Membrane Desalination Technology

Desalination, or demineralization is a treatment process that removes salt and other minerals from brackish water and seawater to produce high quality drinking water.

Various desalination technologies have been in practice for more than 50 years, with nearly 1500 facilities worldwide, according the International Desalination Association (IDA). Geographically, the greatest number of desalination facilities is in the Middle East, followed by the US for the second greatest number of desal plants.

There are also desalination facilities in North Africa, Singapore, Spain, Thailand, Mexico and the Caribbean Islands.

Most early desalination processes were thermal distillation-type (TD) processes, the

- Multi-stage Flash Distillation;
- Multiple-Effect Distillation; and
- Vapor Compression,

which were common in the Middle East due to the availability of low cost steam at power plants.

Desalination through the use of membranes was introduced in the 1960s as an alternative to distillation. A membrane process is a physical separation process, where salt is separated from seawater or brackish water to produce drinking water.

These included

- Electrodialysis (ED); and
- Reverse osmosis (RO).

ED uses voltage to separate the salts, where RO operates under pressure for the separation process.

ED was determined to desalt brackish water more cost-effectively than thermal distillation processes, which was a breakthrough in the industry at that time.

ED was the first membrane process put into commercial application, even before RO. As mentioned above, ED is a voltage driven process that uses an electrical current to move salts through the membrane, leaving behind freshwater that is collected as the product water. ED is common in brackish water demineralization systems, where most of the dissolved salts are ionic in nature.

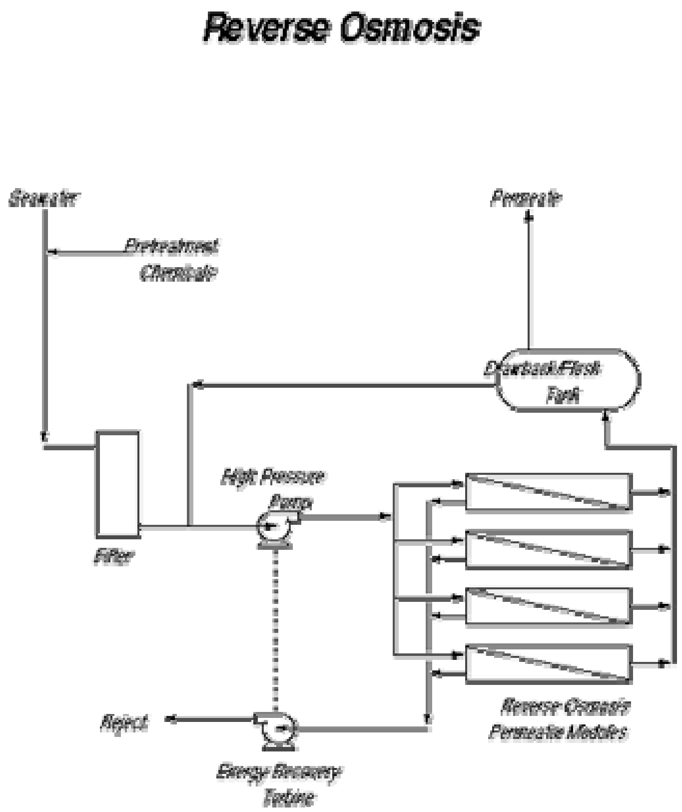
The dissolved ions such as chlorides, sodium, calcium and carbonate move to the electrodes with an opposite electric charge.

ED membranes can also achieve selective passage of either anions or cations. The membranes are arranged with alternating anion-selective membranes followed by cation-selective membranes.

A spacer channel is placed in between each membrane, one carries feedwater, while the next carries the concentrate. The spaces bound by the two membranes are called cells. Each ED unit consists of hundreds of cell pairs, and is called a membrane stack.

RO processes were expensive to operate due to the high-energy requirement of these systems. However, there have been significant improvements to membrane technologies in the past 10 years, which have made reverse osmosis a more viable, cost-effective water supply alternative.

