C.M.S.T. Co. Ltd.
Koh Samui, Thailand 077-415-508

WATER RECOVERY, REVERSE OSMOSIS, OZONE SANATIZATION, DESIGN AND INSTALLATION SPECIALIST

This paper covers Reverse Osmosis (R.O.) Systems in General and Salt Water Recovery Systems in particular. All systems are designer and manufactured in Thailand to EXCEDE International Standards by K & N Thailand ; our R.O. Systems are designed to meet the customer's requirements as well as requested options. Not all systems are the same, thus each system is designed to the customers needs and wishes.

About C.M.S.T. Co. Ltd.

C.M.S.T. Co. Ltd. has been in business in the Electrical and Water System design and manufacturing business for over 15 years in Thailand. We employ both American and Thai Engineers and have a highly trained staff of Thai Installation and Maintenance experts in Electrical and Water treatment systems. Our office and manufacturing was moved to Koh Samui in February of 2002 from our home of 10 years in Bangkok. This new location allows us to better serve our customers through out Thailand.

***Please note*: Salt Water Recovery Systems are generally over twice as expensive to purchase and maintain as fresh water or brackish water systems. Prices will vary according to the quality of the feed water and the required output and options specified.**

Fundamentals of Reverse Osmosis

WHAT IS REVERSE OSMOSIS

Anyone who has been through a high school science class will likely be familiar with the term "osmosis". The process was first described by a French Scientist in 1748, who noted that water spontaneously diffused through a pig bladder membrane into alcohol. Over 200 years later, a modification of this process known as **Reverse Osmosis** allows people throughout the world to affordably convert undesirable water into water that is virtually free of health or aesthetic contaminants. Reverse Osmosis systems can be found providing treated water from the kitchen counter in a private residence to installations used in manned spacecraft. Reverse Osmosis is a technology that is found virtually anywhere pure water is needed. Reverse Osmosis is being used through out the world to provide or supplement drinking water supplies.

In The United States Reverse Osmosis is now providing municipal water to Cape Kennedy, Miami, Florida, Los Angeles, San Diego, and increasingly more Cities in the United States. The Arab world now uses Reverse Osmosis Systems now as their free or cheap gas supplies are dwindling. Europe uses Reverse Osmosis in many cities to provide or supplement their water supplies. On Catalina Island off the coast of Long Beach, California a Reverse Osmosis system is supplying 25% of the islands water. In the Caribbean Reverse Osmosis Systems provide water to numerous Hotels and Resorts, which would have had to close down or severely restrict their occupancy, if not for the installation and use of Salt Water Recovery Reverse Osmosis Systems.

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Reverse Osmosis Systems in general have become very economical and automated in the past few years. The use of PLC controllers, Turbine Recovery systems and Variable Frequency Drive systems have allowed our engineers to save up to half of the energy previously required to produce a Cubic Meter of Water. These continual improvements by the Industry and our Engineers has also greatly increased the useful life of the membranes and the system overall. The Reverse Osmosis Systems we produce are “State of the Art” both in design and operation.

The recovery of Salt Water (Sea Water) in still the most expensive of the basic Reverse Osmosis Systems this is due to many factors.

- Membranes are more expensive due to the requirement to remove contaminants to the Ion level and be able to withstand pressures in excess of 1000 psi.
- Pressure Vessels (the shell which contains the membrane) must be ASME certified and be able to operate at 1500 psi and have a burst pressure rating of 6000 psi. (We are the only manufacturer of the vessels in Asia).
- Materials, piping, pumps, gages; instrumentation must be made of materials which can stand the corrosive water as well as the high pressures in the system.
- Special design considerations must address the flow rates, flux of the membranes, as well as the safety confederations of the equipment and the system as a whole.
- The system is usually supplied fully automatic and provided with full safety alarms and cutout systems.

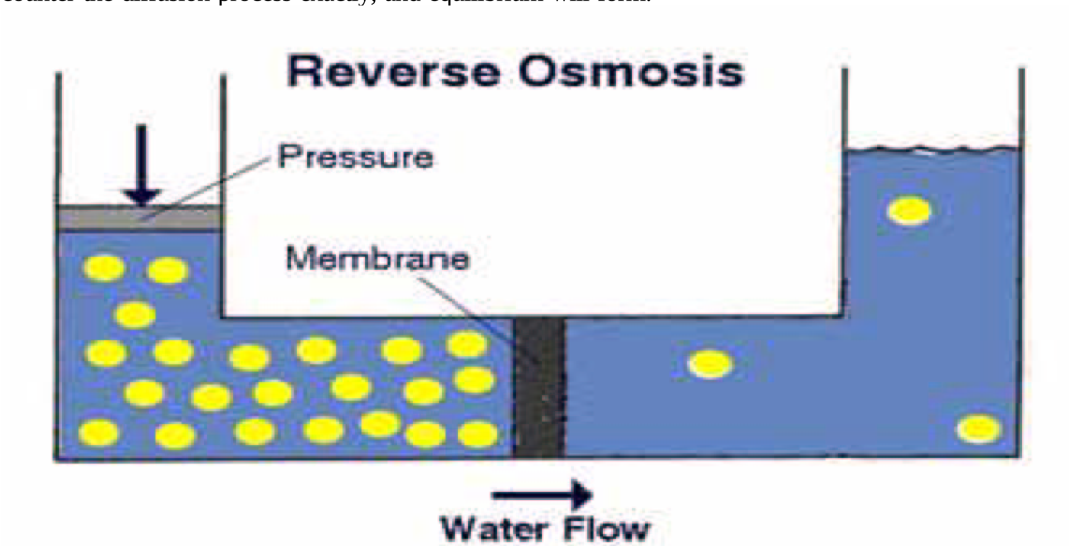
Reverse Osmosis in used for many applications, some of the applications are listed below.

•Drinking Water
•Cosmetics
•Humidification
•Animal Feed
•Ice-Making
•Hatcheries
•Car Wash Water Reclamation
•Hatcheries
•Rinse Waters
•Restaurants
•Biomedical Applications
•Greenhouses
•Laboratory Applications
•Metal Plating Applications
•Photography
•Wastewater Treatment
•Pharmaceutical Production
•Boiler Water
•Kidney Dialysis
•Battery Water
•Water used in chemical processes
•Semiconductor production, High Technology Electronics production.
•Hemodialysis
•Virtually any Industrial application where high quality water is needed, we are even cleaning radioactive waste water.

How Reverse Osmosis Works

A semipermeable membrane, like the membrane of a cell wall or a bladder, is selective about what it allows to pass through, and what it prevents from passing. These membranes in general pass water very easily because of its small molecular size; but also prevent many other contaminants from passing by trapping them. Water will typically be present on both sides of the membrane, with each side having a different concentration of dissolved minerals.

Since the water is the less concentrated solution it seeks to dilute the more concentrated solution and water will pass through the membrane from the lower concentration side to the greater concentration side. Eventually, osmotic pressure (seen in the diagram below as the pressure created by the difference in water levels) will counter the diffusion process exactly, and equilibrium will form.



The process of Reverse Osmosis forces water with a greater concentration of contaminants (the source water) into a tank containing water with an extremely low concentration of contaminants (the processed water). High water pressure on the source side is used to "reverse" the natural osmotic process, with the semi-permeable membrane still permitting the passage of water while rejecting most of the other contaminants. The specific process through which this occurs is called ion exclusion, in which a concentration of ions at the membrane surface from a barrier that allows other water molecules to pass through while excluding other substances.

