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Appendix A  
**Glossary of Terminology**



<b>Abstraction</b>	The removal of feed water from its source to the desalination plant.
<b>Anti-scalants</b>	Chemicals that are used to prevent scale formation.
<b>Brackish Water</b>	Water that has a salinity of between 1000-10,000 mg/L TDS.
<b>Brine</b>	Waste water from the desalination process that usually has a high concentration of dissolved salts (see also Concentrate). Brine may also contain chemicals used during pre-treatment and cleaning.
<b>Cartridge Filters</b>	This is a filter with a fine pore size (1-150µm), typically used upstream of RO membranes.
<b>Concentrate</b>	The concentrated salt solution that is produced as a by-product of the desalination process (see also Brine).
<b>Desalination</b>	Desalination is the process of removing dissolved salts from saline or brackish water to make it fit for human consumption or other domestic purposes, or for agricultural industrial or manufacturing purposes. Common types of desalination include distillation, reverse osmosis and electrodialysis reversal.
<b>Distillation</b>	A process of water purification whereby the feed water is heated to produce steam which is then condensed to produce water of a high purity.
<b>Electrodialysis Reversal (EDR)</b>	A membrane process of desalination, similar to electrodialysis except that several times every hour the flow through the cells is switched and the polarity of the electrodes is reversed. Then the product channel becomes the brine channel and the brine channel becomes the product channel.
<b>Electrodialysis (ED)</b>	A desalination process that uses ion selective membranes. These membranes allow the passage of either positively or negatively charged ions. A direct current (DC) electrical field is applied to the feed water. Positively charged ions are drawn towards the negative pole while the negatively charged ions are drawn to the positive pole, leaving behind an ion free (or desalinated) water.
<b>Electrolytes</b>	Compounds that when in solution conduct an electric current and are also decomposed by that current.
<b>Energy Recovery System</b>	A system incorporated in the plant to recover energy from the process to be used in other parts of the process.
<b>Feed Water</b>	The water that is fed to the desalination equipment. This water can be already pre-treated or source water.
<b>Flocculant</b>	This is a chemical that enables suspended particles to clump together, so that they can be settled out of the solution more easily.
<b>Freeze Desalination</b>	A desalination process whereby salt water is frozen to the point where salt water remains in liquid form but the fresh water has frozen. The frozen water is washed to remove salts and is melted to produce product water.
<b>Fresh Water</b>	Water that has a dissolved solids count of less than 500 mg/L TDS.
<b>Ion Exchange Membrane</b>	A desalination process where ion exchange resins or zeolites are used to remove ions from solution. Membranes which contain embedded ion exchange resins that allow progress of ions with like charges but rejects ions of opposite charge and



water.

**Latent Heat of Condensation**

The amount of heat energy released when vapour is turned into water.

**Mechanical Vapour Compression (MVC)**

A form of distillation. A portion of feedwater is evaporated, and the vapour sent to a compressor. Mechanical energy is used to compress the vapour, which increases its temperature. The vapour is then condensed to form product water and the released heat is used to evaporate the feedwater.

**Membrane Distillation**

This is a form of distillation desalination that also uses membranes.

**Microfiltration (MF)**

A membrane filtration process which only allows small particles through the membrane. It removed colloidal particles, bacteria and suspended solids. MF will not remove ions (salts).

**Multiple Effect Distillation (MED)**

A form of distillation desalination. Evaporators are arranged in series containing hot vapour that is used to condense and produce product water. The vapour from one chamber ('effect') is used to heat the next effect thereby reducing overall energy requirements.

**Multistage Flash (MSF)**

A form of distillation desalination. Feed water is heated and sent to a vessel that is slightly below saturation vapour pressure so that some of the water flashes and forms vapour. This vapour condenses and becomes product water. The salt water is sent to another vessel at a lower pressure where the flashing process is repeated.

**Nanofiltration (NF)**

A membrane filtration process that uses loose RO membranes. These have a lower rejection capability than RO membranes and therefore leak more soluble ions, but can obtain higher recoveries.

**Organic chemicals or compounds**

Chemicals or compounds containing carbon atoms combined with hydrogen and often also with oxygen, nitrogen and other elements. They can be small or large and complex in structure. Organic compounds include substances made by living organisms, plant and animal residues or they can be synthetic.

**Organic contaminants**

Organic chemicals which are toxic to organisms; they may be persistent and mobile in the environment.

**Osmosis**

The natural movement of water from a diluted solution to a more concentrated solution. The movement of water molecules through a thin membrane while leaving the dissolved salts behind, the process occurs in our bodies and is also a technical and commercial method of removing salts from saline water.

