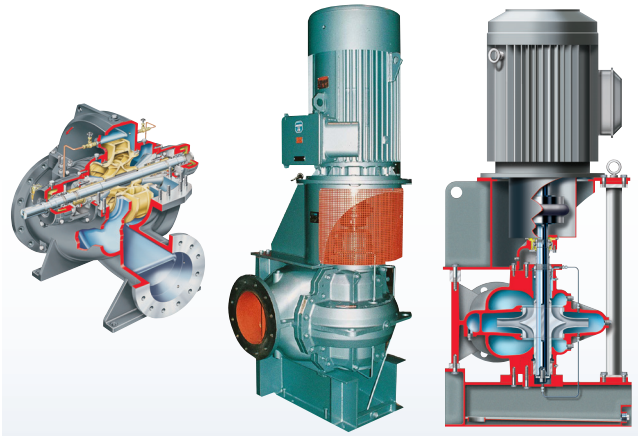
Arguably, the most important pump application in an MED or MSF plant is the seawater intake service. Because of the relatively low recovery rate of these processes, these pumps are much larger than the ones that may be found in an SWRO plant.

WET-PIT



VTP *Byron Jackson® SUBM* *VCT*

DRY-PIT



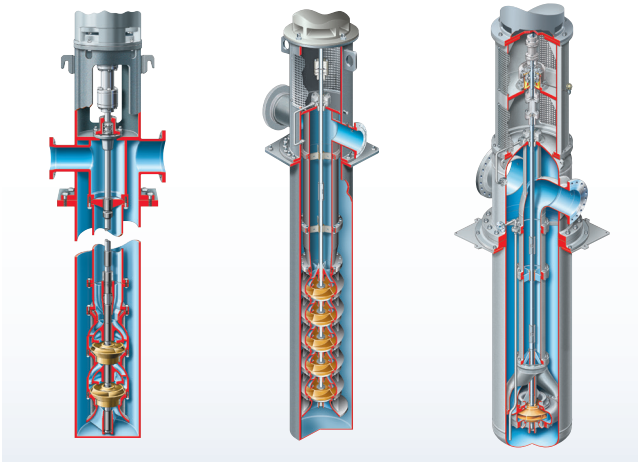
LNN *LNNV*

Brine Recirculation

Another important application in MSF plants is brine recirculation. MED plants also employ brine recirculation in some cases. The most frequently used product for this application is a QL pump.

Flowserve also provides pumps for brine blowdown, distillate extraction and condensate service. Pumps for these services may include the VPC and QL Series.

BRINE RECIRCULATION PUMPS



VPC *QLC*

FLOWSERVE PRODUCTS AND CAPABILITIES IN SWRO

As noted previously, the simple design, lower energy consumption and smaller footprint of the reverse osmosis process have made this technology the choice for most municipal and commercial desalination projects. The combined capability of Flowserve to address all of the major pump and energy recovery requirements makes seawater reverse osmosis particularly attractive to our business and customers. This section contains an overview of the main processes for SWRO, followed by a summary of the major Flowserve products used in these areas.

RO Process Applications Overview

This section focuses on SWRO. It should be noted that brackish water reverse osmosis (BWRO) processes follow the same principles as SWRO, but the necessary pressure and conversion rates in the membranes are different due to the lower salinity levels.

Seawater Intake and Filtration: This is the starting point for desalination. There are two main intake designs. The most common design is an open intake where a large pipe is positioned at the sea level about 20 to 100 m (66 to 328 ft) from the shoreline.

The other design is referred to as *beach wells*. Close to the shore line, large vertical pumps take the water from the beach wells and pump the seawater to the plant site. Beach wells are advantageous because the seawater is pre-filtered to some extent. They are less common, however, because of the destruction of the landscape that occurs when building these pumping stations at the shoreline.

Pretreatment: It is important to remove foreign particles and organics before seawater enters the desalination plant. RO membranes must be protected against these particles to increase performance and service life. Therefore, the pretreatment process is viewed as very important and constitutes a significant capital and operating expense. It is often the largest performance and operating cost variable.

If necessary, chemicals can be added to the feedwater to ensure the plant operates at reasonable recovery rates. This process can vary greatly from location to location based on feedwater quality.

Seawater chlorination is used to avoid biological fouling. Over time, chlorine blocks the membranes, so a dechlorination process which injects sodium bisulfite or metabisulfite is used to clean and protect the membranes.

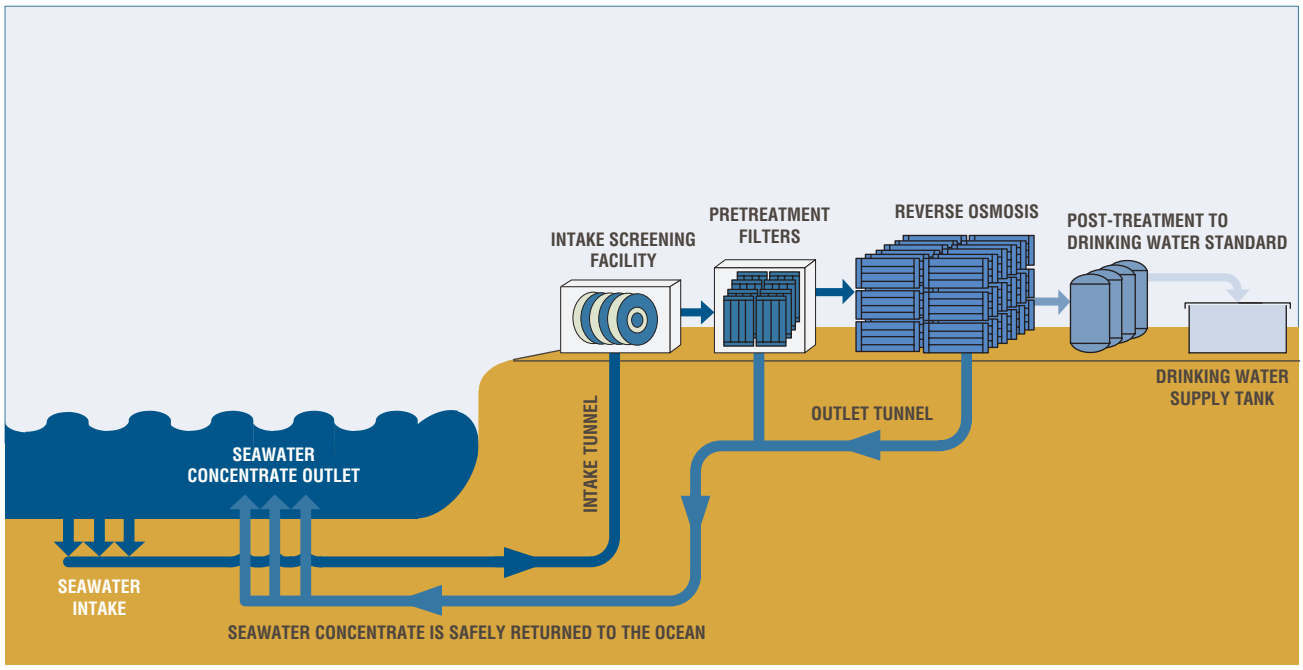
To further treat the feedwater and remove natural organic matter, particles and colloids, plants may employ additional steps such as coagulation and deep media filtration. Based on water quality (pH) and other process variables like time and velocity, plants may also incorporate additional pretreatment steps such as flocculation and sedimentation. Newer, unconventional pretreatment steps might include ultrafiltration.

RO Process Applications Overview *continued*

Before the feedwater enters the membranes, an additional antiscalant solution is injected to protect membranes from scaling. As a last step, many plants incorporate a final filtration step as a safeguard against debris, sand or other foreign particles that could damage membranes.

Reverse Osmosis: Feedwater is pressurized and fed into semipermeable membranes (reverse osmosis). Here the feedwater is separated into a permeate (product) stream at low pressure and a concentrated reject stream which is still at a high pressure. To reduce overall power consumption, energy recovery devices are incorporated to recover and use hydraulic energy from the reject stream. Refer to where different ERD methods are explained.

Post-Treatment: Industrial plants, agricultural applications and public utilities have different requirements for product water quality; therefore, the post-treatment process used therein can vary. In some cases, the first-stage process is sufficient to achieve the water quality necessary for use. Most often, a second-stage membrane arrangement is used to reduce the remaining boron to an acceptable level and further improve overall water quality. Water stored in product tanks can be further processed to fulfill specific industry requirements, such as remineralization for public use.



Basic SWRO process diagram

SWRO vs. BWRO

While SWRO and BWRO desalination operate on the same principles, there are significant differences. The table below highlights some of the major differences.

DIFFERENCES	IMPLICATIONS
Source water differences: • Source water for SWRO plants is surface water from an ocean or sea. • BWRO is usually, though not exclusively, from saline streams or sub-surface aquifers and artesian wells.	Submersible pumps are more important in BWRO applications than in SWRO.
RO driving pressure is dependent on source water salinity.	High-pressure multistage pumps are key in the SWRO product portfolio.
	Efficiency is extremely important in SWRO. In large plants, the membrane rack sizes are largely determined by the availability of proven and competitive high-pressure pumps in the market.
	Opportunities also exist for critical service high-pressure valves in SWRO.
	BWRO plants use industrial products almost exclusively. The high-pressure pumps are single-stage and technically less critical.
The desalinated water produced as a percentage of intake source water (recovery rate) differs.	SWRO produces a higher volume of reject water (concentrate) at higher pressure, resulting in strong emphasis on high-efficiency energy recovery devices.
	CAPEX-driven projects still may consider using turbocharger or energy recovery turbine technologies.
	High-pressure packages with high-pressure and ERD pumps are seen as an integrated sub-system. SWRO is trending away from power recovery turbines and turbochargers and toward isobaric energy recovery devices due to increasing energy costs.
	Turbochargers and energy recovery turbines remain common in BWRO and small SWRO plants.
	Intake and pre-filtration systems are much larger in SWRO plants (three times larger than BWRO) due to the lower recovery rate; the result is larger pumps and valves are used.
Seawater is much more corrosive than brackish water.	SWRO equipment needs to be made in duplex or super duplex stainless steels with PREN[1] >40.
	Materials are a major pain point in the SWRO industry. Breakthrough non-metallic technologies have the potential to be a major product differentiator.
	The BWRO market mainly uses 316L stainless steel. Corrosion is less of a pain point, though non-metallics are still of interest.