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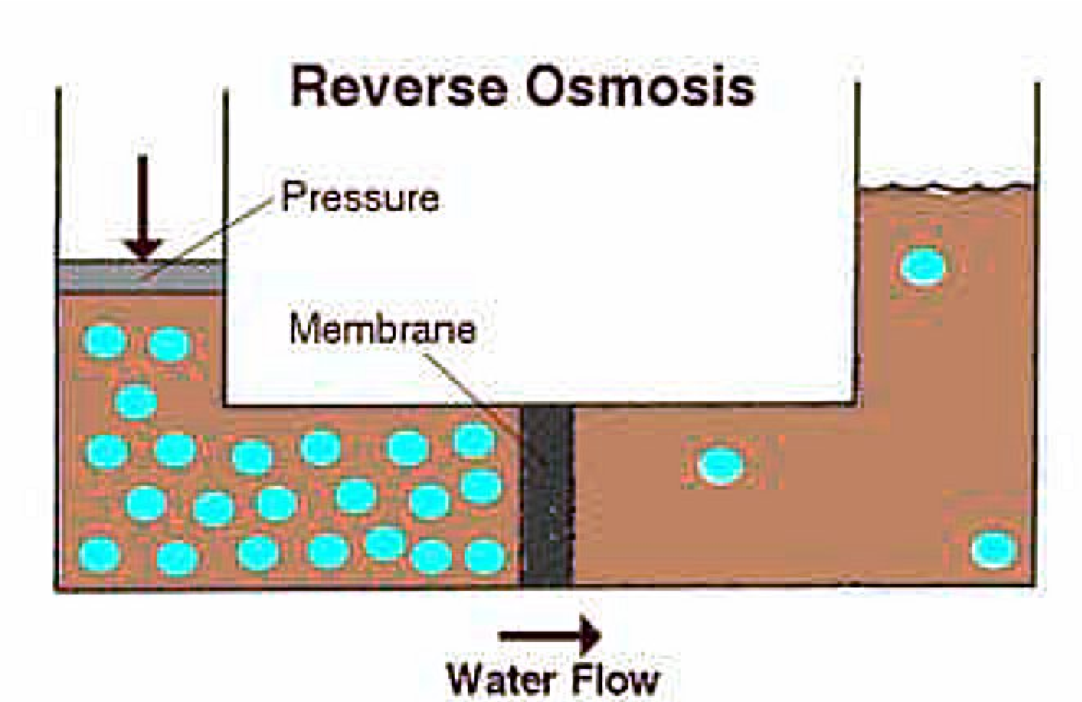

Semi-permeable membranes have come a long way from the natural pig bladders used in the earlier osmosis experiments. Before the 1960's, these membranes were too inefficient, very expensive, and unreliable for practical applications outside the laboratory. Modern advances in synthetic materials have generally solved these problems, allowing membranes to become highly efficient at rejecting contaminants, and making them tough enough to withstand the greater pressures necessary for efficient operation.

Even with these advances, the "reject" water on the source side of a Reverse Osmosis (R.O.) system must be periodically flushed in order to keep it from becoming so concentrated that it forms a scale on the membrane itself .Reverse Osmosis systems also typically require a carbon prefilter for the reduction of chlorine, which can damage an R.O. membrane; and a sediment pre-filter is always required to ensure that fine suspended materials in the source water do not permanently clog the membrane. Hardness reduction, either through the use of water softening for residential units or chemical softening for industrial use, may also be desirable in hard water areas.

HIGH PRESSURE (COMMERCIAL/INDUSTRIAL) SYSTEMS

High-pressure systems typically operate at pressures between 100 and 1000 psig, depending on the membrane chosen and the water being treated. These systems are usually used in industrial or commercial applications where large volumes of treated water are required at a high level of purity. Most commercial and industrial systems use multiple membranes arranged in parallel to provide the required quantity of water. The processed water from the first stage of treatment can then be passed through additional membrane modules to achieve greater levels of treatment for the finished water. The reject water can also be directed into successive membrane modules for greater efficiency (see diagram below), though flushing will still be required when concentrations reach a level where fouling is likely to occur.

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120 M3 BEING DELIVERED TO ABLE SANOH INDUSTRIES CO., LTD.

High-pressure industrial R.O. units typically provide from two to three cubic meters per day up to several thousand cubic meters per day. Pure water recovery rates can be as high as ninety percent. Water purity can be as high as 99.9 percent. Large high-pressure systems are normally more complicated than low pressure systems and this is reflected in their cost.

WHAT REVERSE OSMOSIS TREATS

Reverse osmosis can treat a wide variety of health and aesthetic contaminants. Properly designed RO systems can remove unpleasant taste, color, and odor problems like a salty or soda taste caused by chlorides or sulfates. R.O. systems are ideal for removing biological contaminants, chemicals like arsenic, asbestos, atrazine (herbicides/pesticides). fluoride, lead, mercury, nitrates, radium, and even radioactive particles. Carbon pre-filtering (commonly included with most R.O. systems) removes "volatile" contaminants such as benzene, trichloroethylene, trihalomethanes, and radon. The Water Quality Association and all other responsible authorities and organizations emphasize the importance of a properly designed R.O. system.

CONCLUSION

Reverse Osmosis is the most advanced, cost-effective method of producing pure water for literally thousands of applications. With over 10,000 Large (over 40,000 $M^{3)}$ Salt Water recovery systems in use through out the world and many more under design and construction. Reverse Osmosis is one of the most viable methods to supply potable water to the world.
We have produce over 600 Reverse Osmosis Systems which are in use through out the world; our vessels are in use in systems all over the world. K & N is also the only designer and manufacturer of ASME High Pressure

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Fiberglass R.O. vessels in Asia we ship our vessels all over the world. We are the only designer and manufacturer of Salt Water Recovery R.O. Systems in S.E. Asia.

Below are some photos of Installed Systems

15 M^3 R.O. System

120 M^3 R.O. System

Emergency Water system 760 Liters/day shipped to Viet Nam

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Reverse Osmosis Pre-Filtration

In most cases pre-treatment of the source water is required to prevent damage to the membranes and the system as a whole. C.M.S.T. Co. Ltd. will take samples of the feed water during our site survey for analysis in our lab. The results of this water analysis will determine what pre-treatment if any is necessary for you particular application.

FEEDWATER ANALYSIS

The following feedwater analysis must be completed or attached to this form before C.M.S.T.'S engineering department can design the R.O. System to meet your feedwater conditions. You should ask a testing laboratory to conduct the following tests, or contact C.M.S.T. Co. Ltd. So we can arrange for our Laboratory to conduct your analysis. **NOTE: In general a comprehensive analysis of Sea Water is not necessary as we know the values in our area and they are generally consistent.**

It must be stressed here that ABOSUTLY NO IRON or CHOLORINE can be allowed to reach the membranes or permanent damage will result. Care must be used in selecting Pumps, Piping, and Connectors anything in contact with the SEA WATER must be designed specifically for SWRO usage.

In general 316 SS, 2005 SS, Titanium and most all plastics and Fiber piping are Safe to use, if in doubt ASK your R.O. System Provider. Always have the R.O. System provider inspect your supply system to your R.O. System to be sure that the water supply meets the R.O. System Specifications.

