“Capacity Building and Strengthening Institutional Arrangement”

Analysis and sampling of water and water pollution

Optimization of sustainable use of water, including desalination technology

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DESALINATION TECHNOLOGIES

One convenient and useful way to classify desalination processes is to separate them into those which involve a change of phase to separate the pure water from the feed water and those which accomplish this separation without a change of phase

Those in the single-phase category **(membrane process)** include

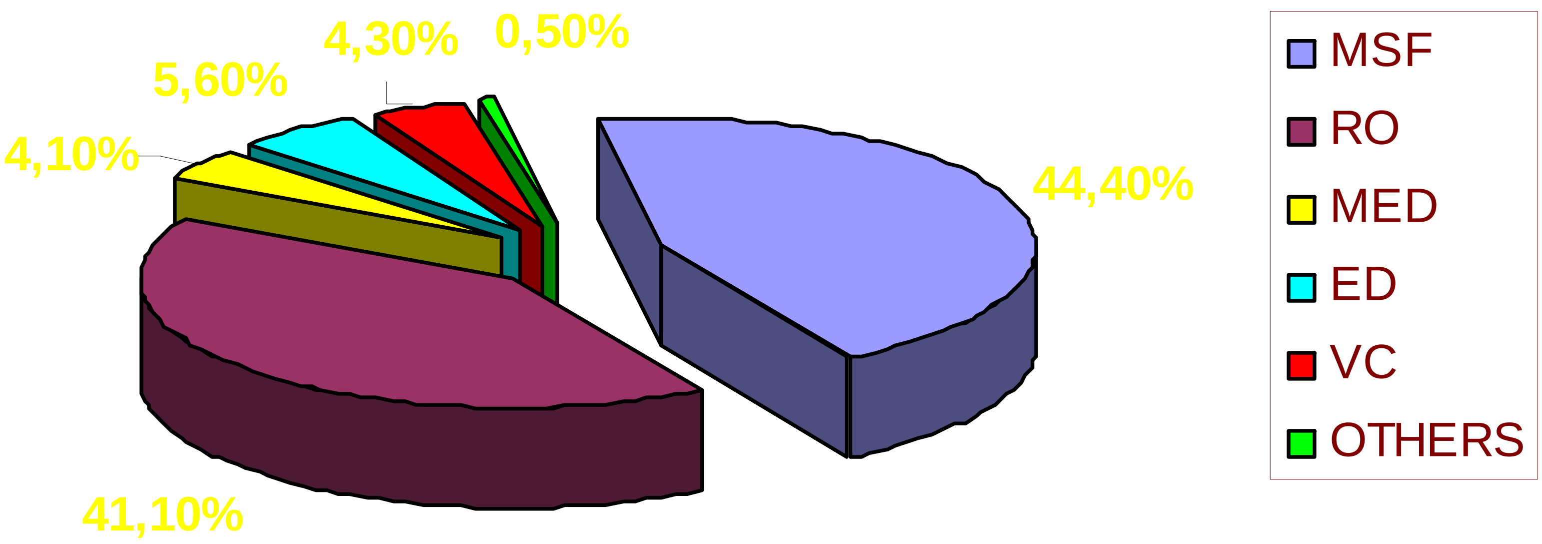
- Reverse Osmosis (RO)
- Electrodialysis (ED)

The phase-change processes **(distillation process)** include:

- Multi-Stage Flash (MSF)
- Multi-Effect Distillation (MED)
- Vapour compression (VC) Thermal and Mechanical
- Solar Distillation