1. PREN refers to Pitting Resistance Equivalence Number and is calculated from the percentages of key alloying components in the material. PREN = %Cr + (3.3 x %Mo) + (16 x %N)

Pumps for SWRO

High-pressure membrane feed

All Flowserve high-efficiency membrane feed pumps (first and second pass) utilize the latest technology and are designed using computational fluid dynamics to provide the best system performance. These critical pumps are manufactured in corrosion-resistant materials to ensure long performance life without degradation. Horizontal split case (DMX-RO, DVSH-RO) or ring section (CSX, MS) models are available.

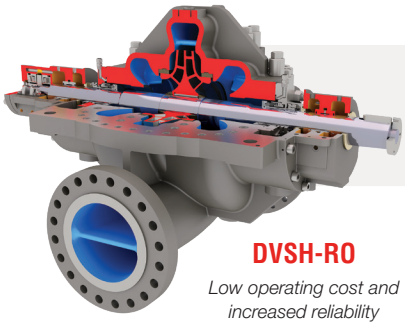
Configurations: Multistage or single-stage, between bearings

Materials: Duplex or super duplex stainless steels

Models: DMX-RO, DVSH-RO, CSX, MS

Flows: 7,000 m³/h (30,820 gpm)

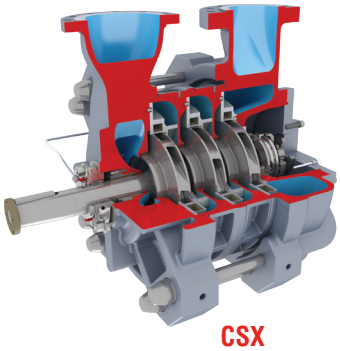
Heads: to 1,000 m (3,281 ft)



Watch the video!

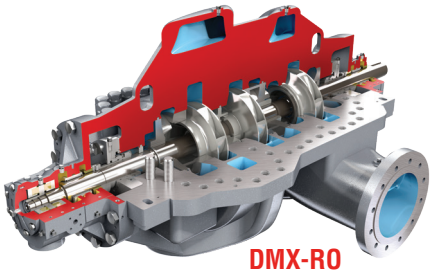
DVSH-RO

Low operating cost and increased reliability



CSX

Long-term, high efficiency and low lifecycle cost



DMX-RO

Increased uptime and easy maintenance

ERD boosters

Flowserve high-pressure booster pumps are designed to operate efficiently under SWRO system pressure, where design pressures can exceed 82 bar (1,200 psi). Horizontal and vertical inline designs are available for these tough applications.

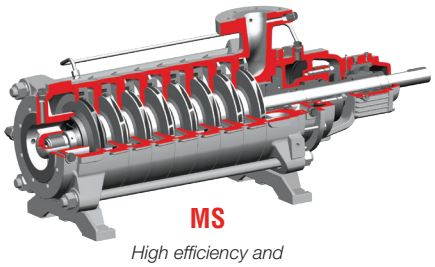
Configurations: High suction pressure, end suction designs

Materials: Super duplex stainless steels

Model: HHPX

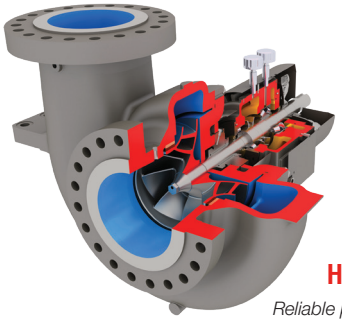
Flows: to 4,000 m³/h (17,611 gpm)

Heads: to 90 m (295 ft)



MS

High efficiency and long-term reliability



HHPX

Reliable performance under high pressure

Other services

Flowserve can provide pumping solutions for virtually all desalination plant support services. Pumps are available in various configurations and materials to meet the precise needs of your site.

- Filtered seawater
- Low-pressure feed booster
- High-pressure feed boster
- Product services
- Potable water
- Backwash
- Flushing pumps

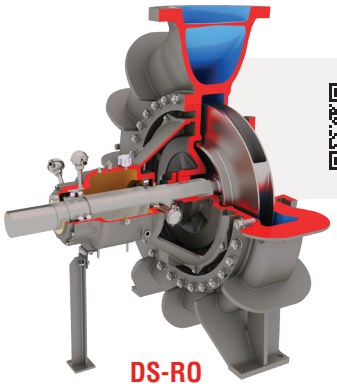
Configurations: Single-stage, end suction or between bearings

Materials: 316 stainless steel, duplex or super duplex stainless steels; non-metallic materials

Models: DS-RO, LNN, Z Series, HPX

Flows: to 30,000 m³/h (132,000 gpm)

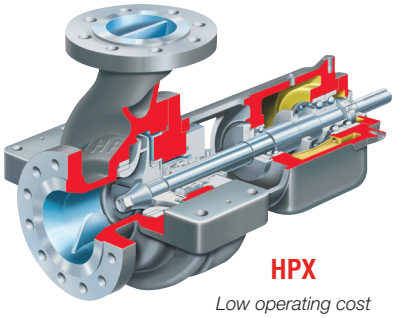
Heads: to 350 m (1,100 ft)



Watch the video!

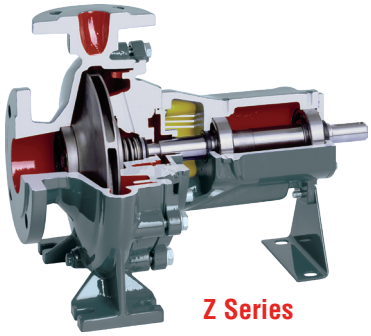
DS-RO

High efficiency and increased uptime



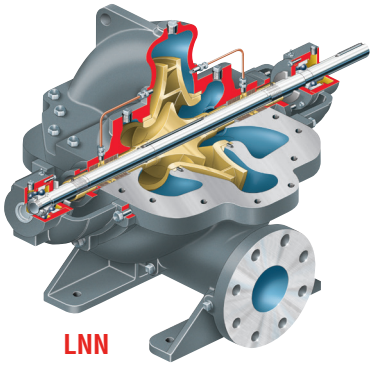
HPX

Low operating cost and longer service life



Z Series

High efficiency and extended reliability



LNN

High efficiency and low NPSH requirements

Source water intake pumps

SWRO source water intake requires pumps that are corrosion-resistant and have the versatility to fit various intake methods. Flowserve offers several highly efficient vertical and horizontal pump models with proven performance to suit your application's needs.

Flowserve vertical source water intake pumps offer broad capacity ranges to maximize system efficiency while minimizing initial cost. Flowserve also offers horizontal pumps for dry-pit installation or space-saving vertical configurations which provide the same premium efficiency with a reduced footprint.

Configurations: Wet-pit and dry-pit

Materials: Duplex and super duplex stainless steels

Models: LNN, LNNV, VCT, VTP, SUBM

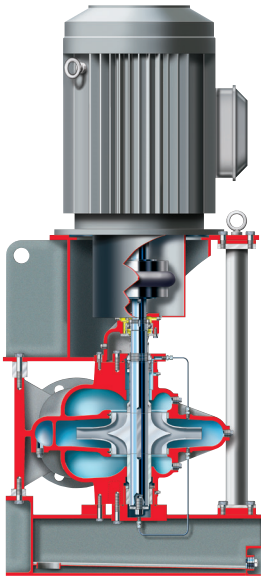
Flows: to 181,700 m³/h (800,000 gpm)

Heads: to 700 m (2,300 ft)

Assembly of 71APM VCT vertical pump

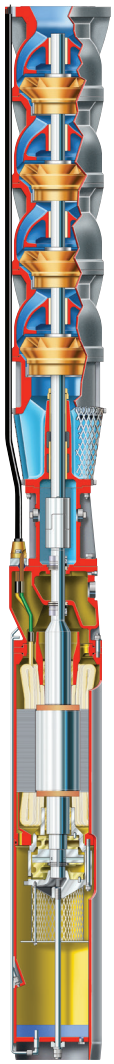
In 2013, the Flowserve operation in Coslada, Spain, assembled one of the largest vertical pumps in that location's history.

Watch here.