**Osmotic Pressure**

The pressure required for the osmotic process to equalise.

**Permeate**

The purified water that membrane desalination processes produce.

**pH**

A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale ranges from 0 to 14.

**Polishing**

This is an end process, where product water undergoes some more processing to refine it to meet high quality product requirements.

**Potable Water**

Water that is considered suitable for human consumption.



<b>Product Water</b>	The fresh water that is discharged from the desalination process.
<b>Recovery</b>	The percentage of the feed water that is recovered in the desalination process as fresh product water.
<b>Rejection</b>	The percentage of solids that the desalination process removes from the feed water.
<b>Reverse Osmosis (RO)</b>	A membrane desalination processes where pressure is applied to feed water so that it moves through a semi-permeable membrane. RO removes ionic and molecular sized substances.
<b>Salinity</b>	The measure of total soluble (or dissolved) salt, ie. Mineral constituents in water. Water resources are classified on the basis of that salinity, measured in terms of mg/L total dissolved salts (TDS).
<b>Scale</b>	The substance that precipitates onto the surface of a desalination plant during the desalination process.
<b>Sea water</b>	Water containing on average 35 grams per litre sodium chloride (table salt), this is the primary dissolved salt. Seawater also contains other types of salts.
<b>Solar Humidification</b>	A desalination process where solar power is used to heat saline water so that some of it evaporates, and the vapour is then condensed and collected as product water.
<b>Suspended Solids (SS or TSS)</b>	Solids, including colloidal material, that are suspended in solution. Turbid water has a high concentration
<b>Thermal Distillation</b>	The method of removing salt from water using thermal energy.
<b>Total Dissolved Solids (TDS)</b>	TDS consists of inorganic salts and small amounts of organic matter that is dissolved in water. Clay particles, colloidal iron and manganese and silica may contribute to TDS if they pass a 0.45µm filter.
<b>Turbidity</b>	The clouding of the solution because suspended materials in the solution reduce the transmission of light.
<b>Ultra-filtration (UF)</b>	This process uses membranes to selectively filter molecules of a particular size and weight. It sits between membrane filtration (MF) and nanofiltration (NF).
<b>Vacuum Freezing</b>	A desalination process that involves the temperature and pressure of the feed water being lowered until the water freezes to form ice. This is then washed and then melted to produce the product water.
<b>Vapour Compression (VC)</b>	A desalination process where some of the feed water is evaporated and then compressed with mechanical or thermal energy where it condenses and is collected as product water. The latent heat released in the condensation process is used to evaporate more feed water.

Appendix B

# Desalination Technologies

## B1 Overview of Desalination Technologies

Desalination is the process of removing dissolved salts from saline or brackish water to make it fit for human consumption and other domestic purposes, or for agricultural and industrial or manufacturing purposes. It is widely utilised globally and is very common in water scarce areas such as the Middle East. Technologies for desalination include membrane processes, thermal distillation and ion exchange. Membrane and thermal distillation processes are the most commonly applied technologies in large desalination plants.

This section provides an overview of currently available desalination technologies.

### B1.1 Thermal Desalination Technologies

#### B1.1.1 Principle

Thermal desalination technologies rely on distillation processes to remove fresh water from salty water. Saline feedwater is heated until it boils, causing fresh water to evaporate as steam. The steam is then collected and allowed to cool (or condense) to form fresh water. Salt and other contaminants will not evaporate; rather they remain behind in a highly salty solution called brine. The brine solution is considered a waste or by-product of the desalination process and will require disposal.

There are three main thermal desalination technologies, each adopting the above process principle:

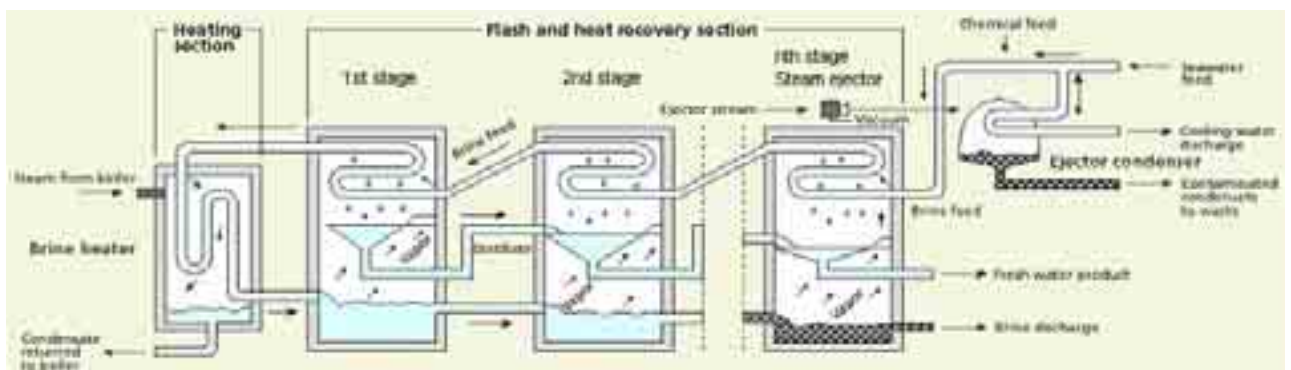
- ▶ Multistage Flash Distillation
- ▶ Multi Effect Distillation
- ▶ Vapour Compression Distillation