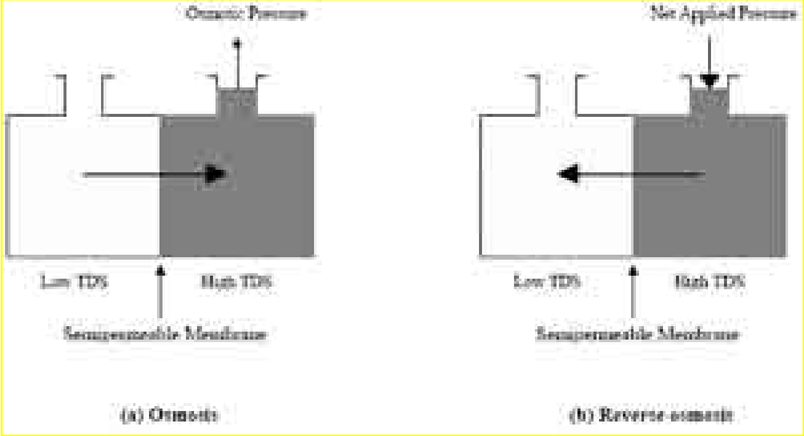
WORLD-WIDE DESALINATION CAPACITY

Global distribution of installed desalination capacity by technologies



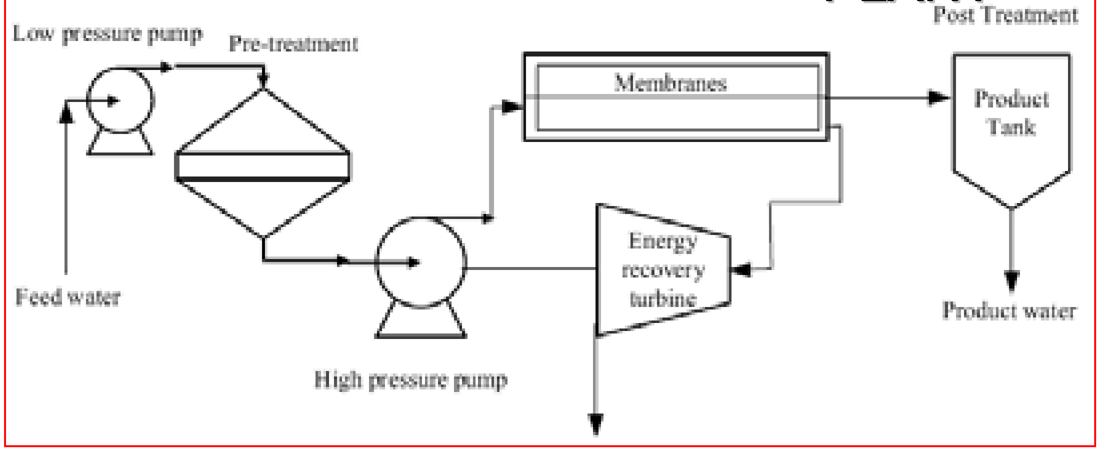
REVERSE OSMOSIS (RO)

Reverse osmosis (RO) is a membrane separation process that recovers water from a saline solution pressurized to a point greater than the osmotic pressure of the solution. Membrane rejects salts, allowing only the water to pass.



Pressurizing the saline water accounts for most of the energy consumed by RO. Since most of energy losses for RO result from realising the pressure of the concentrated brine, large scale RO system are now equipped with device to *recover the mechanical compression energy* from the discharged concentrated stream

SCHEMATIC PRESENTATION OF RO PLANT



RO-ADVANTAGES

- Energy consumption is low
- RO plants are quick and cheap to build and simple to operate
- This process has a high space/production capacity ratio
- It can handle a large range of flow rates due to the modular design of the plant
- The recovery ratio is high therefore the feed water required to produce the same amount of product is limited
- It can remove other contaminants in the water as well as the salt
- There is no need to shut-down the entire plant for scheduled maintenance due to the modular design of the plant. The start up and shut down of the plant does not take long

RO-DISADVANTAGES

- RO membranes are expensive and have a life expectancy of 2-5 years, it is necessary to maintain an extensive spare parts inventory
- The product quality, using seawater, is limited to 300-500 ppm. This salt content is often incompatible with industrial uses.
- RO membranes are very sensitive to fouling caused by suspended solids, plugging, chemical scaling and colloidal material. They require an efficient pre-treatment of the feed water by filtration to decrease turbidity and fouling index, anti-scalant addition to increase solubility of salts of calcium (bicarbonates, sulphates), barium sulphate and strontium sulphate.
- RO membranes are very sensitive to bacterial contamination (biofouling). They require an efficient chemical pre-treatment of the feed water. This contamination would be retained in the brine stream, but bacterial growth on the membrane itself can cause the introduction of tastes and odours into the product water.
- If the plant uses sea water there can be interruption to the service during stormy . This can cause resuspension of particles, which increases the amount of suspended solids in the water.
- The plant operates at high pressure and sometimes there are problems with mechanical failure of equipment due to the high pressure used

RO-MAIN FEATURES

ENERGY NEEDS for 1 m^3 of fresh water produced:

- 1.5 kWh for brackish water
- 6.0 kWh for seawater, without energy recovery systems
- 2.5-4.0 kWh for seawater, with energy recovery systems

RECOVERY FACTOR:

- 70 to 75 % for brackish water
- 40 to 50 % for seawater

OPERATING PRESSURE:

- 15 to 25 bar for brackish water
- 50 to 80 bar for seawater

PRODUCT WATER QUALITY:

- 300-500 ppm

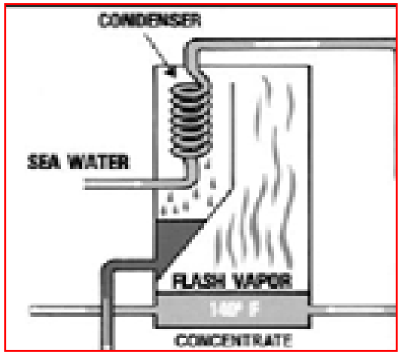
RO-CURRENT TRENDS

Research and development efforts in RO desalination are concentrated on the following aspects

- **decrease sensitivity** of membranes regarding fouling (smoother surfaces, negative charged or neutral membranes);
- **increase rejection** rate of salts;
- **develop new membranes** that would be resistant to oxidising agents
- **improve energy recovery**

MULTI-STAGE FLASH (MSF)

MSF is a distillation process that involves evaporation and condensation of water. The evaporation and condensation steps are coupled so that the latent heat of evaporation is recovered for preheat the incoming water. There are two distinct sections in each stage: the flashing chamber (where the vapors are produced) and the condensing section (where the vapors are condensed)



The MSF process consists of a series of stage in wich “flash” evaporation takes place from brine flowing across the bottom of the stage. The vapour released in flashing, passes through demisters to remove brine droplets anb condenses on heat transfer tubes at the top of the stage. Each stage of an MSF unit operates at a successively lower pressure. The heat to operate the process is supplied by steam condensing in the brine heater.

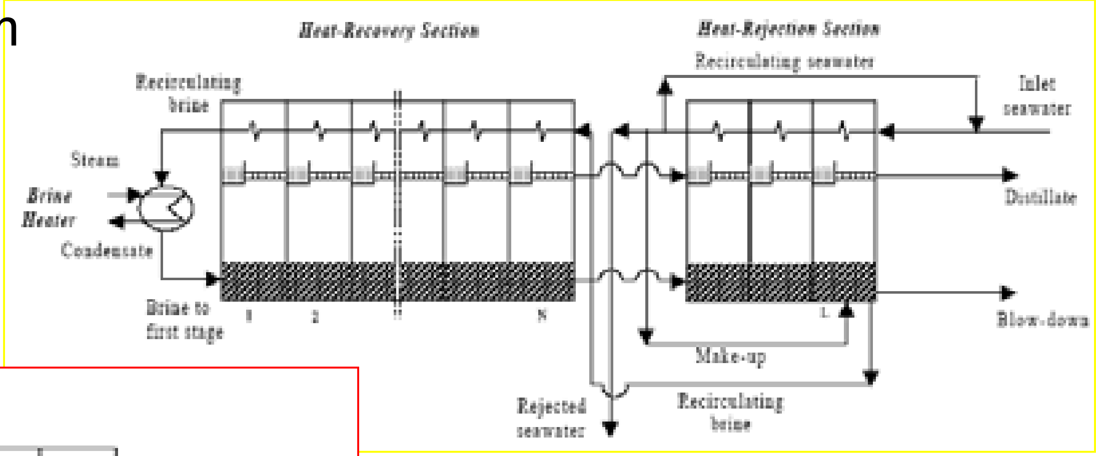
There are tow process arrangements for the MSF process:

- ❑ ONCE-THROUGH DESIGN
- ❑ RECYCLE DESIGN

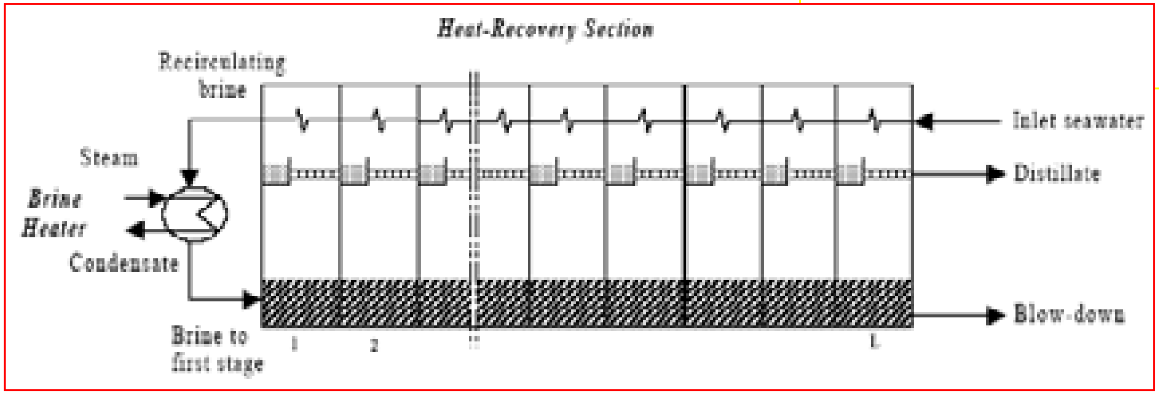
MULTI-STAGE FLASH (MSF)

In **ONCE-THROUGH DESIGN** the feed water is pumped through the recovery section and brine heater, then passes through the flash chambers without recycling.