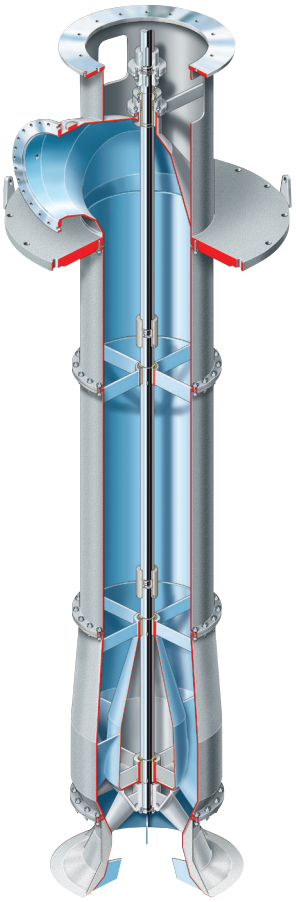
LNNV

High efficiency and low NPSH requirements



Byron Jackson SUBM

Rugged, reliable and long-lasting



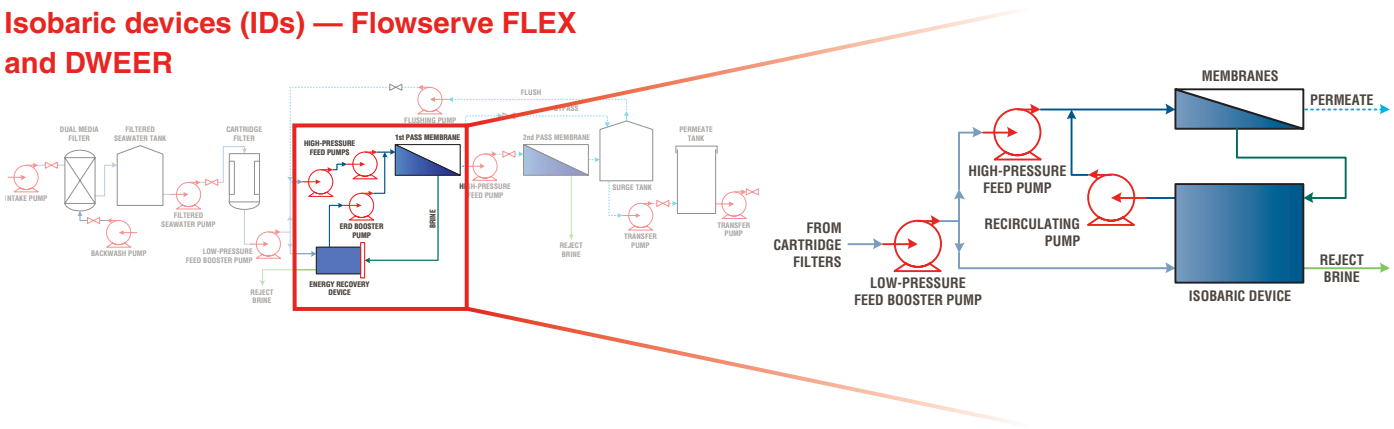
VCT

Outstanding efficiency and long service life

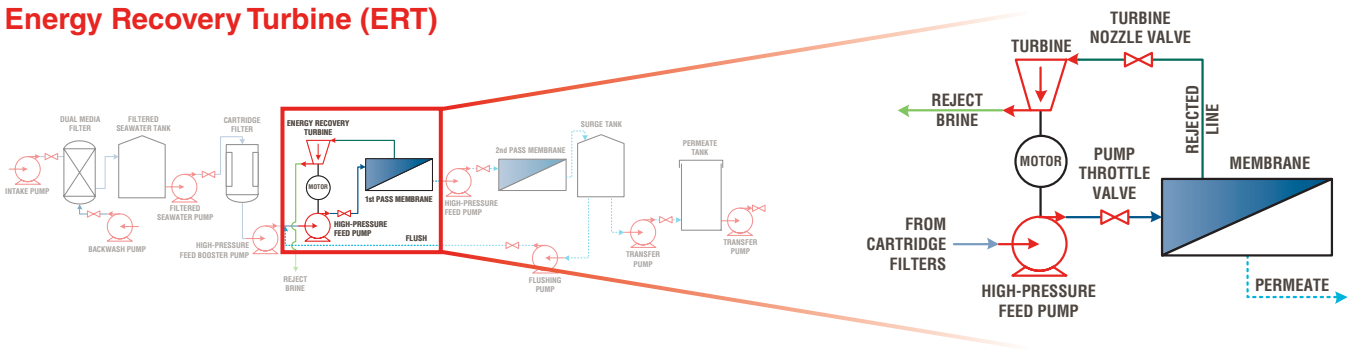
Energy Recovery Devices for SWRO

The figures below schematically show the three main energy recovery technologies and their integration into the SWRO desalination process. Flowserve energy recovery offerings include: (1) isobaric devices, often called *pressure* or *work exchangers* and (2) rotating impact machines or energy recovery turbines. This equipment is essential to any SWRO or BWRO desalination facility, since energy is the biggest operational cost for these facilities.

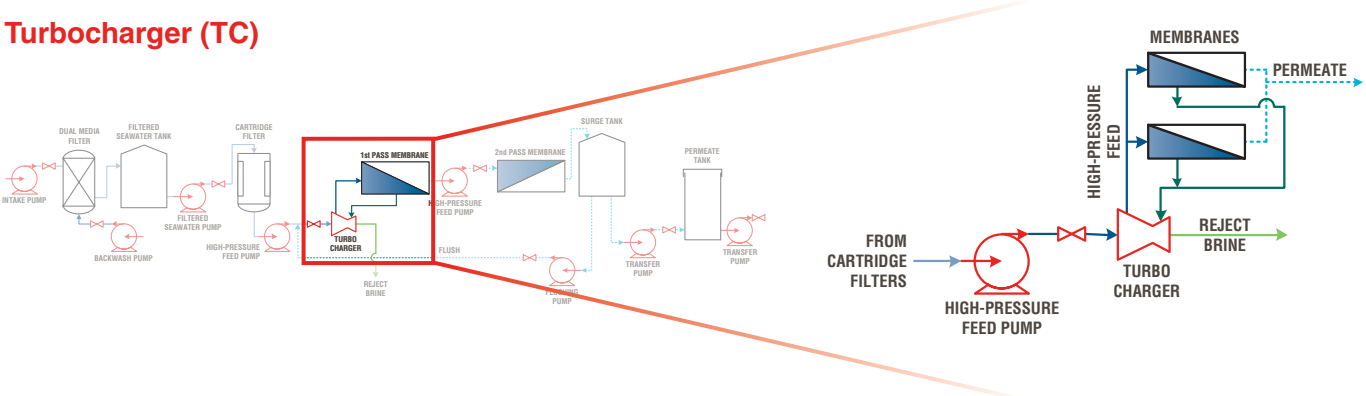
Isobaric devices (IDs) — Flowserve FLEX and DWEER



Energy Recovery Turbine (ERT)



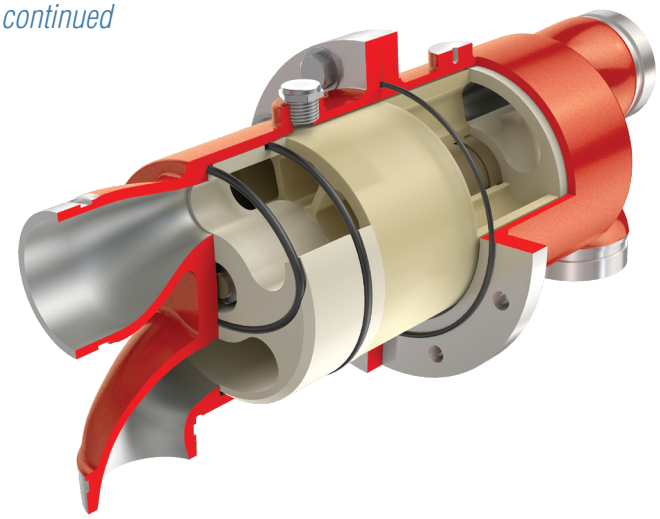
Turbocharger (TC)



Main energy recovery technologies in schematic layout

Energy Recovery Devices for SWRO *continued*

Isobaric Energy Recovery Device — Flowserve FLEX



Energy is the primary cost driver in any reverse osmosis (RO) desalination process. That's why Flowserve designed the Flowserve FLEX pressure exchanger, an isobaric energy recovery device, to be the most efficient and compact device of its type. Capable of recovering more than 98% of hydraulic energy and boasting the highest unit capacity available in the market, it drives down the cost of desalination by substantially reducing operating costs as well as capital expenditures.

The Flowserve FLEX energy recovery device is not only highly efficient, but with only four major components, it's also incredibly simple. Precision machined from highly corrosion- and wear-resistant materials, it ensures a long lifecycle with no maintenance or downtime. And, with the smallest footprint of any isobaric energy recovery device, the Flowserve FLEX is simple and cost-effective to integrate into new installations or retrofit existing plants.