The above technologies vary generally by the way in which distillation is achieved. These distillation technologies are described in further detail below.

#### B1.1.2 Multistage Flash Distillation (MSF)

##### *Description*

The multistage flash distillation (MSF) process is schematically represented in Figure B-1.



**Figure B-1: Schematic representation of MSF Process (AFFA, 2002)**

In a MSF system, the cool saline feedwater enters the process at the same stage that fresh water and brine water exits. The saline water flows counter-currently through the flash chambers to the brine and

freshwater streams. The saline feed water is cooler than the brine solution and steam, and as it passes through each stage it gradually heats up, while causing the steam within each stage to condense.

After passing through all the flash chambers, the saline feedwater (now called the brine feed) is fed into a brine heater, where it is heated by steam generated from an external heat source. The brine solution returns to the first stage, where the ambient pressure is lower. The lower pressure causes the water component of the brine solution to immediately boil and flash into steam. The water vapour passes through a demister pad, to remove any brine droplets, before condensing against the incoming feed stream. The condensate (or fresh water) is then collected and delivered to the next stage. This process is repeated in each stage. Typically MSF plants contain 15 –25 stages depending on the volume of product required.

### **Process Characteristics**

- ▶ Sources of feedwater that can be treated: most saline feedwaters can be treated. For economic reasons MSF facilities are typically used for the desalination of highly saline waters such as seawater.
- ▶ Yield of fresh water vs. feed is ~ 25-50 % in modern MSF plants (AFFA, 2002).
- ▶ Capacity typically 4,000-57,000 m<sup>3</sup>/d (Buros, 2000).



**Figure B-2: Aerial view of a large MSF Distillation Plant**

- ▶ TDS product water quality typically ~ 50 mg/L. Such water tends to be slightly acidic due to absence of alkalinity (calcium carbonate) making it potentially corrosive. This water may be blended with brine to raise salinity and buffering salts to acceptable level for a drinking water supply. Further, with mixing, the cost per kilolitre of product water may be reduced. Alternatively pH correction and stabilisation with chemicals such as lime will be required. See Appendix D1.3 for a more detailed description.
- ▶ Top brine temperature 90°-110° C while higher temperature increases efficiency also increases scaling by CaCO<sub>4</sub>.
- ▶ A by-product of the distillation process is a brine solution, which has high levels of salt. The costs to manage and dispose of the brine solution can be high and require careful consideration when designing and selecting distillation processes.
- ▶ In Australia the majority of thermal distillation is undertaken within coastal communities, as source waters with high TDS concentrations are uncommon further inland. Thermal facilities operate at higher efficiencies than membrane technologies when desalinating seawater, generating smaller volumes of brine. In addition to this, the infrastructure requirements and costs associated with brine



disposal via ocean outfalls is often less than those experienced with inland facilities, assisting in the minimisation of brine disposal costs.

**Economic and Energy Considerations**

MSF plants are generally constructed to handle large streams of highly saline water (typically seawater). Capital and operating costs are not influenced by salinity levels in the feed water, with the cost of treating brackish water being on par with the cost of treating seawater. Cost efficiencies can be achieved for larger plants, where large economies of scale can be employed.

The high salinity levels in feedwater and brine solutions and the high operating temperature increase the potential for corrosion and scaling. The high capital costs are mainly attributed to the need for special corrosive resistant materials to be used in construction.

- ▶ Capital Costs: Range from: A\$ 2,000-3,800 per kL/day of production capacity (Semiat, 2000)).
- ▶ Operational Costs: dependant on energy costs.

Electrical and thermal energies are both required to power MSF plants. The electrical demands are generally restricted to operating ancillary equipment such as pumps. Thermal energy, in the form of steam, is the primary energy source required by MSF plants.