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Analysis Item	Raw Water	Product Water Requirements
PH *		
Turbidity *		
Conductivity (mmhos/cm		
TDS (ppm) *		
P-alkalinity (ppm as CaC03)		
M-alkalinity (ppm as CaC03) *		
Total Hardness (ppm as CaC03)		
Ca-Hardness (ppm as CaC03) *		
Mg-Hardness (ppm as CaC03) *		
Chloride (ppm as CaC03)		
Sulfate (ppm as S04) *		
Iron (ppm as Fe) *		
Silica (ppm as Si02) *		
Phosphate (ppm as P04)		
Sulfite (ppm as S03		
Nitrite (ppm as N02)		
Chlorine (ppm as CL2) *		
Sodium (ppm as Na) *		
Fluoride (ppm as F) *	.	
Manganese (ppm as Mn2+)		
Barium		
Strontium		
Total Bacteria (Colonies/ml.)		
Bacteria,E.Coli (MPN/100ml.)		
Coliform Bacteria (MPN/100ml)		
Temperature *		
SDI *		

*** Indicates minimum water test required to design R.O. system.**

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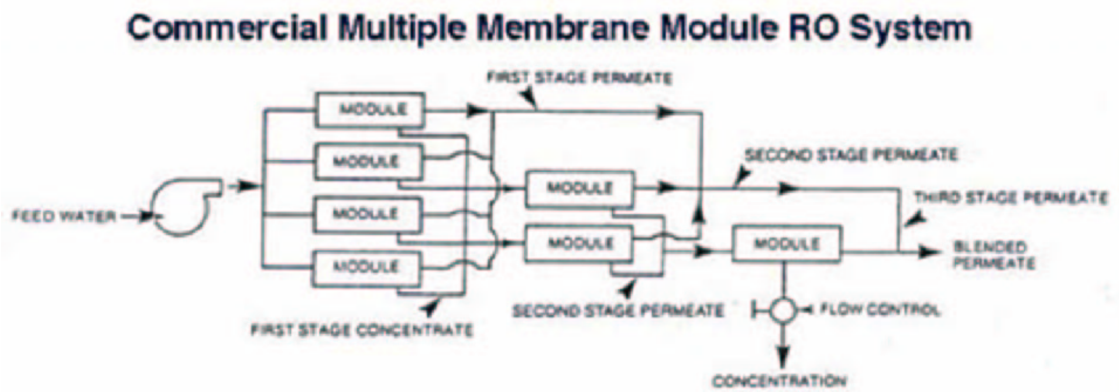
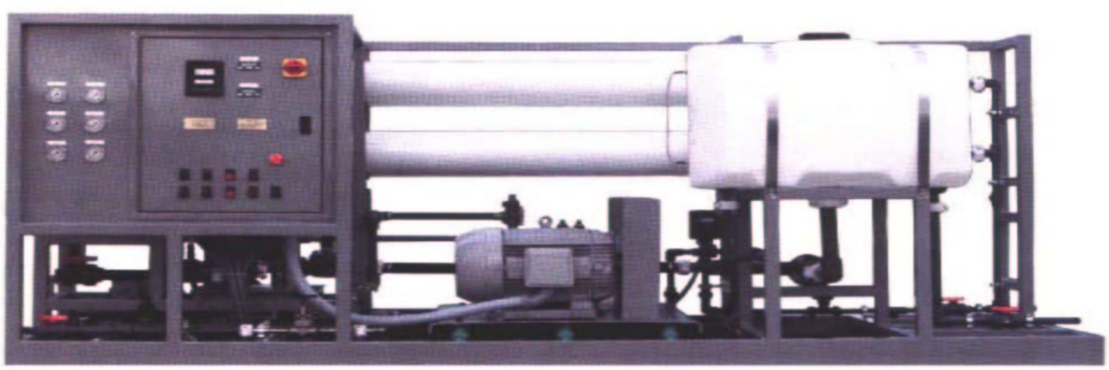


Double Pass Reverse Osmosis Systems (Ultrapure Water)

Double-Pass R.O. systems are used in applications where the water quality needs to be ultrapure. These include some very specialized industries such as electronics and medical grade water for Hemodialysis. In a true double pass R.O. system the water is run through the first stages of R.O. modules and then the permeate (RO filtered water) is then passed a second time through a R.O. module. Water purity through a true double pass system can be as good as deionized or distilled water (TDS = 0.00 ppm).

Double-pass R.O. systems can also be configured to minimize the amount of Reject (concentrate) water. In the diagram above, the reject water is passed through a second and third stage to greatly increase water recovery.



250 M3/day Salt Water Recovery System

Desalination Reverse Osmosis System

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SEMI-PERMEABLE MEMBRANES ARE AT THE HEART OF ANY R.O. SYSTEMS

The process of reverse osmosis (RO) is the highest level of liquid filtration available today. While ordinary liquid filters use a screen to separate particles from water streams, an R.O. system employs a semi-permeable membrane that separates an extremely high percentage of unwanted molecules. For example, the membrane may be permeable to water molecules of dissolved salt. If this membrane is placed between two compartments in a container, and a salt solution is placed in one half of the container and pure water in the other, water passes through the membrane while the salt cannot.

PRESSURE IS APPLIED TO REVERSE NATURAL OSMOTIC FLOW

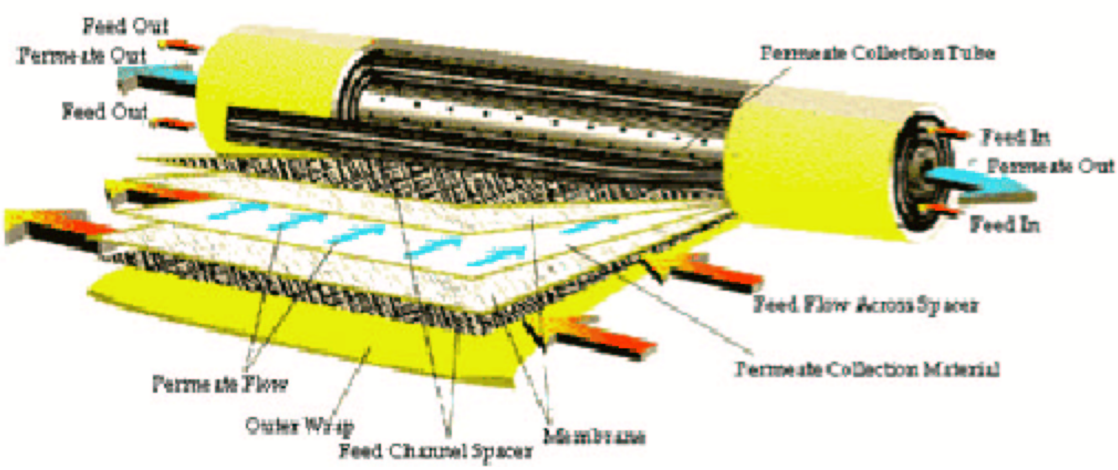
Now a fundamental scientific principle comes into play. That is, dissimilar liquid systems will try to reach the same concentration of materials on both sides of the membrane. The only way for this to happen is for pure water to pass through the membrane to the salt-water side in an attempt to dilute the salt solution. This attempt to reach equilibrium is called osmosis. But if the goal in our water purification system is to remove the salt from water, it is necessary to reverse the natural osmotic flow by forcing the salt water through the membrane in the reverse direction. This can be accomplished by applying pressure to the salt water as it's fed into the system, creating a condition known as "reverse osmosis."