Flowserve FLEX 6300
Flow: to 68 m^3/h (300 gpm)
Pressure: to 82 bar (1,200 psi)

Flowserve FLEX 8600
Flow: to 135 m^3/h (600 gpm)
Pressure: to 82 bar (1,200 psi)

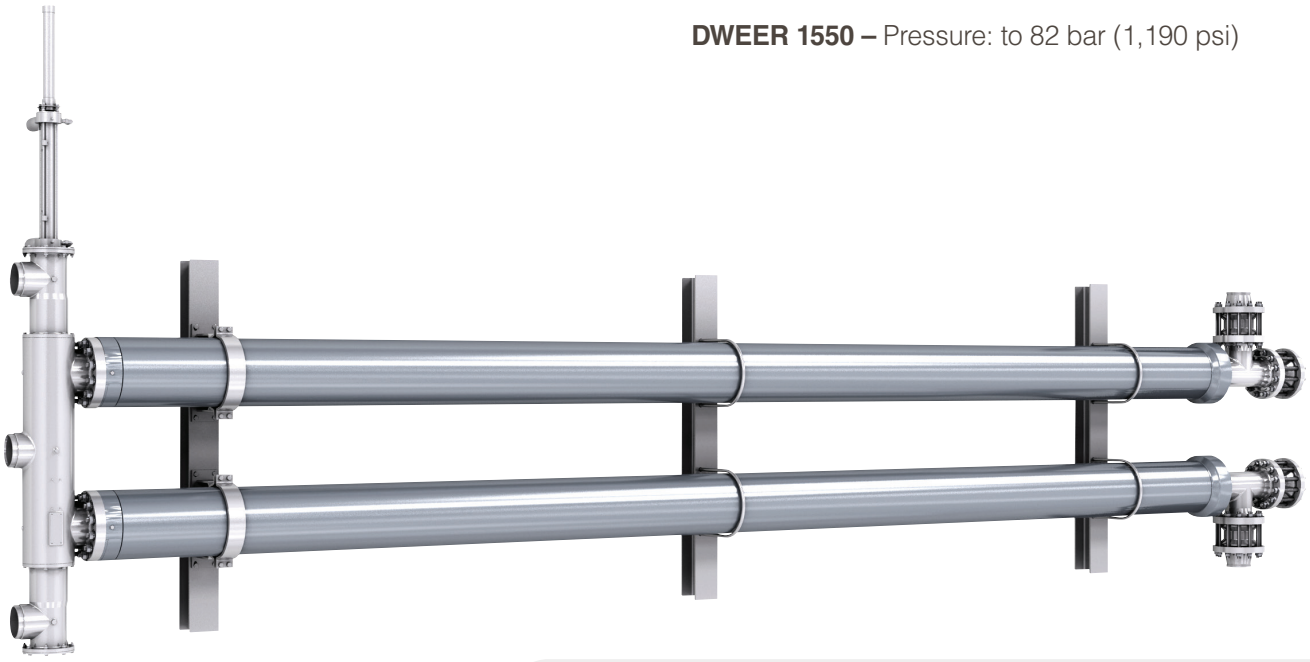
Energy Recovery Devices for SWRO *continued*

Isobaric Energy Recovery Device—DWEER

The DWEER dual work exchanger energy recovery device is the most efficient energy recovery device ever developed. It can recover up to 98% of the energy in the brine waste stream. The recovered energy is used to pressurize raw water, reducing the energy input required for the high-pressure feed pumps by up to 60%. With the DWEER, the high-pressure pump does not have to be connected to the energy recovery device. This permits the use of fewer, but larger, high-efficiency pumps.

The DWEER 1550 has a maximum capacity per unit of 350 m^3/h (1,541 gpm). In cases where the flow exceeds this maximum, the DWEER equipment is installed in parallel. With this technique, the size of a rack is theoretically open-ended. Currently, the largest installed rack contains 20 DWEERs running in parallel. Most trains have two to six DWEERs running in parallel. Details on DWEER ERD operating principles, construction and operational advantages can be found in Appendix B.

DWEER 1550 – Pressure: to 82 bar (1,190 psi)



DWEER energy recovery device

Customer testimonial

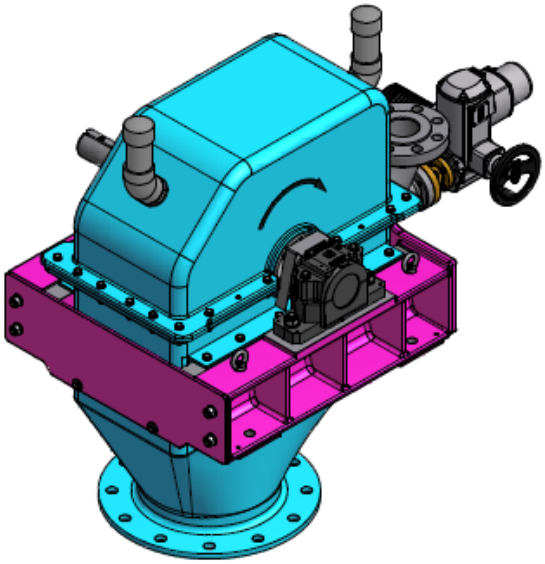
"Flowserve successfully installed and commissioned 10 units (30 DWEERs in total) of Energy Recovery System (ERS) at the 30 MIGD SingSpring desalination plant at Tuas, Singapore. The ERS units met the design specification and to date have operated very successfully within the design parameters. We appreciate the reliable performance of the DWEER products and the support provided by Flowserve throughout all these years."

— Senior General Manager, Hyflux Engineering Pte Ltd.

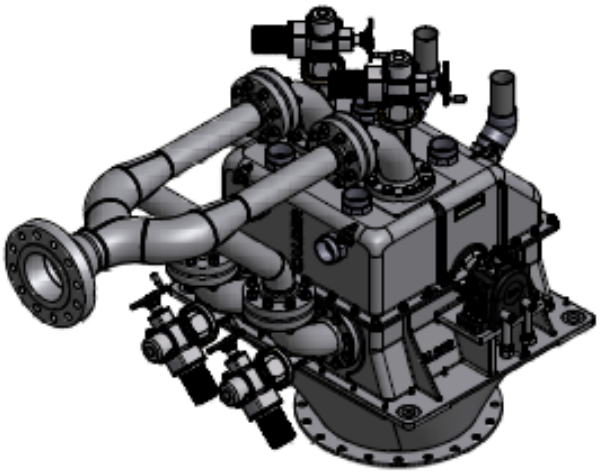
Energy Recovery Turbine Impact Machine

Flowserve offers a standard range of energy recovery turbines (ERTs). They are available in 50 and 60 Hz models for global application. Flowserve can manufacture custom-engineered products for applications outside this operating range. Example configurations are also shown.

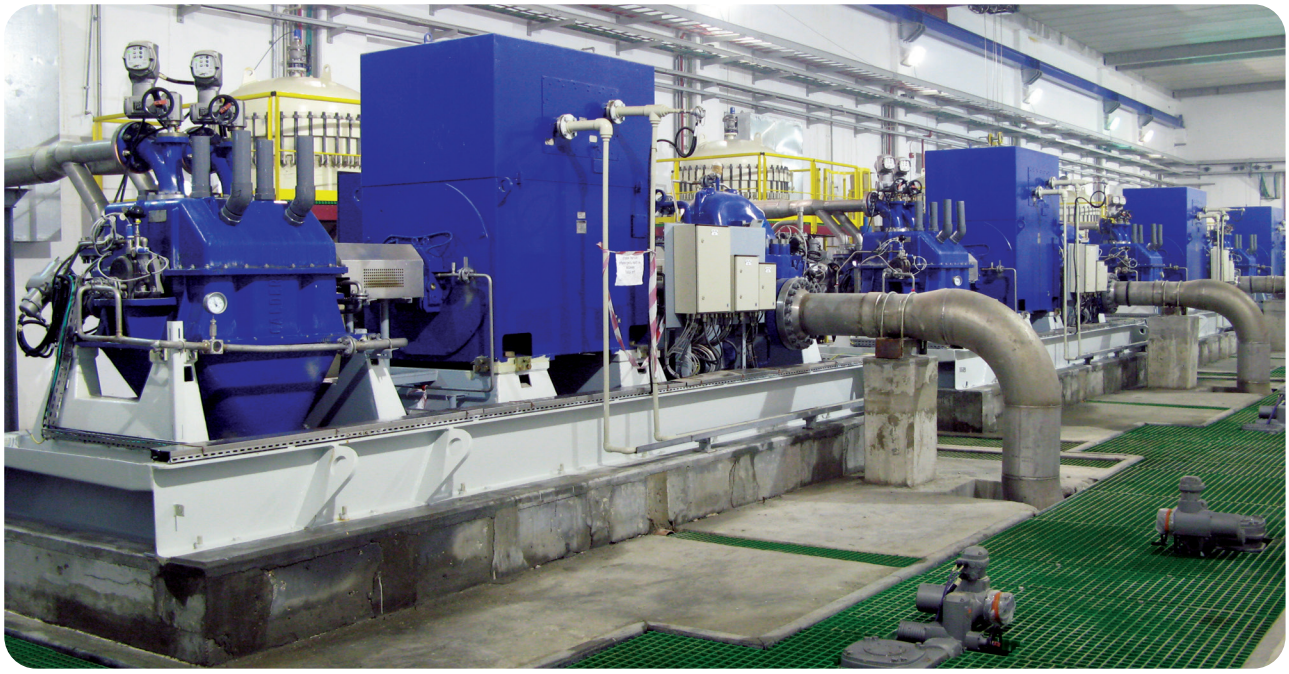
Details on ERT operating principles, construction and operational advantages can be found in Appendix C.



GRP turbine with single inlet



Super duplex turbine with four inlets



Pump Models and ERDs Application Guide — At-a-Glance

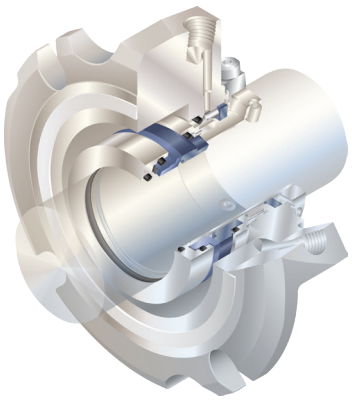
		APPLICATION														
		RO MEMBRANE											MSF/MED			
Pump Type	Flowserve Pump Model	Intake	Filter Feed	UF Filter Feed	UF Cleaning	Booster Pumps	ERD Booster	Energy Recovery	First Pass Membrane Feed	Second Pass Membrane Feed	Treated Water	DAF Pressurization	Seawater Intake	Brine Circulation	Blowdown	Distillate
Vertically suspended, wet-pit	Byron Jackson SUBM	X														
	VTP	X														
	VCT	X											X			
	VPC													X	X	X
	QLC													X	X	X
Between bearings, single-stage	LNNV	X											X			
	LNN		X	X	X	X					X					
	DVSH-RO								X	X						
Between bearings, multistage	DMX-RO								X	X						
	CSX								X	X						
	MS								X	X						
Overhung	HPX						X			X						
	HHPX						X									
	DS-RO	X	X	X	X	X					X	X	X			
	Z-Series	X	X	X	X	X					X	X				
Energy recovery devices	Flowserve FLEX							X								
	DWEER							X								
	ERT							X								

Mechanical Seals for SWRO

Mechanicals seals are integral to the range of pumps used in SWRO desalination plants, providing maximum reliability with minimal downtime.