In comparison to TD and ED, RO is relatively new, with the first successful commercial unit installation in the Florida Keys in 1971.



RO is a membrane separation process in which the water from a pressurized saline solution is separated from the solutes (the dissolved material) by flowing through a membrane.

No heating or phase change is necessary for this separation. The major energy required for desalting is for pressurizing the feed water.

In practice, the saline feed water is pumped into a closed vessel where it is pressurized against the membrane. As a portion of the water passes through the membrane, the remaining feed water increases in salt concentration. At the same time, a portion of this feed water is discharged without passing through the membrane.

Without this controlled discharge, the pressurized feed water would continue to increase in salt concentration, creating such problems as precipitation of supersaturated salts and increased osmotic pressure across the membranes.

The amount of the feed water discharged to waste in this brine stream varies from 20 to 70 percent of the feed flow, depending on the salt content of the feed water.

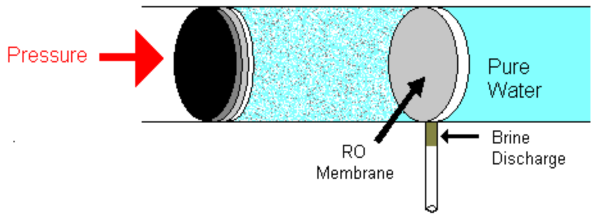
Pretreatment is important in RO because the feed water must pass through very narrow passages during the process. Therefore, suspended solids must be removed and the water pre-treated so that salt precipitation or microorganism growth does not occur on the membranes. Usually the pretreatment consists of fine filtration and the addition of acid or other chemicals to inhibit precipitation.

The high-pressure pump supplies the pressure needed to enable the water to pass through the membrane and have the salts rejected. This pressure ranges from 17 to 27 bar for brackish water and from 54 to 80 bar for sea water.

The membrane assembly consists of a pressure vessel and a membrane that permits the feed water to be pressurized against the membrane. The membrane must be able to withstand the drop of the entire pressure across it. The semi-permeable membranes are fragile and vary in their ability to pass fresh water and reject the passage of salts. No membrane is perfect in its ability to reject salts, so a small amount of salts passes through the membrane and appears in the product water.