The average energy requirements are:

- ▶ Electrical Energy (kWh/kL): 3.25 – 3.75
- ▶ Thermal Energy (kW/kL): 6.75 – 9.75

Thermal energy costs can be substantially reduced if a suitable waste heat source can be located within close proximity of the MSF plant.

**Advantages and disadvantages of MSF Facilities**

**Table B-1 MSF Facilities – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ Process is insensitive to initial feed concentrations and the presence of suspended solids (Van der Bruggen and Vandecasteele, 2002).</li> <li>▶ Well-proven technology. MSF plants are the oldest method of desalination in use and a lot of process improvement has been undertaken on this process.</li> <li>▶ Feedwater salinity does not influence costs.</li> <li>▶ It produces a high quality product water.</li> <li>▶ Pretreatment requirements are minimal.</li> <li>▶ Product water temperatures above 70°C, render the water sterile, thereby reducing the need for disinfection.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Energy intensive process. Heating of water is expensive due to the high specific heat of water and low recovery rates (less than 50%).</li> <li>▶ Inflexible. The plant cannot be operated below 70% of its design capacity.</li> <li>▶ Anti-scalants are required as the high operating temperatures (110 °C) results in CaSO<sub>4</sub> precipitation (Buros, 2000).</li> <li>▶ The large production of brine due to its low process efficiency can cause waste disposal problems.</li> <li>▶ High operating and maintenance costs.</li> </ul>

MSF plants are usually only used for very large scale operations due to the high capital cost and energy cost. Furthermore to be economical MSF plants rely on the availability of inexpensive energy sources.

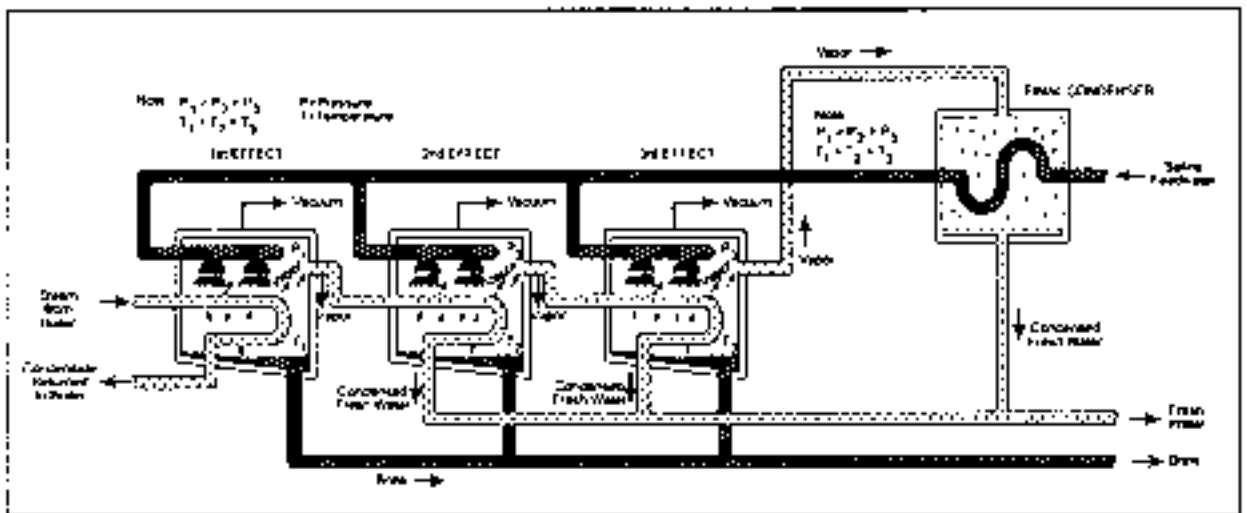
**Trends in MSF Technology**

MSF plant suppliers are investigating new types of corrosion resistant construction materials to reduce plant capital costs. Effort is also being put into using chemicals (to reduce scaling) to allow operation at higher temperatures.

**B1.1.3 Multi Effect Distillation (MED)**

**Description**

MED processes use the same principles of heating and evaporation as MSF processes (described in Appendix B1.1.2), however the process configuration is slightly different to that of MSF. The majority of the evaporation is achieved by boiling (as opposed to flashing), however condensation and evaporation occur at reduced ambient pressure in the various effects (vessels), by applying a vacuum system.