Unmatched expertise in metallurgy combined with the application of sophisticated mechanical seal technology in the toughest applications allow Flowserve to extend mean time between failure (MTBF) of critical equipment.

As a general guide, the following seals are used in SWRO services:

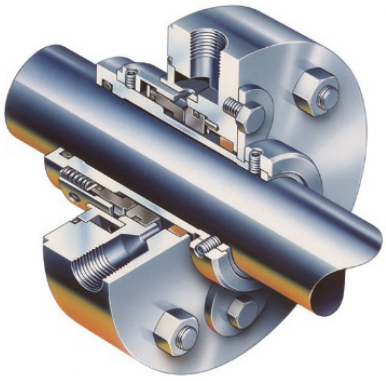


ISC2-PX

Single cartridge O-ring pusher seal for general applications

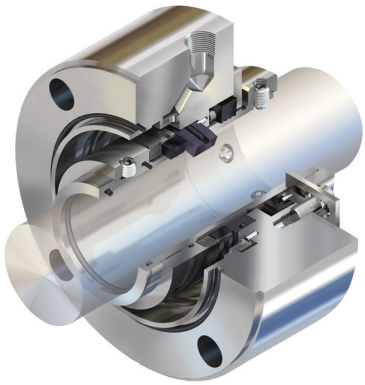
ISC2-BX

Single cartridge metal bellows seal for crystallizing fluid conditions



QB

Single cartridge O-ring pusher seal for higher-pressure requirements



BX

Single cartridge metal bellows seal for higher-pressure crystallizing service

Mechanical Seals for SWRO *continued*

Materials of Construction

Materials of construction for mechanical seals used in SWRO applications can be summarized as follows:

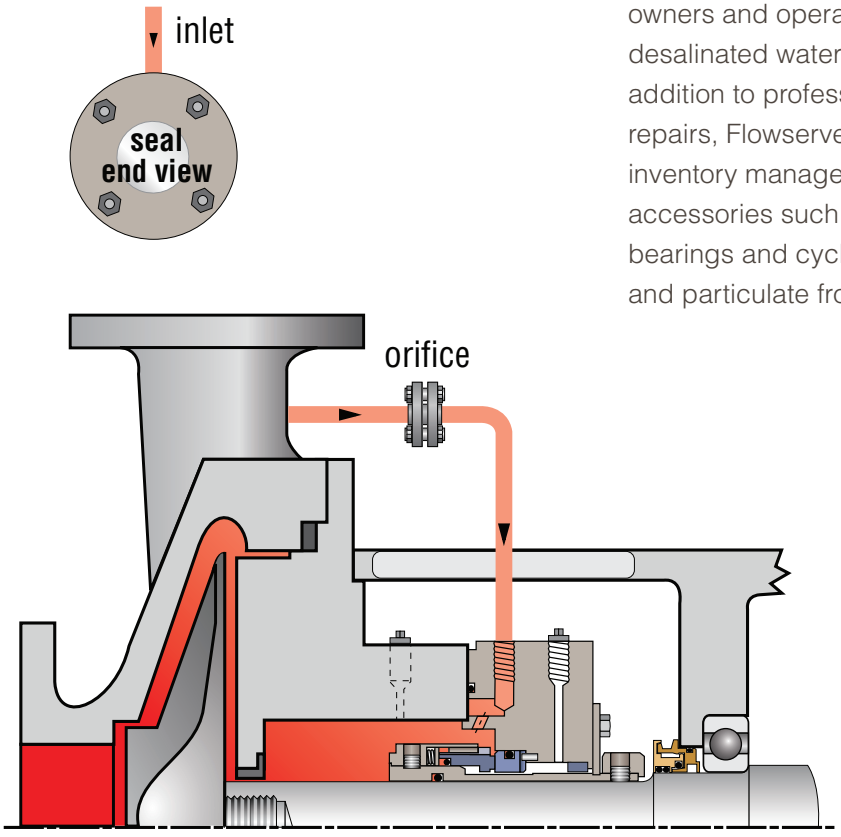
- **Metal Components:** stainless steel for general water service; Alloy 20 for seawater, brine and chlorides; super duplex when specified
- **Metal Bellows:** Alloy C-276 bellow for all services
- **Seal Faces:** carbon vs. silicon carbide for clean services; silicon carbide vs. silicon carbide for services with solids or abrasives; add diamond coatings to extend life

Flush Plans

Plan 11 bypass flush from pump discharge (see illustration) is usually recommended. Additional cooling with Plan 21 or 23 may be required if water temperature exceeds 80°C (180°F).

Aftermarket Services

Because of our proven ability to quickly respond to unplanned equipment downtime through our local Quick Response Centers worldwide, our aftermarket services may prove to be a point of differentiation. Our aftermarket service teams are well-equipped to troubleshoot and correct mechanical seal issues, bringing real value to owners and operators responsible for delivering desalinated water at an agreed-upon cost. In addition to professional technical advice and repairs, Flowserve QRCs provide seal upgrades, inventory management, equipment service, and accessories such as BearingGards to protect bearings and cyclone separators to remove sand and particulate from flush lines.



Typical Plan 11 configuration shown flushing a QB seal

Valves for SWRO

Flowserve can supply competitive products for the butterfly and check valve packages required in SWRO plants.

For butterfly valves, Valtek® TX3, Durco® TX3 or Durco BX are recommended. Each of these products is available in the requisite materials of construction, including duplex and super duplex stainless steels.

For check valves, the Edward® Tilting Disk is recommended. This product meets the necessary material and pressure class ranges.

Edward Tilting Disk

Durco BX

Valtek TX3

Durco TX3

Materials of Construction in SWRO

In the desalination industry, equipment is operated in a very corrosive environment. This is especially true in SWRO applications where equipment is in contact with total dissolved solids (TDS), seawater or even brine. Therefore, all Flowserve equipment that is in contact with seawater or brine is delivered in super duplex stainless steel.

For high-pressure and ERD booster pumps, Flowserve can supply equipment in Flowserve Alloy, a special austenitic stainless steel. Flowserve has specified this material in desalination applications very successfully for decades. It is ideal for applications in desalination where high temperatures and salinity make for very aggressive fluids.

Aftermarket Support

Over the last few decades, ERDs, pumps and membranes have been continuously improved as new technologies are developed. With efficiency and reliability improvements, there is a high potential for upgrading existing installations to help owner/operators in three areas:

- Increasing plant efficiency
- Increasing plant production
- Reducing plant maintenance
- Increasing availability

This can be accomplished by overhauling existing equipment with additional reliability features, upgraded hydraulics or other capabilities. In addition, existing ERDs can be replaced with newer technologies that improve efficiency or product capacity. Here are four specific upgrade opportunites for RO installations:

Brine Concentrator

Add booster pump and skid with high-salinity membranes to increase production capacity and lower specific energy consumption (SEC).

Full Retrofit

Combine membrane skids or add new ones to lower SEC and potentially increase production capacities.

Partial Retrofit (ERT Replacement)

Flow to the Flowserve FLEX depends on possible high-pressure membrane feed pump capacity, since the high-pressure membrane feed pump has to be powered with less ERT support.

Cascade Retrofit

Use the Flowserve FLEX to feed added RO skid (with or without booster pump) to increase plant capacity.

COMMUNICATING OUR VALUE

FLOWSERVE VALUE PROPOSITION IN DESALINATION

FLOWSERVE	PROPOSITION	CUSTOMER BENEFIT
Ethical business practices	Flowserve sets the highest standards in business integrity in its dealings with suppliers and customers.	A trustworthy partner to work toward their project success
Quality	Flowserve manufactures to the most rigorous quality standards to provide reliable products.	Satisfaction in supplier choice, on-time commissioning and project startup
Engineering excellence	The Flowserve depth of engineering experience is unparalleled in SWRO desalination.	Optimized product and material selection for each application ensures reliable operation.
Experience	Flowserve has been a leader in desalination since the process was commercialized on a large scale.	Lessons learnt have been built into today's products, increasing reliability, maintainability and product life.
Broad product range	Flowserve comprises a list of world-renowned heritage brands and a wide portfolio of products and services.	A product for every service designed by specialists in their respective fields ensures low-cost, high-efficiency solutions, from intake to distribution and energy recovery.
Project management	Dedicated project managers certified by IPMA	Professional team to handle documentation and ensure on-time delivery
After-sales support	Dedicated after-sales support engineers	Implanted within project management, with the sole objective to resolve warranty issues quickly and painlessly
Local Quick Response Centers	Fully equipped Quick Response Centers in the region	Skilled team to handle upgrades and repairs; localized to reduce downtime, full access to Flowserve component drawings, procedures and standards
Aftermarket solutions	Long-term maintenance	Specialist group capable of maintaining, servicing and upgrading equipment to meet operating goals throughput