CROSS-FLOW FILTRATION PERMITS LONG-TERM PERFORMANCE

While the principles of reverse osmosis are simple, in practical terms, the R.O. process cannot go on indefinitely unless steps are taken to ensure that the membrane doesn't become clogged by the precipitated salts and other impurities forced against the membrane by the pressurized stream of feedwater. To significantly reduce the rate of membrane fouling, R.O. systems employ cross-flow filtration, which allows water to pass through the membrane while the separate flow of concentrate sweeps rejected salts away from the membrane surface.

Deleted: feed water

Thin Film Fully Aromatic Polyamide Advanced Membrane



SPIRAL WOUND R.O.MEMBRANEs

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VARIOUS FRP MEMBRANE SIZES

Integration of Advanced High Pressure Pumps and Energy Recovery Equipment Yields Reduced Capital and Operating Costs of Seawater RO Systems

Abstract

High-pressure pumping and brine energy recovery equipment account for as much as 40% of the capital costs in seawater reverse osmosis (SWRO) desalination systems. Energy consumption by the high pressure feed pump accounts for at least 35% of the operating costs.

Recently developed equipment integrates into one package the function of high pressure pumping, energy recovery and control of feed and brine flows resulting in a substantial reduction in capital and operating costs of SWRO systems.

The integrated equipment package is based on proven technology blended with state-of the-art fluid machine design and clever integration of numerous components heretofore installed individually in SWRO systems. This package will make a substantial contribution toward the reduction of capital and operating costs for SWRO systems with capacities between 50 m3/day and 500 m3/day permeate production per train.

Keywords:

Desalination, reverse osmosis, RO, energy recovery, pumps, turbines, Hydraulic Pressure Booster, HPB

Introduction

The brine energy recovery turbine / Hydraulic Pressure Booster or HPB™, was designed for seawater RO service. The unit combines simplicity and ease of installation of turbocharger devices with much improved performance through superior hydraulic design and manufacturing. The HPB™ is believed to be the lowest priced energy recovery unit offered for SWRO service and has the highest efficiency of its type.

RO systems require other expensive equipment including means to regulate feed band brine flows. Typically, valves in a high-grade SS alloy are used for flow control through a throttling process. However, a variable frequency drive (VFD) provides the most efficient means to regulate flow and pressure (when used with centrifugal feed pumps).

Often, a pump is needed to periodically circulate a cleaning solution through the membrane to reduce fouling and to restore membrane performance. In some cases, another pump is needed to re-circulate a portion of the brine through the membrane to obtain higher flow velocities in the membrane feed channels. The SWRO original equipment manufacturer (OEM) needs to obtain and install several pumps, an energy recovery turbine and flow control components described above, all of which must be in materials that are expensive and often with long delivery times. The negative potentials of this critical task are threefold; the commercial success of the OEM is jeopardized due to high cost of manufacture, system reliability and performance can be compromised and general acceptance of SWRO may be impeded.

For small scale SWRO to advance as a mainstream industry, integrated packages must be introduced that includes all pumping function (high pressure feed, cleaning and brine re-circulation where needed), brine energy recovery and means to control feed and brine flows. The consistency of performance and quality possible with pre-engineered packages will allow SWRO to achieve its fullest commercial potential.

Objectives for an Integrated Equipment Package

The objective is to integrate the following components into a single package:

- High pressure feed pump;
- Energy recovery turbine;
- Membrane pressure and flow control;
- Membrane cleaning pump; and
- Brine re-circulation pump (where needed).

The heart of the integrated RO package (IROP) is the feed pump and the energy recovery turbine. For IROP to gain acceptance, these components must be reliable, efficient, easy to maintain and have a low cost. Some of the considerations in component selection are discussed below.

Energy Recovery Turbine

The HPB™ is a free-running single stage turbine driving a single stage feed booster pump. The HPB™ uses the high-pressure brine to energize the turbine, which drives the single stage feed booster pump. The feed pressure boost generated by the HPB™ reduces the required feed pump discharge pressure resulting in energy savings and a reduction in size of the feed pump and motor. See Figure 2.

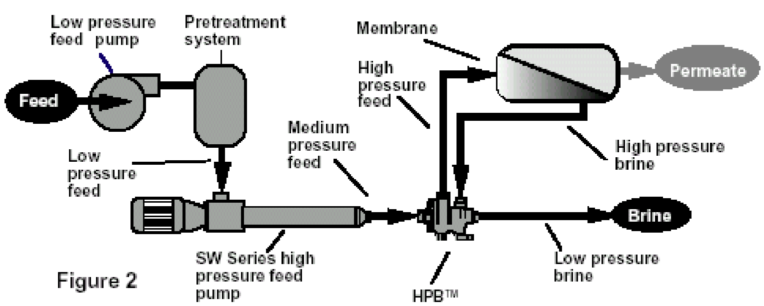

Figure 2

HPB™ design objectives included significantly improved efficiency, improved corrosion resistance and improved reliability while reducing the selling price by at least 30% compared with competing units. All of these objectives were met through improved fluid flow path design and full utilization of CNC (computer numerical control) manufacturing technology. See Figure 3.

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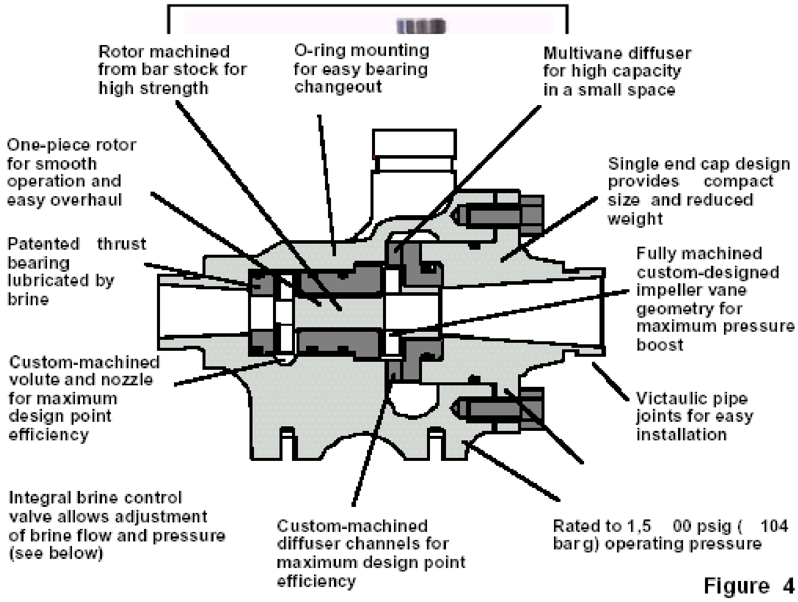

Figure 4

The HPB™'s compact size, smooth and quiet operation and high-energy recovery efficiency made it the logical choice for the IROP. Figure 4 shows the internal construction and features of the HPB™.