**Figure B-3: Schematic representation of a MED process (Buros, 2000)**

The saline feedwater enters the process after exchanging heat with the product stream in the final condenser. Feedwater is distributed (sprayed) evenly over the heat exchange area in each effect. The sprayed feedwater heats up as it comes into contact with the hot tubes conveying vapour (or process steam in the first effect) from the previous effect. Pure water contained within the feedwater is then vaporised, with the vapour being collected and directed to the next stage. As the vapour passes through each stage, its heat is transferred to the brine solution, causing the vapour to cool and condense. The condensate from each effect is collected to form the product water stream. The process is shown in Figure B-3.

A typical MED plant will comprise of between 8-16 effects (Buros, 2000).



### **Process Characteristics**

Characteristics important for comparison:

- Sources of feedwater that can be treated: The MED can be fed by most saline feed stocks. Similar to MSF plants, MED plants are generally used to desalinate seawater.
- Yield of fresh water vs. feed is ~ 40-65 % in MED plants (AFFA, 2002).



**Figure B-4: Aerial view of a large Multi Effect Distillation Plant**

- Capacity typically 2,000-20,000 kL/d (Buros, 2000), though can be used for production capacities as low as 120 kL/d.
- TDS of product water typically <10 mg/L (AFFA, 2002).
- Most plants operate at a top brine temperature 70 ° C to minimise scaling.
- The cost of brine disposal is an integral component in the selection of a desalination technology. In Australia the majority of thermal distillation is undertaken within coastal communities, as source waters with high TDS concentrations are uncommon further inland. Thermal facilities operate at higher efficiencies than membrane technologies when desalinating seawater, resulting in smaller volumes of brine. In addition to this, the infrastructure requirements and costs associated with brine disposal via ocean outfalls, are often less than those experienced with inland facilities, assisting in the minimisation of brine disposal costs.
- As with MSF, blending / post treatment processes are required to reduce the corrosiveness of the product water. A disinfection stage is needed when product water is utilised for potable purposes. A more detailed description of these treatment processes is outlined in Appendix D1.3 and D1.5

### **Economic and Energy Considerations**

As with the MSF process, MED plants are considered feasible for large product water requirements (economy of scale) and the desalination of highly saline feedwaters.

- Capital costs range from: A\$ 2,500-3,900 per kL/day of production capacity (AFFA, 2002). These capital costs represent direct capital costs, 20-30% should be added to cover engineering and contingency costs.
- Operating cost: The operating cost range from A\$ 1.8-2.8 per kL/day of product water for MED plants not using waste heat and from A\$ 0.55-0.95 per kL/day of product water for MED plants using waste heat. The cost only represents the desalination operating costs, and post treatment and transportation costs need to be incorporated (AFFA, 2002).



MED plants require both thermal and electrical energy source, with thermal energy required to drive the process and electrical energy to operate ancillary equipment. The average energy requirements for MED plants are:

- ▶ Electrical Energy (kWh/kL): 2.5 – 2.9
- ▶ Thermal Energy (kW/kL): 4.5 – 6.5

The power consumption of MED plants is considerably lower than MSF plants. The lower energy consumption is due in part to the higher freshwater yields achieved by MED plants.

***Advantages and disadvantages of MED Facilities***

**Table B-2 MED Facilities - Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ Pre-treatment requirements are minimal. Anti-scalants are still required, however the lower operating temperature means they are less critical. It is also advisable to reduce suspended solids.</li> <li>▶ Product water quality is very high.</li> <li>▶ The technology is well proven and reliable.</li> <li>▶ Operating costs are dramatically decreased when waste heat sources can be used..</li> <li>▶ The costs of the plant are relatively insensitive to the level of salinity.</li> <li>▶ The process can tolerate less than optimal maintenance levels.</li> </ul>	<ul style="list-style-type: none"> <li>▶ The capital and energy costs are high (though lower than MSF).</li> <li>▶ Complex design and operation required.</li> <li>▶ The product water may require cooling in some instances before it can be used.</li> <li>▶ Inflexible operation, as the plant cannot be operated below 70% of its design capacity.</li> <li>▶ The recovery (at 40-65%) is still low.</li> </ul>

MED processes are mostly used in large-scale processes, in association with an inexpensive energy source or a source of waste heat. The economy of scale advantage of this technology is relatively large (although not as large as for MSF). As it operates at lower temperatures, the process is ideally suited to effectively use waste heat.

***Trends in MED Technology***

The following trends are being experienced with MED technology:

- ▶ Research into falling film MED processes is being carried out. This will reduce pumping requirements, allow for higher heat transfer efficiencies and reduce pressure differentials.
- ▶ Chemical dosing to allow higher operating temperatures.
- ▶ Higher thermal efficiencies to reduce fuel and energy costs.
- ▶ Investigating opportunities for hybrid plant configurations.