INNOVATIVE WAYS FLOWSERVE ADDRESSES CUSTOMER CHALLENGES

Expertise and Experience	- Flowserve has over 30 years of experience in desalination - More than two out of every three mega SWRO projects have Flowserve pumps and/or ERDs - Specialist “Center of Excellence” focusing on desalination
Single-Source Provider	- Optimizing equipment selections from early stage - Optimized overall efficiency of interacting products – pumps and ERDs - Specialist Desalination Center of Excellence - Less time evaluating - Reduced procurement activities
Streamlined Execution	- Global project management: *Single point of contact, flawless execution* - Simple communication and fast clarification channels - Reduced time to operation
Local Support Worldwide	- Local support ensured through a global network of service centers - Support during installation and commissioning - Service and maintenance contracts for highest availability and continuous efficiency optimization - Support and repair ensured through local service centers - Upgrade opportunities through Desalination Center of Excellence - Full operation and service training
Optimizing Efficiency	- Optimized high-pressure feed pumps *Widest range in the industry to cover any train capacity with the most efficient hydraulics* - Optimized low-pressure feed and ERD booster pumps *Highly efficient and reliable pump range for desalination* - Optimized energy recovery devices *Flowserve FLEX: Most compact, efficient and reliable device of its type* *DWEER: Most efficient device* *ERT: Robust and reliable design*

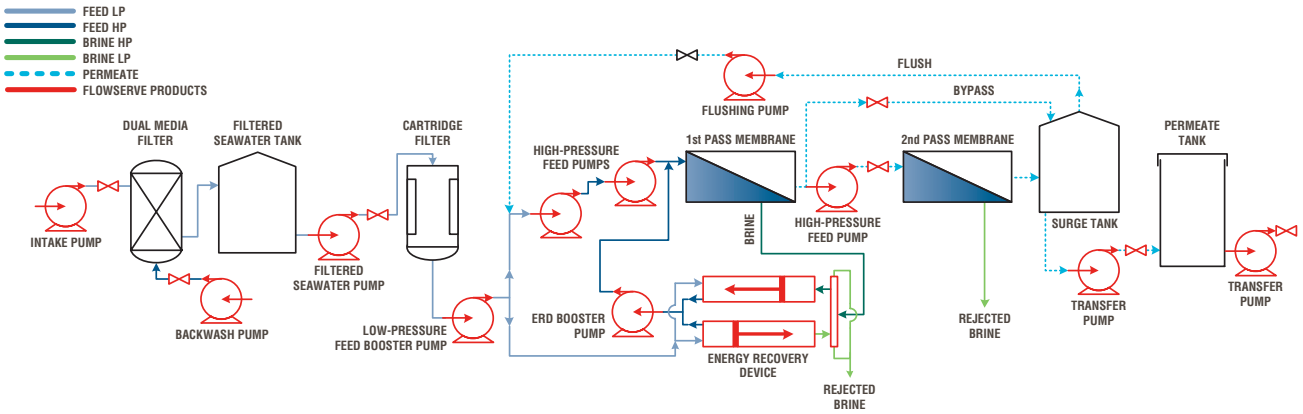
APPENDICES

FLOWSERVE FLEX OPERATING PRINCIPLES AND OTHER USEFUL INFORMATION

The Flowserve FLEX pressure exchanger, an isobaric energy recovery device, is the most efficient and compact device of its type. Energy is the primary cost driver in any reverse osmosis (RO) desalination process, so we designed the next-generation Flowserve FLEX pressure exchanger to be capable of recovering more than 98% of hydraulic energy.

It also boasts the highest unit capacity available in the market, substantially reducing operating and capital costs.

The Flowserve FLEX energy recovery device is not only highly efficient, but with only four major internal components and one moving part, it's also incredibly simple and reliable. Precision machined from highly corrosion- and wear-resistant materials, it ensures a long lifecycle with no maintenance or downtime. And, with the smallest footprint of any isobaric energy recovery device, the Flowserve FLEX is simple and cost-effective to integrate into new installations or retrofit existing plants.



Schematic of SWRO process employing the Flowserve FLEX energy recovery device

Flowserve FLEX Advantages

Performance advantages summary:

- Best-in-class hydraulic efficiency
- Industry-leading mixing rate (total dissolved solids increase); approximately 2 to 3% at membrane inlet; therefore, system requires lower membrane feed pressure to achieve same production
- Minimal lubrication can take optimized advantage of the energy available in the brine
- Highest unit capacity and low installation costs: Fewer units are needed to achieve the total flow capacity of the plant
- Highly corrosion-and wear-resistant materials ensure a long lifecycle with no maintence or downtime

Operation advantages summary:

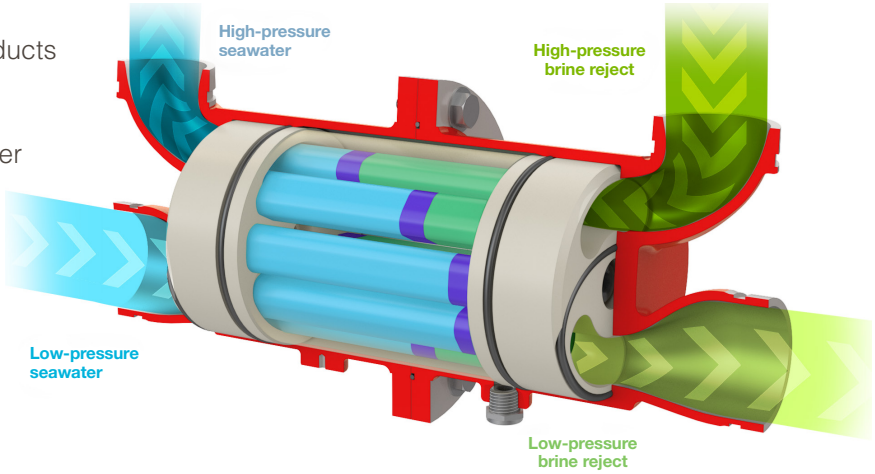
- Robust design
- Quiet operation
- Compact and easy to retrofit
- Easy, minor maintenance requiring only low-cost parts
- Self-adjusting to flow and pressure changes
- IoT enabled

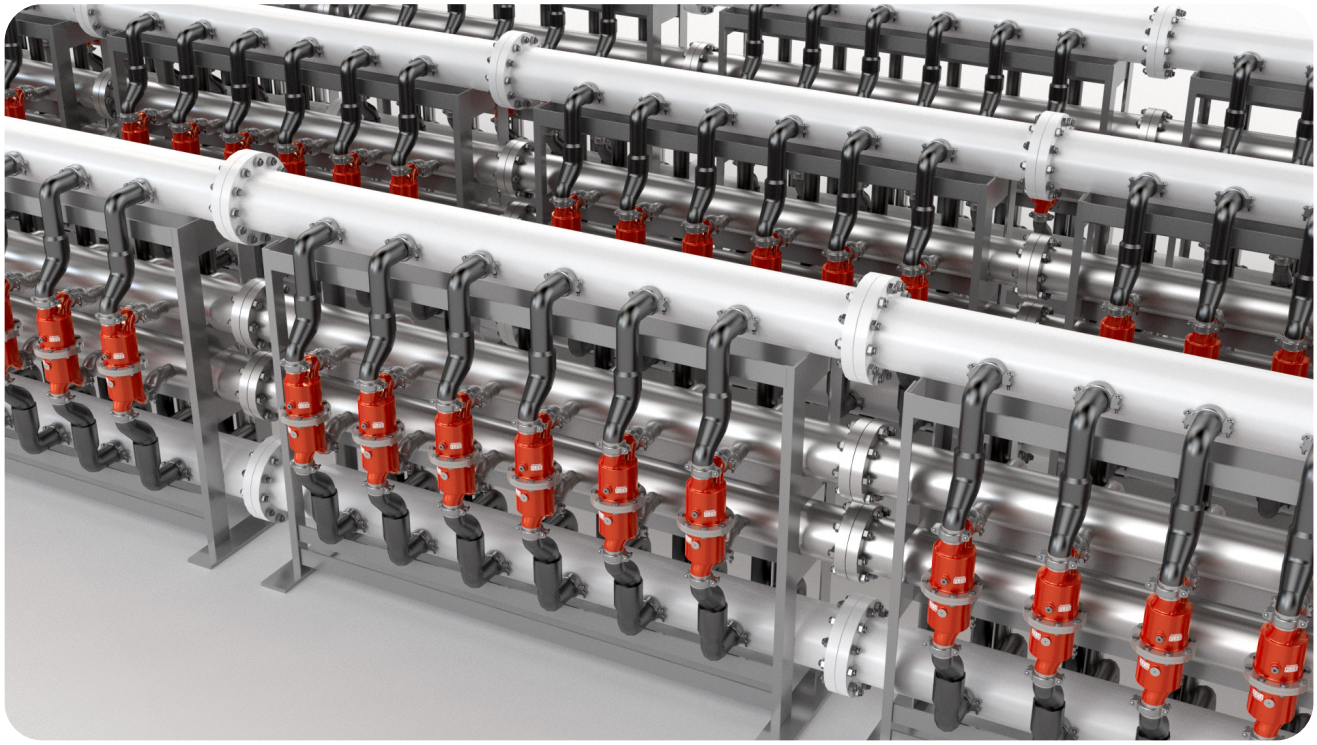
The Flowserve FLEX Operating Principle

The working principal of the Flowserve FLEX is basically the same as any other pressure exchanger:

- Low-pressure feed (seawater) filling the ducts
- Low-pressure brine is driven to waste
- High-pressure is pressurizing the seawater
- High-pressure feed (seawater) is driven toward the membrane