Membrane Pressure Control

RO membranes require control of feed and brine flows and pressures to accommodate changes in feed water temperature, feed chemistry and membrane fouling. This important function should be handled by the IROP. The optimal solution is to use a VFD to change pump-operating speed as required for the desired feed pressure without energy-wasting throttling. The brine flow may be adjusted using the HPB™ brine valve.

As discussed above, the VFD also allows higher speed operation, which substantially reduces the cost and increases the capacity of the high pressure feed pump. In those cases where a VFD is not used, a pressure control valve is required between the feed pump discharge and the feed inlet to the HPB™.

Other Functions of the Integrated Package

In some systems a check valve is used on the high pressure feed side. This valve may be located between the feed pump discharge and HPB™ feed inlet. A screen to catch any debris that may pass from the pump is advisable. To monitor pump and HPB™ performance a pressure indicator should be used between these two components. Many SWRO systems include a membrane cleaning system with a separate pump for circulating cleaning solution through the membrane. This function should be incorporated into the package. Some R.O. process applications may use concentrate (i.e. brine) recirculation to enhance membrane performance. Means should be available to carry out this function.

Integrated Reverse Osmosis Package

The objective is to integrate into the IROP all of the following:

- High pressure feed pump and motor;
- HPB™ Energy recovery device;
- Membrane pressure control;
- Cleaning pump;
  - VFD Drive
- Screen;
- Interconnecting feed piping between the various components.

- If needed, the following functions may be added:

- Feed pressure control valve (required if a VFD is not used);
- Check valve; and
- Concentrate re-circulation pump.

The Multifunction Adapter
The key to the IROP is the multifunction adapter. The adapter is a modified HPB™ end cap. The feed inlet passage to the end cap is enlarged and lengthened to accommodate a screen, pressure indicator port, and, if needed a feed pressure regulating valve and check valve. The adapter bolts directly to the HPB™ casing and is connected to the SW pump discharge using a Victaulic clamp. In its most basic form, the adapter may replace up to four individual components; a check valve, pressure control valve, debris screen and interconnecting piping between the pump and the energy recovery turbine. The axial discharge of the SW pump makes in-line mounting of the above components relatively easy. Other modifications to the multifunction adapter are discussed below. If a pressure control valve is included in the adapter, the HPB™ could be subjected to undesirable turbulence generated by a partially closed valve. In such cases, the HPB™ includes a screen that suppresses the turbulence as well protects the HPB™ and membranes from any debris that may be in the feed stream.

Concentrate Re-circulation
Re-circulation of concentrate can be integrated into the HPB™ and multifunction adapter. The adapter is modified to include an integral eductor that uses the pressure drop between the brine and the pump discharge pressure to help raise the pressure of the feed entering the HPB™. The eductor recovers hydraulic energy that otherwise would be destroyed in a throttling process thereby reducing the energy penalty from using brine re-circulation. Figure 5 shows a schematic of the process. Note that the re-circulating flow does not pass through the feed pump.

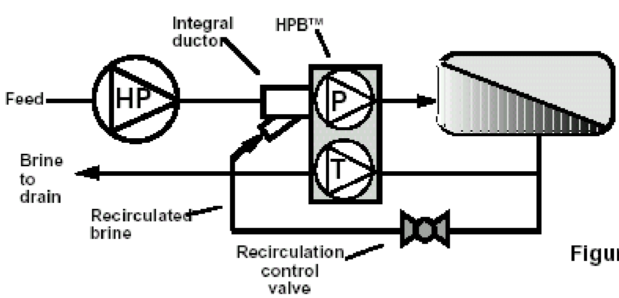

Figure 5

Membrane Cleaning Function

Many RO systems include equipment used to circulate a cleaning solution through the membrane array. The SW pump may be used for circulation of cleaning solution by simply reducing the pump speed with the VFD to the level needed for the desired flow and pressure. Note that the solution may pass through the HPB™ feed and brine sides. The HPB™ will provide some energy recovery that helps minimize temperature rise in the re-circulating flow. In the event that the turbine side imposes too much flow resistance, a small ball valve attached to the HPB™ brine plug can be used to reduce flow resistance as needed.

Other IROP Features
The SW pump and HPB™ turbine with multifunction adapter form the heart of the IROP. The package is designed to also:

- Maintain the same pipe connection locations, even with different SW pumps and HPB™ turbine, which allows us to develop standard piping assemblies for a wide capacity range;
- Allow pump inlet pipe connection and HPB™ high pressure feed and brine connections to be rotated in 90 degree increments to maximize OEM piping options; and
- Allow adjustment of all control valves (e.g. feed, brine, and re-circulation) from one location.

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Impact on Cost of the RO Systems

We at C.M.S.T. Co. Ltd. face a constant challenge to reduce capital costs while delivering a system with high reliability, low maintenance and low operating costs. The integrated feed pump, ERT-control valve-cleaning pump package with optional re-circulation eductor eliminates a multitude of discrete components and greatly simplifies the high-pressure piping. One package with essentially identical pipe connection locations can handle feed flows from about 50 gpm (12 m3/hr) to 200 gpm (45 m3/hr) thus allowing us to standardize much of the high pressure piping design. The VFD makes the IROP a world package; able to operate with equal efficiency with 50 or 60 Hz electrical power. The VFD blends well with automated controls that that we may provide.

VARIABLE FREQUENCY DRIVE SYSTEM
A variable frequency drive (VFD) provides efficient control of pump discharge pressure by control of pump operating speed. With fixed-speed operation, a throttle valve is needed to regulate feed pressure. The valve should be placed between the HP pump discharge and the HPB™. The valve may be a full-port ball valve as the throttle differential is usually small (e.g. zero to 100 psi).
The variable frequency-drive (VFD) provides efficient control of the pump discharge pressure by control of the pump operating speed. The VFD also eliminates the need for a throttling valve and allows for super-soft motion starting and easy regulation of feed water pressure. The VDF also ensures minimum energy consumption.

A 120-Ton Example
We wish to build a SWRO system with a 120 m3/day permeates output. Recovery is to be 36% and the average operating pressures are 60.0 bar and 58.0 bar for the feed and brine respectively. The SW5520 feed pump and HPB-20 energy recovery turbine would be suitable. See Figure 7. Table 1 summarizes system performance.

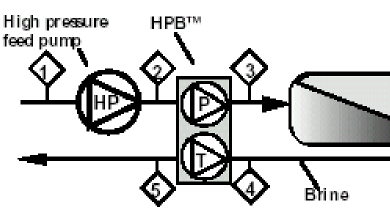

Figure 7

The electrical input for the SW5520 with HPB-20 is quite low at 4.7 kW-hr per cubic meter of permeate. In additional to feed pumping and energy recovery, the IROP includes the cleaning pump function, the feed piping to the HPB™ and a base plate for the motor, pump and HPB™.

Table 1 – 120 ton/day example

	Flow (m3/hr)	Pressure (bar)
1	13.9	2.0
2	13.9	39.0
3	13.9	60.0
4	8.9	58.0
5	8.9	0.5
Shaft power (kW)		21.6
KW-hr/m3 permeate		4.7

Total weight is about 290 kg with an overall length of about 2.9 meters. The package operates with negligible vibration, has very smooth flow and may be bolted to the membrane skid. The cost of this assembly is believed to be lower than any other package with similar performance.