### B1.1.4 Vapour Compression Distillation (VC)

#### Description

Vapour compression distillation (VC) differs from MED and MSF technology in that it uses a compressor to produce enough heat to evaporate pure water from a saline solution.

As illustrated in Figure B-5 the incoming saline feedwater is pre-heated from the waste brine solutions and product water. Once heated the feedwater is combined with a recirculating brine solution before being sprayed onto tubes containing condensed fresh water vapour. Heat released by the vapour as it is compressed is used to vaporise pure water from the saline feedwater. Vapour produced during this heat transfer is demisted and compressed in a mechanical (MVC – Mechanical Vapour Compression) or steam (TVC – Thermal Vapour Compression) driven compressor. Part of the brine is recycled to achieve higher efficiencies. The VC process can be seen as a one-effect MED in which the product stream is recycled. This configuration gives a high level of thermal efficiency. The MED process generally incorporates several effects.

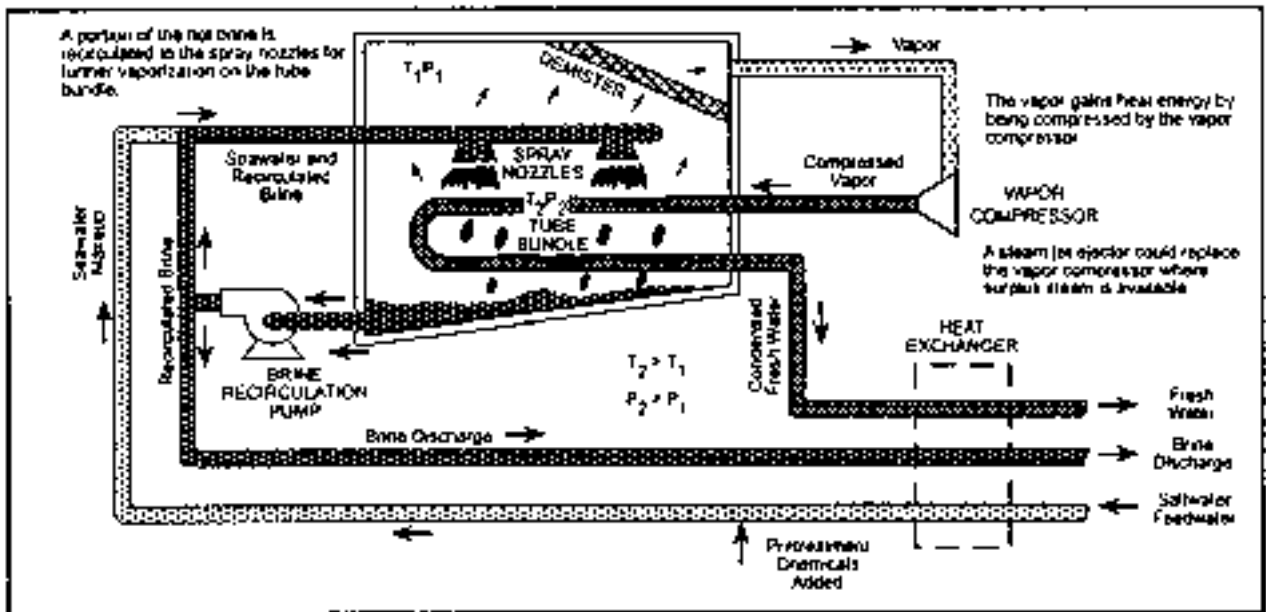


Figure B-5: Schematic representation of the vapour compression (VC) distillation process (Buros, 2000)

### **Process Characteristics**

- ▶ Sources of feedwater that can be treated: VC can be fed by most saline feed stocks.
- ▶ Yield of fresh water vs. feed is ~ 50 % (AFFA, 2002).
- ▶ Capacity ranges from a few litres to 8000 m<sup>3</sup>/d (AFFA, 2002).