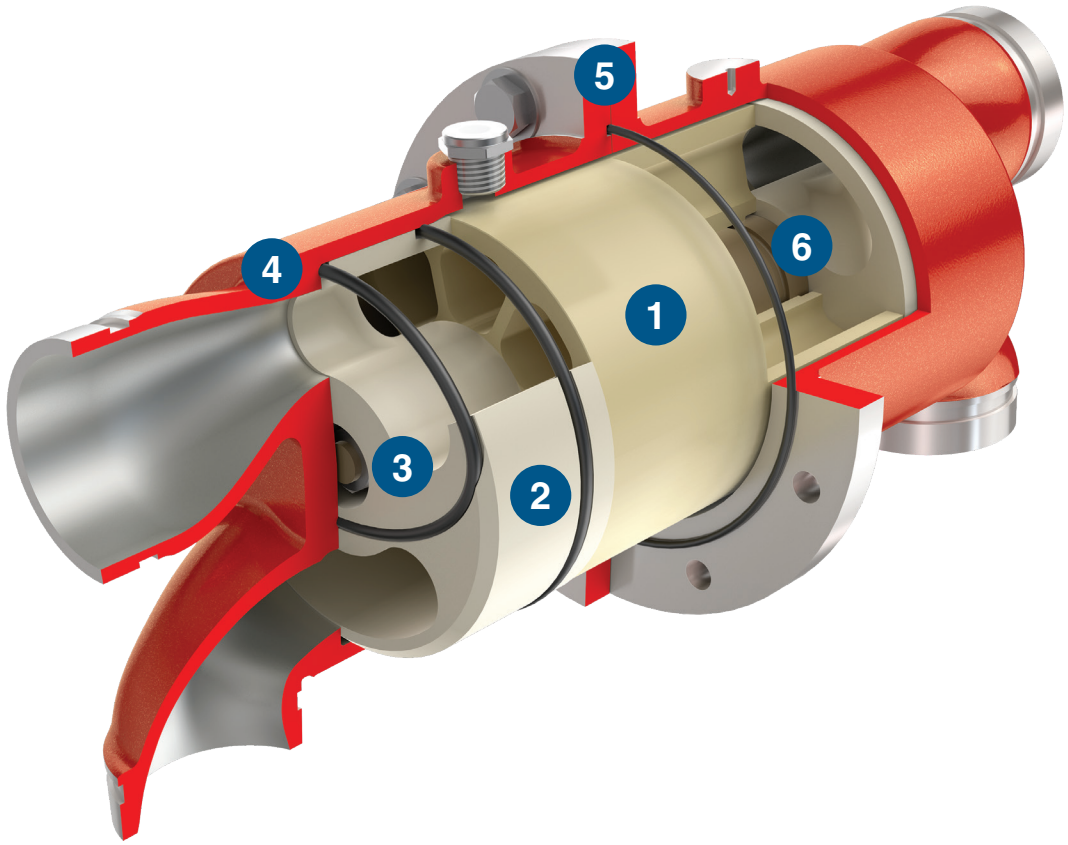
No external drive required — the rotation is driven by the low-pressure feed.





Flowserve FLEX Features

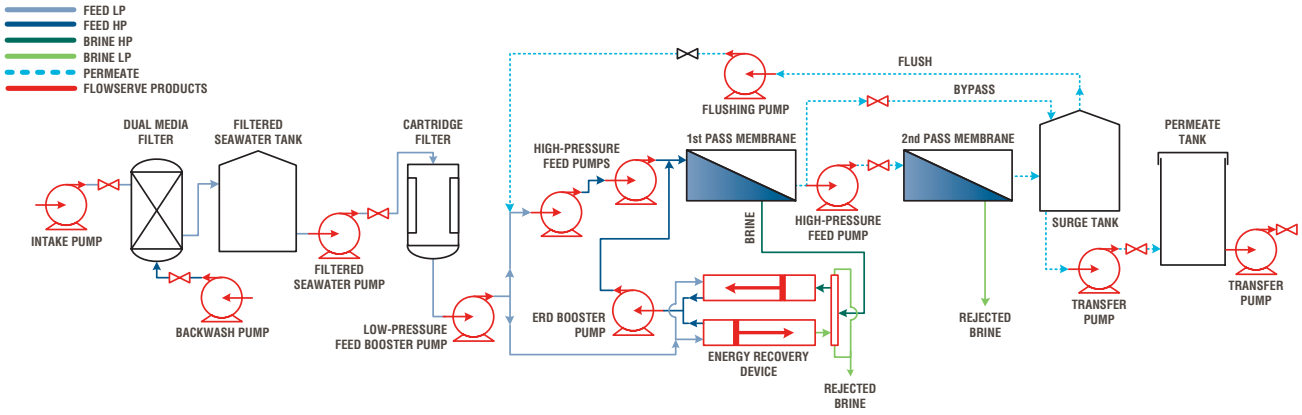
- The axle guided rotor (1) allows large rotor outside diameter and large ducts. Maximizes the flow area and therefore, flow capacity, for a given size. Special seal design and high-precision clearances reduce leakage.
- Specially manufactured and designed end covers (2) minimize cavitation.
- Large low-pressure balance pockets (3) control leakage flow and minimize elastic deformation due to high-pressure forces.
- Highly corrosion-resistant materials like the titanium casing (4) and non-metallic parts ensure a robust, reliable and long-lasting design.
- Split-casing design with only one seal (5) ensures leak-proof operation and easy access for inspection and maintenance.
- Stationary axle (6) affixed to the end covers provide hydrostatic and hydrodynamic bearing features to maintain proper rotor position.



FLOWSERVE DWEER OPERATING PRINCIPLES AND OTHER USEFUL INFORMATION

As noted, the DWEER is the most efficient energy recovery device ever developed. It can recover the hydraulic energy of the brine stream.

The DWEER is frequently specified where the highest efficiencies and lowest OPEX are required in SWRO plants. Typically, it is used in mid- to extra-large sized projects. Flowserve has installed more than 650 units, which recover energy in excess of 330 MW.



Schematic of SWRO process employing DWEER energy recovery device

DWEER Advantages

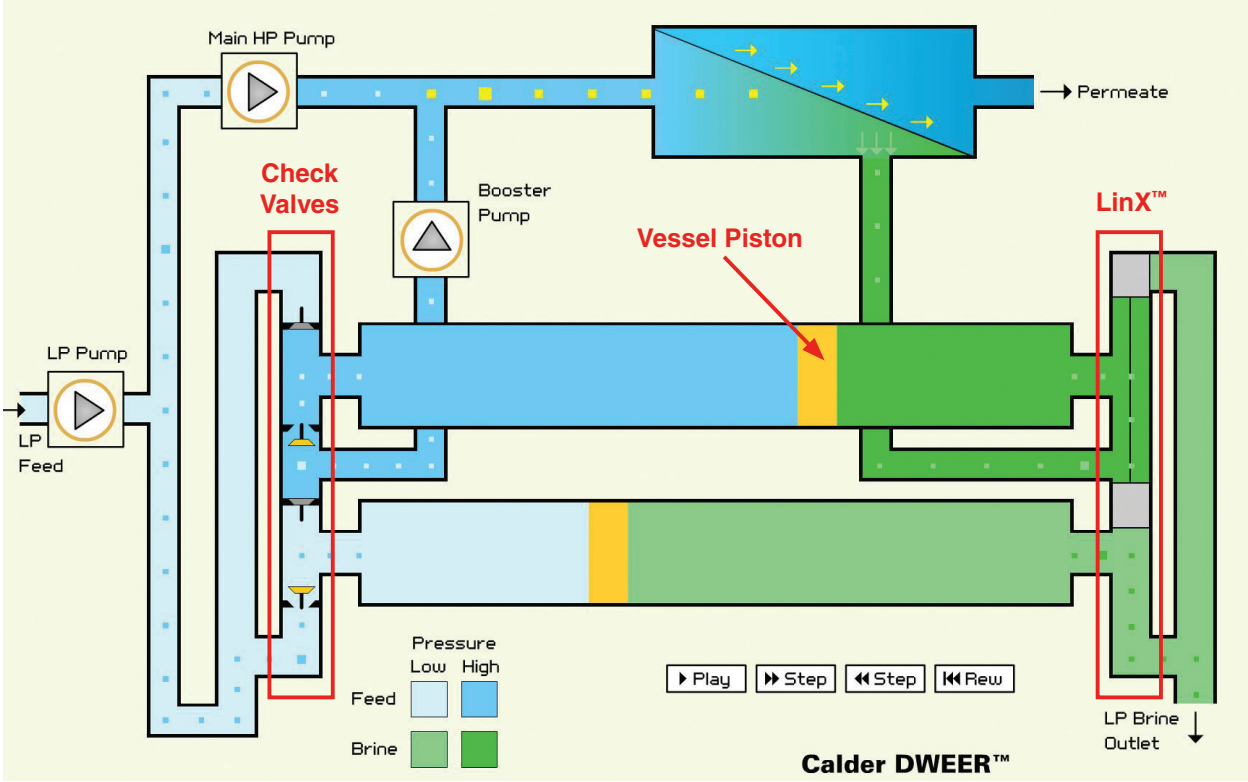
Performance advantages summary:

- Hydraulic efficiency
- Lowest mixing (total dissolved solids increase); approximately 1% at membrane inlet. Therefore, system requires lower membrane feed pressure to achieve same production.
- No leakage means the DWEER can take full advantage of the energy available in the brine.
- No brine outlet pressure required
- Stable efficiency over lifetime of product means no performance degradation.