In **RECYCLE DESIGN** the evaporator is broken into two distinct sections: the *rejection section* and the *recovery section*. The rejection section is the “heat sink” of the process, whereas the recovery section allows to raise the temperature of the recycle stream



ONCE-THROUGH DESIGN



RECYCLE DESIGN

SCHEMATIC PRESENTATION OF MSF PLANT

MSF-ADVANTAGES

- MSF plants can be constructed to handle large capacities
- It produces very high quality product water with a salt content less than 10 ppm
- There is a minimal requirement for pre-treatment of feed water
- The salinity of the feed water does not have much impact on the process or costs
- There is a long history of commercial use and reliability
- It can be combined with other processes, eg using the heat energy from an electricity generation plant

MSF-DISADVANTAGES

- MSF process is highly energy intensive
- MSF plants are expensive to build and operate, requiring a high level of technical knowledge
- The recovery ratio is low, therefore more feed water is required to produce the same amount of product water
- Blending is often required when there is less than 50 ppm in the product water
- The plant can not be operated below 70-80% of the design capacity

MSF-MAIN FEATURES

ENERGY NEEDS ***for 1 m^3 of fresh water produced*** :

- 3.5 to 4 kWh

SPECIFIC THERMAL ENERGY CONSUMPTION:

- 7 to 9 m^3 of fresh water for tonn of steam

RECOVERY FACTOR :

- 8 to 10%

TOP BRINE TEMPERATURE :

- 100-110°C

PRODUCT WATER QUALITY:

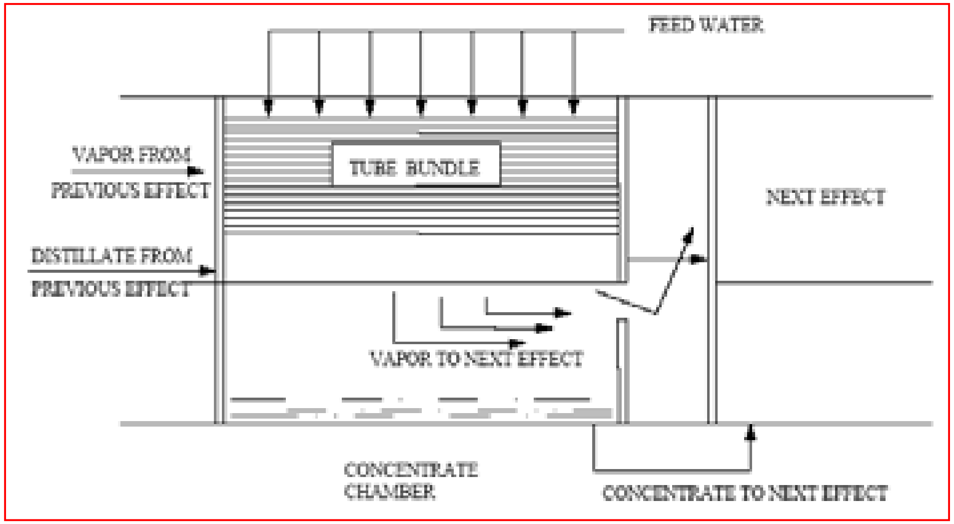
- *<10 ppm*

MULTI-EFFECT DISTILLATION (MED)

This process takes place in a series of ***effects*** (vessels) and uses the principle of reducing the ambient pressure in the successive effects. This causes the feed water to undergo boiling in a series of effects without supplying additional heat after the first effect. Vapor generated in the first effect gives up heat to the second effect for evaporation and is condensed inside the tubes. This continues for several effects. Three arrangements have evolved for MED process:

- ❑HORIZONTAL TUBE ARRANGEMENT
- ❑VERTICAL TUBE
- ❑VERTICALLY STACKED TUBE BUNDLE

SCHEMATIC PRESENTATION OF MED HORIZONTAL TUBE ARRANGEMENT



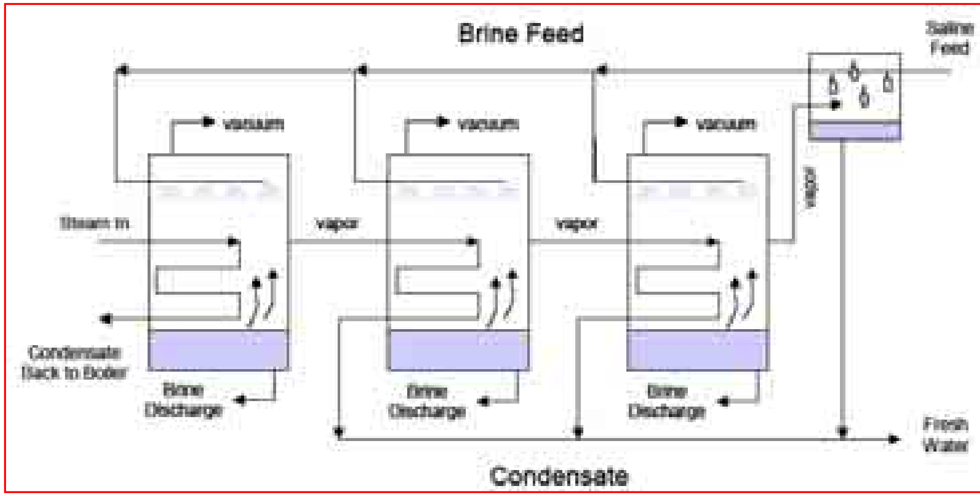
The seawater is either sprayed, or otherwise distributed onto the surface of evaporator tubes in a thin film to promote rapid boiling and evaporation

MULTI-EFFECT DISTILLATION (MED)

It can use **low-temperature, low pressure steam** as the main energy source. The primary steam is used to evaporate heated seawater and to generate more steam at a lower pressure while the primary steam condensate is taken back to the generation chamber, or to the steam generator of the power station. The condensate from the boiler steam is recycled to the boiler for reuse.

The process of producing vapor in each effect and using it to heat the next lower effect, continues throughout all the effects until the vapor from the last effect is condensed in the main condenser. The distillate produced in each effect is joined with the condensate from the main condenser and becomes the product water

SCHEMATIC PRESENTATION OF MED PLANT



MED-ADVANTAGES

- It produces very high quality product water with a salt content less than 10 ppm
- The salinity of the feed water does not have much impact on the process or costs
- Superior thermodynamic efficiency (compared to MSF)
- Development of a unique design of a falling film horizontal tube evaporator gives high heat transfer coefficient
- There is a minimal requirement for pre-treatment of feed water
- Possibility of using low-cost/low grade heat available through cogeneration schemes to minimize the energy cost component.
- The low temperature operation has made possible the utilization of economical and durable material of construction

MED-DISADVANTAGES

- They are expensive to build and operate
- The recovery ratio is low, although not as low as for MSF
- Blending is often required when there is less than 50 ppm in the product water

MED-MAIN FEATURES

ENERGY NEEDS ***for 1 m³ of fresh water produced*** :

- 2.5 to 3 kWh

SPECIFIC THERMAL ENERGY CONSUMPTION

- 5 to 6 m³ of fresh water for tonn of steam

RECOVERY FACTOR :

- 30 to 40%

TOP BRINE TEMPERATURE :

- 60-70°C

PRODUCT WATER QUALITY:

- *<10 ppm*

COMPARISON OF DISTILLATION AND MEMBRANE PROCESS

ADVANTAGES OF USING MEMBRANE OVER DISTILLATION PROCESS

- Membrane plants normally have lower energy requirements
- The capital cost for membrane plants is lower than distillation plants
- Membrane plants generally have higher recovery ratios than distillation plants
- Membrane plants have a high space/production capacity plants
- Membrane plants operate at ambient temperature minimizing the scaling and corrosion potential, which increase with higher temperature

ADVANTAGES OF USING MEMBRANE OVER DISTILLATION PROCESS

- Distillation plants produce higher quality product water than membrane plants
- The performance of membrane plants tend to decline progressively with time due to fouling of the membrane
- Membrane process do not destroy biological substances, unlike distillation process, therefor they must be removed in either pre-treatment or post-treatment if the water must to be used for potable water or process water
- Membrane plants need to be cleaned more regularly than distillation plants
- Distillation plants have been estabilished for a long time and have proven to be a reliable means of desalination
- Distillation plants do not need to be cleaned as often as membrane plants
- Distillation plants only require a minimal amount of operating staff

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DISADVANTAGES OF USING DISTILLATION PROCESS OVER MEMBRANE

- Distillation plants require more feed water for the same amount of product water due to their lower recovery ratio
- Distillation plants have a higher capital cost than membrane plants
- Distillation plants require more room for a given capacity than membrane plants