A PD pump, by comparison, would consume 5.8 kW-hr/m3 of permeate (assuming an HPB™ is not used). The pump cost, including accumulators and base plate would typically exceed 15,000 USD (nickel aluminum bronze pump and 316 SS accumulators). And, the pumping package would weigh several times more than the IROP.
Operating factors such as noise, vibration, maintenance and general reliability may be expected to be less favorable than the SW centrifugal pump and HPB™.

A 500-Ton Example

The example system is to produce 500 m3/day with a 45% recovery and pressures of 64.0 and 62.0 bars for the feed and brine respectively. Here, the SW12520 and HPB-60 units integrated with the multifunction adapter would be suitable.

Table 2 summarizes the performance. Note that the HPB™ generates an 18.6 bar pressure boost in the feed stream. The feed pump energy consumption is 4.18 kW-hr per cubic meter. The package weighs 850 Kg with an overall length of about 4.1 meters. The IROP could be easily mounted on the membrane skid.

Table 2 – 500 ton/day example

	Flow (m3/hr)	Pressure (bar)
1	47.3	2.0
2	47.3	45.4
3	47.3	64.0
4	26.5	62.0
5	26.5	0.5
Shaft power (kW)		81
KW-hr/m3 permeate		4.18

A typical multistage centrifugal pump of 67% efficiency coupled to a Pelton Wheel of 83% efficiency would consume about 2% more energy per unit of permeate. Such a package would be larger, require a brine disposal re-pressurization system and have a much higher installation cost. Also, the multiple precision shaft alignments between the motor, pump and turbine can place severe requirements on base plate strength and rigidity. The IROP requires a 125 hp (93 kW) motor compared with a 200 hp (149 kW) motor for the conventional pump and Pelton Wheel. Likewise, the IROP SW pump cost is much less due to a lower discharge pressure, which permits fewer stages and a smaller base plate. If a PD pump were to be used, the pump with required accumulators and base plate would cost over 36,000 USD (nickel aluminum bronze construction). The IROP including the VFD would cost significantly less than the PD pump without energy recovery equipment.

Conclusion

With the IROP pre-engineered equipment package, we can be assured of predictable performance and uniform quality with single supplier responsibility. Despite the IROP's great improvement in the economics of small SWRO systems, the technology is evolutionary rather than revolutionary. Hence, higher reliability and low cost can be expected in the future.

We have produce over 400 Reverse Osmosis Systems, which are in use through out the world. Over 4,000 of our Local supplier's vessels are in use in systems all over the world. They are also the only designer and manufacturer of ASME High Pressure Fiberglass R.O. vessels in Asia And ship vessels all over the world. We are the only designer and manufacturer of High Efficiency "Poseidon™" Salt Water Recovery R.O. Systems in S.E. Asia.

At present with our fully automatic energy efficient Salt Water R.O. system water production costs are at or below 16 baht a cubic meter. Cost may vary depending of local rates.

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Notes:
Product water output my very depending on the feed water conditions. (BW- membranes are fiberglass outer wrapped - average salt rejection 99.5%)

Special membranes are available for wastewater, Hot water and custom design flow rates.

Prices are subject to change without notice, please call to confirm your order.

Terms of payment;
Funds are to be in cash or transferred to our company bank account.
50 % with order
35 % 45 days on inspection at manufacturing facility.
15 % on installation and start-up (not to exceed 15 days after unit is received on site)
Export orders 50% with order and balance with our exact worded irrevocable letter of credit.

Prices **do not include VAT** or packing, shipping, handling, water analysis fees, site survey and installation charges.

Water Supply to the system is NOT INCLUDED in any pricing; it is the task of the purchaser to supply sufficient and required quality feed water to the system.

(SEE the Caution and water requirements on page 7)

Orders usually take 60 to 120 days to complete and ship. Customers are informed of infrastructure, utilities and electrical requirements necessary for installation and start-up in the final quotation.

Installation drawings and site drawings and detailed design information will be provided after the down payment is received in our bank account.

Operation and maintenance manuals spare parts, final, as built drawings and customer training will be provided by C.M.S.T. CO. LTD. upon receipt of final payment.

C.M.S.T. Co. Ltd. is not responsible for lack of site infrastructure, water supply or electrical supply required for installation.

C.M.S.T. Co. Ltd. shall be paid the balance owed at the end of 15 days after delivery of the unit to the customers site weather the installation is completed or not.

C.M.S.T. Co. Ltd. warrants all it's Reverse Osmosis system to be free from defects in materials and workmanship under normal use when operated within the operating parameters specified in the quotation and Operation manual for a period of 1 year from the date of startup at the customers site or the date of shipping if not installed by C.M.S.T. Co. Ltd. . C.M.S.T. Co. Ltd. will repair or replace any part of the Reverse Osmosis System with the exception of the filters, membrane and filter media. The RO membrane carries a 12-month warranty. C.M.S.T. Co. Ltd. Warranties the K&N Fiberglass vessels for 5 years under normal use.

Conditions of Warranty

The above warranty shall not apply to any part of the C.M.S.T. Co. Ltd. Reverse Osmosis System that is damaged because of neglect, misuse, alteration, accident, misapplication, physical damage, fouling, and/or scaling of the membrane by minerals, bacterial attack, sediment or damage caused by fire, freezing, hot water, or an Act of God.
C.M.S.T. Co. Ltd. and K&N Thailand assumes no warranty liability in connection with this Reverse Osmosis System other than as specified herein. C.M.S.T. Co. Ltd. and K&N Thailand shall not be liable for consequential damages of any kind or nature due to the use of C.M.S.T. Co. Ltd. and K&N Thailand products.

SEE the Caution and water requirements on page 7

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Parts Warranty Service

Warranty service will be provided by C.M.S.T. Co. Ltd. under the following conditions:

1) Contact C.M.S.T. Co. Ltd. who will authorize the return.
2) Ship the unit or part freight prepaid to C.M.S.T. Co. Ltd. for warranty evaluation or service. Unit must be packed and protected to prevent possible damage during shipping. Systems or parts covered under the warranty shall be repaired (or, at our option replaced) and returned without charge.

Glossary of Terms

Carbonate Hardness - That hardness in water caused by bicarbonates and carbonates of calcium and magnesium. Carbonate hardness is also called temporary hardness because it can be precipitated by boiling. If alkalinity exceeds total hardness, all hardness is carbonate hardness. If hardness exceeds alkalinity, the carbonate hardness equals the alkalinity.

Concentrate Recycle - In reverse osmosis and electrodialysis applications, a technique for increasing the amount of product water by recycling a fraction of the concentrate stream back though the membrane or membrane stack.

Concentrate Stream - In reverse osmosis applications, the stream into which rejected ions and materials are concentrated.

Conditioned Water - Any water which has been treated by one or more processes (adsorption, deionization, reverse osmosis, etc.) to improve the water's usefulness and/or aesthetic quality by reducing undesirable substances (iron, hardness, etc.) or undesirable conditions (color, taste, odor, etc.)

Conductance - A measure of the ability of a solution to allow an electric current to flow through it; the reciprocal of resistance. The unit of measure for conductance is the mho, which is the reciprocal of the ohm (the unit of measure for resistance). In electrolytic or ionic solutions, the current is carried by ions; liquids such as pure water, glass, and high polymers (such as rubber and cellulose) exhibit poor conductance.