Operation advantages summary:

- Robust design
- Low noise level
- Slow operating speed
- Easy, minor maintenance requiring only low-cost parts
- Self-adjusting to flow and pressure changes
- Controls support plant diagnostics
- Materials in super duplex stainless steel

The DWEER Operating Principle



Simplified cross-section of a DWEER system in operation

IMPORTANT: DWEER operating principles are difficult to understand without strong visual reference. A helpful animation describing these principles is available at: https://www.youtube.com/watch?v=QaKYbHwv4k4.

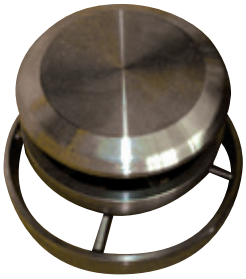
Advances in Flowserve DWEER Technology

Electric Actuators

We now supply DWEERs as standard with electric actuators. This completely eliminates the need for the hydraulic units formerly used to drive the LinX valve. Although at minimal cost, the hydraulic units were responsible for about 70 to 80% of maintenance work. The electric actuator reduces maintenance costs and substantially increases availability.

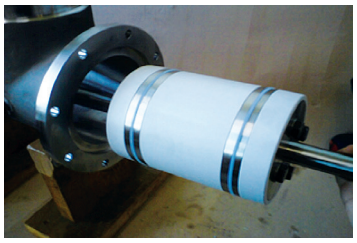
FRP Vessels

Flowserve developed a special FRP design for vessels. They have operated successfully since 2011 in various desalination plants. In addition to eliminating the risk for corrosion, these vessels have the potential to reduce investment costs.



Check Valves

Flowserve has developed and integrated its own DWEER check valves. The design was improved to optimize efficiency and minimize maintenance. As of the publishing of this guide, we have experienced four years of service with no check valve failures since its introduction in 2012.



LinX Piston Seals

The LinX piston seals ensure highest efficiency because leakage can be reduced to basically 0%. Also, no lubrication flow is required, so the high-pressure pump flow and power consumption can be minimized.

Supply of Complete Racks

Flowserve now supplies the DWEER as complete racks, preinstalled and aligned. This significantly reduces installation time and risk.

FLOWSERVE ENERGY RECOVERY TURBINE PRINCIPLES AND OTHER USEFUL INFORMATION

Flowserve energy recovery turbines are designed and manufactured specifically for reverse osmosis desalination. They can recover the hydraulic energy remaining in the brine stream, converting it into rotary power for the high-pressure pumps. Highly efficient and reliable, Flowserve ERTs are installed in nearly 1,000 SWRO and BWRO plants worldwide, with a total installed capacity in excess of 350 MW.

The ERT is a Pelton turbine design, which has been used successfully in RO desalination for more than 30 years. The main advantage of the product is its simplicity and robustness, resulting in almost maintenance-free equipment. The ERT has a wide range of standard models and is therefore used in all project sizes, from small to extra-large. For BWRO projects, the product's hydraulics are typically specially designed for the application. The product is selected in projects where the focus is simplicity, low CAPEX and the cost of energy is relatively low.

ERT Advantages

Performance advantages summary:

- Hydraulic efficiency
- No mixing (total dissolved solids increase) or leakage
- No brine outlet pressure required
- Takes full advantage of the total brine energy
- Flat efficiency curve covering typical flow and pressure variations in RO plants

Operation advantages summary:

- Simplicity product and process; easy to apply
- No ERS booster pump required (necessary for isobaric devices)
- Less piping, valves and instrumentation required compared to isobaric devices
- Robust design
- Basically maintenance-free except bearing lubrication
- Self-adjusting to flow and pressure changes within typical RO plant range
- Supplied and tested as part of the high-pressure pump package – single-source responsibility
- Materials in super duplex stainless steels

The ERT Operating Principle

Flowserve ERTs capture the high-pressure energy that remains in the concentrate (brine) from the reverse osmosis process. The high-pressure concentrate drives the ERT rotor, which then produces rotating power used to assist the main electric motor in driving the high-pressure pump. The Calder™ ERT rotor and nozzle are optimized to convert the kinetic energy of the jet into rotating mechanical energy, enabling the turbine to operate at maximum efficiency. Because of this, smaller, less costly motors may be utilized to drive the high-pressure feed pump. It is possible to size the electric motor for as little as 60% of the total power required to drive the high-pressure pump.

Flowserve ERTs are designed to operate with either centrifugal or positive displacement pumps and may be direct coupled to motors or pumps. A range of standard turbines is available with a power recovery potential up to 1.5 MW. Larger units are available as engineered products.

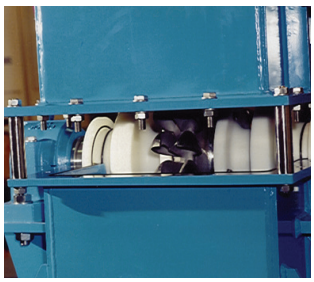
ERT Selection

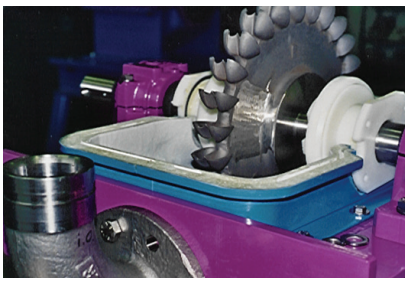
In order to select a turbine, Flowserve needs the following minimal information:

- Number of units
- Brine flow
- Brine pressure
- Turbine speed (usually same as pump speed)

With this information, business units can make a turbine selection and prepare a proposal. Special selections can be made with the help of desalination specialists at one of our manufacturing locations.

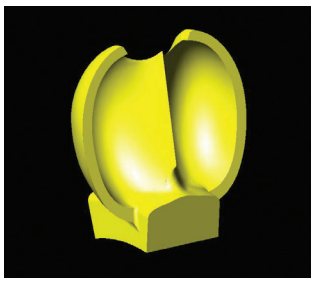
Advances in Flowserve ERT Technology

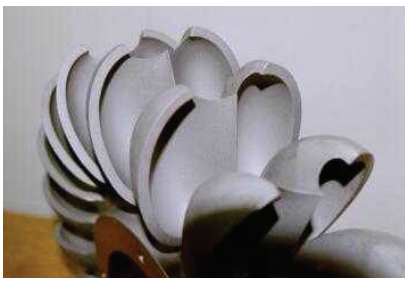




Horizontal Split Casing

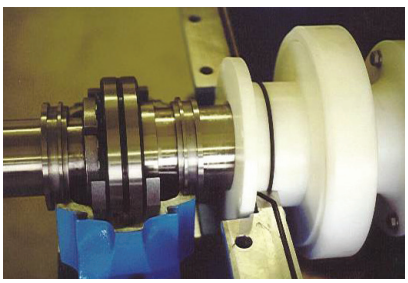
The horizontal split case design ensures easy access for inspection.





Precision Design

3D modeling and investment (lost wax) casting ensure precision of the Pelton wheel: the heart of the Pelton turbine.



Labyrinth Seals

Non-metallic, non-contact labyrinth seals ensure maintenance-free sealing of the turbine casing.

REDRAVEN IoT TECHNOLOGY AND SERVICES PLATFORM

A Revolution in Flow Motion IoT

Flow control equipment is the lifeblood of your plant. Flowserve designed its RedRaven platform to give you the insights and tools you need to monitor, analyze and predict equipment performance — so you can respond to problems quickly and minimize disruptions and downtime.

The Flowserve RedRaven platform includes a suite of solutions, including equipment sensors, secure communication, performance analytics and trend reporting tools. It also includes a range of offerings that can be customized to meet your plant's unique needs. Options include condition monitoring services, which allow you to capture asset performance data for analysis, and predictive monitoring capabilities, which apply data analysis software and algorithms to identify and diagnose equipment problems.

With access to advanced analytics and trend data, you can identify the slightest changes in equipment performance, variations that can indicate a problem is looming. The RedRaven platform uses engineered analytics, diagnostic and predictive capabilities that tell you how your flow control equipment is performing. You won't just receive data, you'll also get real insights needed to make more informed decisions to improve your plant's efficiency, productivity and bottom line.

With Flowserve innovative IoT products, analytics technology and expert service, you can:

Predict equipment behavior. Respond to problems quickly and minimize disruptions and downtime. Use trend analysis data to make informed decisions about plant-wide reliability improvements.

Refocus maintenance efforts. Focus on those assets that require attention, thus avoiding unplanned downtime and optimizing maintenance efforts so you spend less time evaluating healthy equipment.

Enhance equipment efficiency. By knowing where all your assets are on their respective operating curve, you can optimize for maximum efficiency.

Reduce costs. Reduce total cost of ownership by easily recognizing when to schedule equipment maintenance and reducing spare part inventories.

Improve safety. By alerting technicians to a problem and what the failure mode might be, the RedRaven platform helps them respond to performance issues quickly, limiting the time they spend in hazardous environments.

Technology, services and capabilities

Innovative sensors
Wired and/or wireless sensors collect vibration, pressure and temperature data for analysis. Long-range wireless sensors enable cost-effective monitoring of thousands of assets over sprawling facilities.

Application-specific analysis
Equipment performance data is analyzed with technology designed specifically for pumps, valves and seals, so you can gain a clearer understanding of how to increase the efficiency, productivity and reliability of the equipment you use every day.

Secure communications
Our secure system architecture collects data from equipment sensors and transmits it via a secure encrypted network.

Trend reporting and notifications
Get insights and alerts about equipment performance and problems, so you can take immediate action as needed.

North America

Latin America

Europe

Middle East

Africa

Asia-Pacific

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Experience In Motion