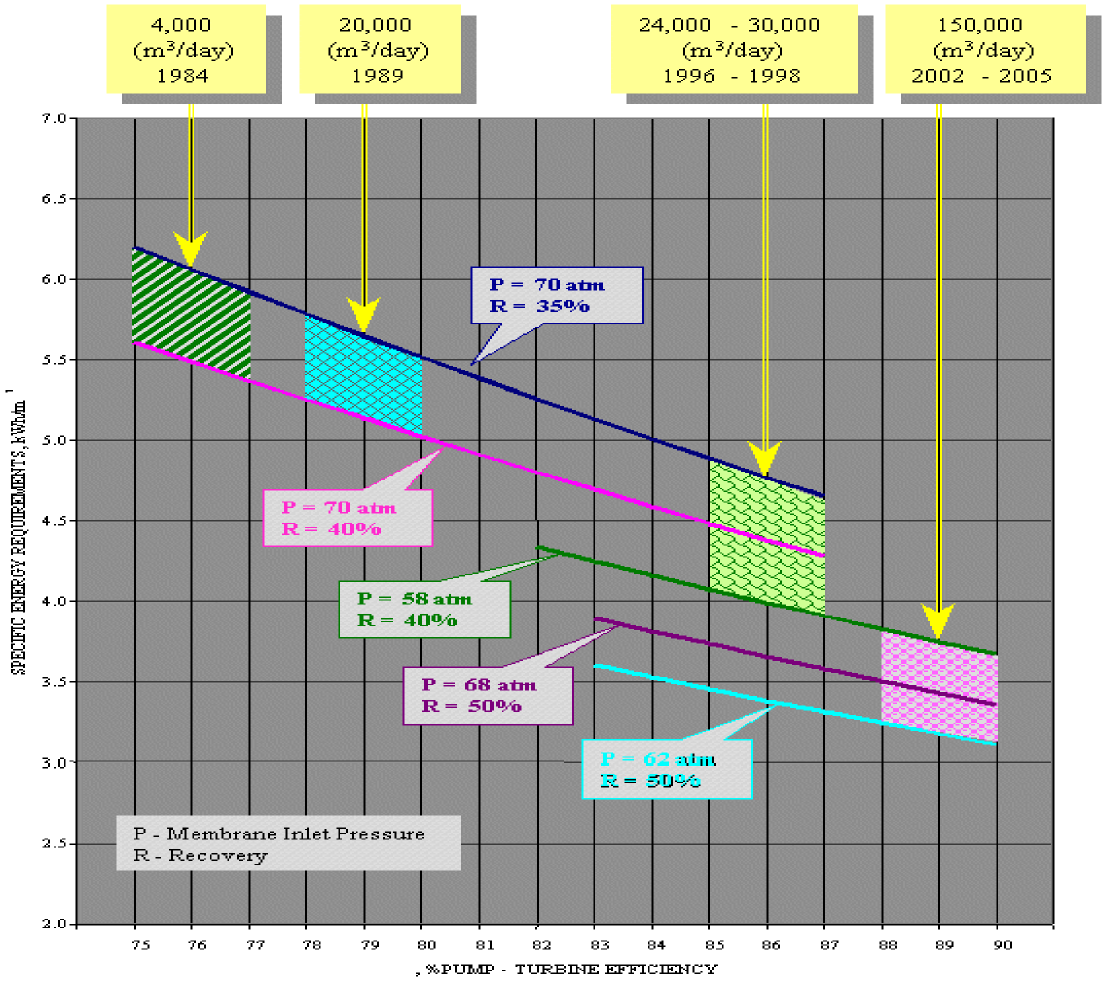
RO membranes are made in a variety of configurations. Two of the most commercially successful are spiral-wound and hollow fine fiber. Both of these configurations are used to desalt both brackish and sea water, although the construction of the membrane and pressure vessel will vary depending on the manufacturer and expected salt content of the feed water.

Post-treatment consists of stabilizing the water and preparing it for distribution. This post-treatment might consist of the removing gases such as hydrogen sulfide and adjusting the pH.



Very important component that affected desalination cost reductions is the significant decrease in unit energy costs, resulting from improvements in pump, membrane and turbine technology for recovery of energy from the reject brine.

This factor, combined with the trend of building larger installations, enabled a reduction in energy requirements in 1998 from 5.5-6.0 kWh/CM to 4.0-4.5 kWh/CM (see attached picture).



Relation between Specific Energy Consumption in Sea Water RO Plants vs. Pump-Turbine Efficiency, Process Pressure and Recovery Factor

This development, together with the lower cost of electricity resulting from the decrease in fuel prices, has led to a 30%-40% reduction in desalination energy costs.

The development of membranes that can operate efficiently with lower pressures and the use of energy recovery devices paid major contribution for reduction of water production cost.

The low-pressure membranes are being widely used to desalt brackish water. The energy recovery devices are connected to the concentrate stream as it leaves the pressure vessel. The water in the concentrate stream loses only about 1 to 4 bar relative to the applied pressure from the high-pressure pump. These energy recovery devices are mechanical and generally consist of turbines or pumps of some type that can convert pressure drop to rotating energy.

The accelerated progress in desalination technologies has substantially lowered drinking water production costs. This factor, together with increased demand and the trend to establish bigger plants, will lead to a reduction in water costs in the coming years.

International research network, with wide-ranging collaboration between research institutions and industry, is targeting to advance research in various aspects of desalination. These projects are likely to accelerate progress in the treatment of polluted brackish waters other than seawater, such as drainage from agricultural and urban waste sources.

A goal of desalinated seawater at 50 US¢ per cubic meter is not a "Mission Impossible", if the planning, preparation and management are carried out properly.