Conductivity - The property of a substance to conduct (carry) heat or electricity; the unit of measure is the mho, which is the reciprocal of the resistivity.

Contaminant - Any undesirable physical, chemical, or microbiological substance or matter in a given water source or supply. 1. Anything in water which is not chemically **water** may be considered a contaminant. 2. Any foreign component present in another substance.

Desalination - The removal of inorganic solids (salts) from a solution, such as water, to produce a liquid free of dissolved salts. Desalination is typically accomplished by distillation, reverse osmosis, or electrodialysis.

Dissolved Solids - The weight of matter, including both organic and inorganic matter, in true solution in a stated volume of water. The amount of dissolved solids is usually determined by filtering water through a 0.45 pore-diameter filter, and weighing the filtrate residue after the evaporation of the water at 180 degrees Centigrade.

Feed Pressure - The pressure at which water is supplied to a water treatment device.

Fouling - In electrodialysis applications, the deposit of organic or other materials on the surface of the electrodialysis membrane surface, causing membrane inefficiencies. In filtration or ion exchange applications, the accumulation of undesirable foreign matter in a filter or ion exchange media bed causing clogging of pores or coating of surfaces and inhibiting or limiting the proper operation of the bed and the treatment system. In reverse osmosis or ultrafiltration applications, a phenomenon in which a reverse osmosis or ultrafiltration membrane adsorbs, interacts with, or becomes coated by solutes and/or precipitates in the feed stream, resulting in a decrease in membrane performance by lowering the flux and/or affecting the rejection of solutes.

Grains Per Gallon (gpg) - A common method of reporting water analysis results in the United States and Canada. One grain per gallon equals 17.1 parts per million, or 17.1 milligrams per liter. Grains per Imperia Gallon equals 14.3 mg/L.

Greensand - A naturally occurring mineral that consists largely of dark greenish grains of glauconite, and which possesses ion exchange properties. Greensand was the original product used in commercial and home cation exchange water softening units and was the base product for manufacturing manganese green sand and Zeolite products.

Hard Water - Water containing total hardness in the amount of one grain per U.S. Gallon (or more) measured as calcium carbonate equivalent.

Hardness - A common quality of water which contains dissolved compounds of calcium and magnesium and, in some cases, other divalent and trivalent metallic elements. Hardness prevents soap from lathering by causing the development of an insoluble, cruddy precipitate in the water. Hardness typically causes the buildup of hardness scale (such as that seen in cooking pans). Dissolved calcium and magnesium salts are primarily responsible for scaling in pipes and water heaters and cause numerous problems in laundry, kitchen and bath applications. Hardness is usually expressed in grains per gallon (or ppm) as calcium carbonate equivalent. The degree of hardness standard as established by the American Agricultural Society of Engineers (S-369) and the Water Quality Association (WQA) is:

Term	Grains/Gallon	Mg/Liter (ppm)
Soft	Less than 1.0	Less than 17.1
Slightly Hard	1.0 to 3.5	17.1 to 60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very Hard	10.5 and Above	180 and Above

Hemodialysis - The process of purifying a kidney patient's blood by means of a dialysis membrane.

Hemodialysis Grade Water - Water which meets the requirements set forth by the American National Standards for Hemodialysis Systems and covered in the Association for the Advancement of Medical Instrumentation (AAMI) standards.

Hydraulic Staging - Multiple passes of water between electrodes used in an electrodialysis or through a sequence of subsequent membranes or filters used in a reverse osmosis or filtration system to achieve further treatment.

Hyper-filtration - A water treatment process in which desalination of water is achieved by forcing salt solutions, under pressure, through a membrane which passes water more readily than salts. An early term for reverse osmosis technology.

Lime Scale - Hard water scale formed in pipes and vessels (more severe in hot water fixtures) containing a high percentage of calcium carbonate ($CaCO_3$) or magnesium carbonate ($MgCO_3$).

Membrane - A thin sheet or surface film, either natural or man-made, of micro-porous structure that performs as an efficient filter of particles down to the size range of molecules or ions. Such membranes are termed "semi-permeable" because some substances will pass through, while others will not. Small ions, water, solvents, gases, and other very small molecules can pass easily through a membrane. Other ions and macromolecules like proteins and colloids are barred. Man-made (synthetic) membranes are highly engineered polymer films about 100 angstroms thick, with controlled distributions of pores ranging from 5 to 5000 angstroms in diameter. Membranes are used in reverse osmosis, electrodialysis, nanofiltration, ultrafiltration, and as pleated final filter cartridges in water treatment.

Micromho - One millionth of a mho. The micromho is the practical unit of measurement for conductivity and is used to approximate the total dissolved solids content of water. Water with 100 mg/L (ppm) of sodium chloride will have a specific resistance of 4,716 ohms-centimeter and a conductance of 212 micromhos per centimeter. Absolute pure water, from a mineral content standpoint, has a conductivity of 0.055 micromhos per centimeter at 25 degrees C. Also called microSieme.

Micron - A metric unit of length equal to one millionth of a meter, or one one-thousandth of a millimeter which equals approximately 0.00003937 inches. The symbol for a micron is the Greek letter mu. A micron is also called a micrometer.

Milligram per Liter (mg/L) - The unit of measure used in reporting the concentration of matter in water as determined by water or wastewater analyses. Since a liter of water weighs one million milligrams, mg/L is used interchangeably with parts per million (ppm) in water analyses.

Module - The membrane element and its housing in a reverse osmosis unit.

Nanofiltration - A membrane treatment process which falls between reverse osmosis and ultrafiltration on the filtration/separation spectrum. The nanofiltration process can pass more water at lower pressure operations than reverse osmosis and removes particles in the 300 to 1,000 molecular weight range (like humic acid, and organic color bodies present in water) and rejects selected (typically polyvalent) salts. Nanofiltration may be used for selective removal of hardness ions in a process known as membrane softening.

Noncarbonate Hardness - Hardness caused by calcium or magnesium existing in compound form with chloride, sulfate, and nitrate anions, rather than with the more common carbonate or bicarbonate anions. Noncarbonate hardness is the excess of total hardness over total alkalinity. High concentration (e.g., as caused by evaporation) of noncarbonate hardness anions can increase the water's corrosivity. The term noncarbonate hardness has largely replaced the term permanent hardness, which has the same meaning.

Osmosis - The natural tendency for water to spontaneously pass-through a semi-permeable membrane separating two solutions of different concentrations (strengths). The water will naturally pass from the weaker (less concentrated) solution containing fewer particles of dissolved substance to the stronger (more concentrated) solution containing more particles of a dissolved substance. The natural osmosis causes the stronger solution to become more diluted, and tends to equalize the strength of the solutions on both sides of the membrane.

Osmotic Pressure - The pressure and potential energy difference which exists between two solutions on either side of a semi-permeable membrane because of the tendency of water to flow in osmosis. Every 100 ppm (mg/L) of TDS generates about one pound per square inch of osmotic pressure. This osmotic pressure must first be overcome by water pressure for a reverse osmosis membrane to become effective.

Part Per Billion (ppb) - A measure of proportion by weight which is equivalent to one unit weight of solute (dissolved substance) per billion unit weights of the solution. This measure is often used as a measure of concentration when analyzing water for contaminants. Since one liter of water weighs one billion micrograms, one ppb is the equivalent of one microgram per liter when used in water analysis.