**Figure B-6: View of a large Vapour Compression Distillation Plant**

- ▶ TDS product water typically ~10 mg/L (AFFA, 2002).
- ▶ Operating temperatures below 70 °C are possible.
- ▶ A by-product of the distillation process is a brine solution, which has high levels of salt. The costs to manage and dispose of the brine solution can be high and require careful consideration when designing and selecting distillation processes.
- ▶ The cost of brine disposal is an integral component in the selection of a desalination technology. In Australia the majority of thermal distillation is undertaken within coastal communities, as source waters with high TDS concentrations are uncommon further inland. Thermal facilities operate at higher efficiencies than membrane technologies when desalinating seawater, generating smaller volumes of brine. In addition to this, the infrastructure requirements and costs associated with brine disposal via ocean outfalls is often less than those experienced with inland facilities, assisting in the minimisation of brine disposal costs.
- ▶ As with MSF and MED technologies VC distillation requires blending / post treatment processes to reduce the corrosiveness of the product water. A disinfection stage will be needed when product water is utilised for potable purposes. A more detailed description of these treatment processes is outlined in Appendix D1.3 and D1.5.

### **Economic and Energy Considerations**

- ▶ Capital costs range from: A\$ 1,600-1,700 per kL/day of production capacity (Semiat, 2000).
- ▶ Operating Costs: depends on energy costs.

Energy requirements for vapour compression systems are relatively low (compared to the other thermal desalination processes). Mechanical vapour compression systems can also be run using only electrical energy. If waste steam sources are available it is possible to compress the vapour using steam driven compressors.



The typical energy requirements for a mechanical vapour compression system (MVC) are:

- ▶ Electrical Energy (kWh/kL): 9.5 – 17
- ▶ Thermal Energy (KW/kL): Not applicable.

**Advantages and Disadvantages of VC Facilities**

**Table B-3 VC Facilities – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ Pre-treatment requirements are minimal. Some chemicals for scale prevention have to be added, but because of the low temperature scaling is greatly reduced.</li> <li>▶ Product water quality is very high.</li> <li>▶ Simple operation.</li> <li>▶ Potential to blend high quality product waters with brackish waters to reduce overall costs.</li> <li>▶ Second most popular desalination technology in the Australia behind reverse osmosis.</li> <li>▶ VC processes are very compact and can be designed to be portable.</li> </ul>	<ul style="list-style-type: none"> <li>▶ They require an auxiliary heater for start up.</li> <li>▶ The recovery is low at 50%.</li> <li>▶ No economy of scale because of the need for larger or extra compressors, which are the most costly piece of equipment.</li> </ul>

The VC process is ideally suited for small-scale operations for producing fresh water, as it is compact and highly reliable. VC processes can be designed to be portable, which can be an advantage when being used by several councils.

**B1.2 Membrane Based Desalination Technologies**

**B1.2.1 Principle**

Membrane based desalination technologies use exclusion membranes to separate fresh water (containing low salt levels) from saline waters. Feedwater is brought to the surface of a membrane, which selectively passes water but excludes the salts. The technology is relatively young compared with thermal technologies with the first plants coming into operation during the early 1960's (using the electro dialysis method) and early 1970's (using the reverse osmosis method) (Buros, 2000).

The two most common membrane based desalination processes (reverse osmosis and electro dialysis) will be further explained below.

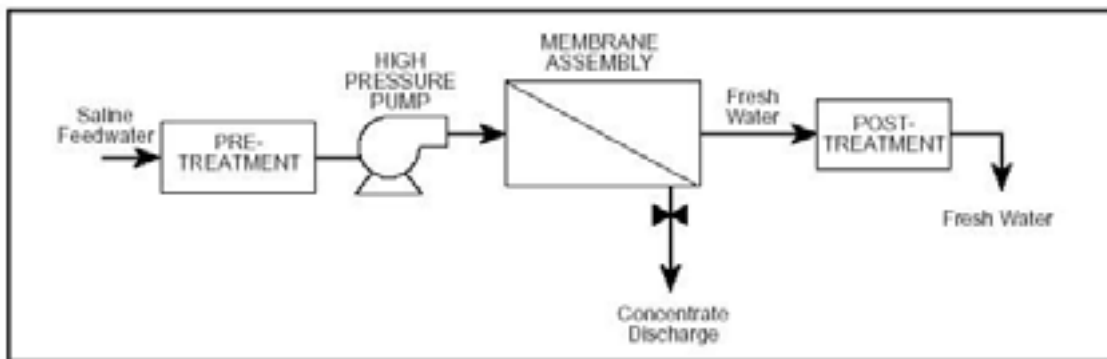
## B1.2.2 Reverse Osmosis (RO)

### Description

If two compartments of water are separated by a semi permeable membrane, one having a high concentration of salt and one a low concentration, the two compartments will, after being connected to each other, exchange water from the less saline to more saline until equilibrium is reached. This phenomena is called osmosis and osmotic pressure is what drives the saline solution to the less saline solution.