Part Per Million (ppm) - A measure of proportion by weight which is equivalent to one unit weight of solut e (dissolved substance) per million unit weights of the solution. Since one liter of water weighs one million milligrams, one ppm is equal to one milligram per liter (mg/L). Ppm is the preferred unit of measure in water or wastewater analysis.

Percent Recovery - The percentage of the feedwater which becomes product water. Determined by the number of gallons (or liters) of product water divided by the total gallons (or liters) of feedwater and multiplied by 100. The percent recovery is called recovery rate in reverse osmosis and ultrafiltration applications.

Deleted: feed water

Percent Rejection - In reverse osmosis and ultrafiltration applications, percent rejection is the percentage of total dissolved solids (TDS) in the feedwater that is prevented from passing the membrane with the permeate. It is calculated as the difference obtained from the TDS in the feedwater minus the TDS in the permeate (product water) divided by the TDS in the feedwater, multiplied by 100.

Permeate - That portion of the feedwater which passes through the membrane to become product water.

pH (Potential of Hydrogen) - A measure of the degree of the acidity or the alkalinity of a solution as measured on a scale (pH scale) of 0 to 14. The midpoint of 7.0 on the pH scale represents neutrality, i.e., a "neutral" solution is neither acid nor alkaline. Numbers below 7.0 indicate acidity; numbers greater than 7.0 indicate alkalinity. It is important to understand that pH is a measure of intensity, and not capacity; i.e., pH indicates the intensity of alkalinity in the same way temperature tells how hot something is - but not how much heat the substance carries. * More specifically, pH is the logarithm of the reciprocal of the hydrogen ion concentration in a sol ution. The hydrogen ion concentration is the weight of hydrogen ions, in grams, per liter of solution. In neutral water, for example, the hydrogen ion concentration is 10E -7 grams per liter; the pH is therefore 7. * Since it is hydrogen that is responsible for acidity and alkalinity, the abbreviation pH is believed to stand for either "power of hydrogen" or "potential of hydrogen." The neutral point of 7.0 actually indicates the presence of equal concentrations of free hydrogen and hydroxide ions.

Pharmaceutical Grade Water - The collective term for six types of purified water as defined by the U.S. Pharmacopoeia:

1. Purified Water
2. Water for injection
3. Bacteriostatic water for injection
4. Sterile Water for Inhalation
5. Sterile water for injection
6. Sterile water for irrigation

Pretreatment - Any water treatment step performed prior to the primary treatment process, such as filtration prior to deionization.

Process Water - Water used in a manufacturing or treatment process or in the actual product manu factured. Examples would include water used for washing, rinsing, direct contact, cooling, solution makeup, chemical reactions, and gas scrubbing in industrial and food processing applications. In many cases, water is specifically treated to produce the quality of water needed for the process.

Product Staging - In reverse osmosis applications, the practice of using some of the product water from the first stage of R.O. treatment as feedwater for the second stage.

Deleted: feed water

Reject Water - A term used in distillation, electrodialysis, reverse osmosis, and ultrafiltration applications to describe that portion of the incoming feedwater that has passed across the membrane, but has not been converted to product water and is being sent to the drain. Also called brine, concentrate, or retentate.

Deleted: feed water

Rejection Rate - In a reverse osmosis or ultrafiltration system, rejection rate is (1) the quantity of the feedwater that does not pass through the membrane expressed as a percent of the total quantity of incoming feedwater; or (2) the concentration of contaminants that do not pass through the membrane as a percent of the total concentration of those particular contaminants in the feedwater.

Deleted: feed water

Reverse Osmosis - A water treatment process that removes undesirable materials from water by using pressure to force water molecules through a semi-permeable membrane. The process is called "reverse osmosis" because the pressure forces the water to flow in the reverse direction (from the concentrated solution to the dilute solution) to the flow direction in natural osmosis (from the dilute solution to the concentrated).R.O. removes ionized salts, colloids, and organic molecules down to a molecular weight of 100. May also be called hyperfiltration.

Sand Filter - The oldest and most basic filtration process, which generally uses two grades of sand (coarse and fine) for turbidity removal, or as a first stage roughing filter or prefilter in more complex processing systems. * Municipal water treatment systems often used gravity rapid-rate sand filters. Pressure-type sand filters plus coagulants are used for commercial applications. For home use or for small swimming pools, a pressure sand filter is also commonly used.

Scale - A coating or precipitate deposited on surfaces such as kettles, water pipes, or steam boilers that are in contact with hard water. Waters that contain carbonates or bicarbonates of calcium or magnesium are especially likely to cause scale when heated. Also called hard water scale.

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Silt Density Index (SDI) - A test used to measure the level of suspended solids in feedwater for membrane filtration systems. The test consists of the time it takes to filter 500 milliliters of the test water through a 0.45 micron pore-diameter filter.

Deleted: feed water

Single-Stage R.O. System - A reverse osmosis system in which water is passed through a membrane or membranes only once.

Turbidity - The amount of small particles of solid matter suspended in water as measured by the amount of scattering and absorption of light rays caused by the particles. Turbidity blocks light rays, and makes the water cloudy, or even opaque in extreme cases. Turbidity is measured in nephelometric turbidity units (NTU). Potable water should not exceed 0.5 NTU.

Thin-Film Composite Membrane - A class of reverse osmosis membranes made with polyamide-based polymer and fabricated with different materials in the separation and support layers.

Total Dissolved Solids (TDS) - The total weight of the solids that are dissolved in water, expressed in units of ppm per unit volume of water (mg/L). TDS is determined by filtering a given volume of water (usually though a 0.45 micron filter), evaporating it at a defined temperature (usually 103-105 degrees Celsius) and weighing the residue.

Total Hardness (TH) - The total of the amounts of divalent metallic cations (principally calcium and magnesium hardness), expressed in terms of calcium carbonate equivalent. * See also Carbonate Hardness, Noncarbonate Hardness.

Total Solids (TS) - The weight of all organic and inorganic solids, both dissolved and suspended, per unit volume of water. The weight of total solids in a solution is generally determined by evaporation of a measured volume of water at 105 degrees Celsius in a pre-weighed dish.

Total Suspended Solids - The particles removed from a solution by filtration, usually specified as matter which will not pass through a 0.45 micron pore-diameter filter.

Ultrafiltration - A method of cross-flow filtration (similar to reverse osmosis, but using lower pressures) which uses a membrane to separate small colloids and large molecules from water and other liquids. The ultrafiltration process falls between reverse osmosis and microfiltration processes in terms of the size of particles removed, with ultrafiltration removing particles from the 0.002 to 0.1 micron range and typically rejecting organics over 1000 molecular weight while passing ions and smaller organics.

Ultrapure Water - Highly treated water that is deionized and mineral free, with high resistivity and no organics. It is commonly used in the semiconductor and pharmaceutical industries. Ultrapure is not considered biologically pure (potable) or sterile. There is no set numerical standard to determine exactly what "ultrapure" water is - or should be.

Wastewater - In general, water that has been used, and is being discarded. In reverse osmosis, ultrafiltration, or electrodialysis applications, wastewater refers to the stream of water (not product water) created as a result of the treatment process - the reject water or condensate. In ion exchange or filtration applications, the term refers to the spent water used in the total backwash and/or regeneration cycle.

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Thank You

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