The reverse osmosis process relies on applying enough pressure to overcome the osmotic pressure and drive the solution through a membrane. The membrane will only allow the passage of clean water through it, leaving a highly saline solution (brine) behind.

The key components in a RO plant are shown in Figure B-7 below.



**Figure B-7: Schematic representation of the reverse osmosis process (Buros, 2000)**

The pre-treatment stage is very important for membrane processes, as the membranes are very susceptible to fouling and clogging, which in turn affects their performance. The type and level of pre-treatment required will depend on the quality of the feed water, membrane type and configuration. Refer to Appendix C for a more detailed description on pre-treatment processes. Typical pre-treatment steps include:

- ▶ Removal of suspended solids by filtration.
- ▶ Dosing of anti-scalants to prevent the scale formation on the membrane surface.
- ▶ Dosing of biocides to prevent the growth of biofilms, which may clog membrane surfaces.

RO membranes typically require replacement every 3 to 5 years. The frequency of membrane replacement depends on the degree of pre-treatment and process optimisation. Membrane life span is increased when the process is optimised and pre-treatment requirements are adequately assessed. Effective pre-treatment also improves recovery rates and minimises the need for cleaning.

Once pre-treated, the feed is pressurized via a high pressure pump and directed to the membrane pressure vessel. The pressure vessel consists of a high-pressure vessel containing a number of membranes, usually either hollow fibre or spiral wound (GHD, 2003). Here the pressurized feed is separated into a brine solution and a fresh water stream. The brine solution is retained on the out side of the membranes, while the clean water is allowed to pass through the membrane and trapped inside.



The fresh water stream generally undergoes post-treatment, to remove gasses (eg H<sub>2</sub>S, CO<sub>2</sub>) adjust the pH and recover alkalinity and disinfection. The post-treatment requirements for any specific application will depend on the final use of the product water. Appendix D provides details regarding post-treatment process.

Membranes are not totally impermeable to salts, so the product water will usually contain up to 500 mg/L of TDS (AFFA, 2002). This is only applicable to single pass membrane units treating seawater and is much lower for brackish waters.

### **Process Characteristics**

Characteristics important for comparison:

- ▶ RO processes can handle most feedwaters, but the process becomes less efficient and the costs increase as salinity levels in the feedwater increase.
- ▶ Brackish waters can result in recoveries of 70% or greater, while seawaters efficiencies are generally in the order of 35 – 45%.
- ▶ Capacity ranges from a few litres to 20 ML/d per train. Multiple trains can be used to meet product water requirements.
- ▶ Membrane processes operated near ambient temperatures, the pressures applied are very high ranging from 15 to 25 Bar for brackish water and from 54-80 Bar for seawater (Buros, 2000).
- ▶ TDS concentrations achievable in product water ranges from 20 mg/L (brackish water) to 500 mg/L (seawater).



**Figure B-8: Aerial view of a large Reverse Osmosis Plant**

Higher TDS means a higher osmotic pressure and therefore the pressure required to overcome osmotic pressure increases, resulting in increasing capital and operating costs. The efficiency decreases as the salt content in feedwater increases as the salt concentration in the brine solutions can only increase to the point at which precipitation is reached. In general RO processes cannot be used at feedwater TDS concentrations higher than 50,000 mg/L (in comparison thermal techniques can go up to 500,000 mg/L TDS) (Water Korea, 2002).

### **Economic and Energy Considerations**

Capital and operating costs for RO plants are dependent on the raw water feed quality and quantity of product water required. Capital and operating costs generally increase with increasing TDS levels in the feedwater. Other factors that affect RO costs include:

- ▶ Recovery ratios – Increased recovery ratios most often result in increased operating costs. These elevated costs are due to greater technical requirements, high design standards and increased



chemical costs and volumes. An exception to this occurs when concentrate disposal by volume is extremely expensive.

- ▶ Suspended Solids and Turbidity in feedwater – unless the feedwater contains low levels of suspended solids and turbidity, pre-treatment in the form of filtration may be required. Pre-filtration can add approximately 10-15% to the capital cost.
- ▶ A by-product of the RO process is a brine solution, which has high levels of salt. The costs to manage and dispose of the brine solution can be high and require careful consideration when selecting RO processes.
- ▶ The capital costs of RO range from A\$ 700-1000 per kL of production capacity for brackish waters, to A\$ 1,700-2,400 per kL/d of production capacity for seawater (AFFA, 2002). It should be noted that the capital costs discussed here only cover direct construction costs associated with the desalination plant and pre-treatment requirements.
- ▶ Operating costs range from: A\$ 0.65-1.50 per kL of product water using brackish water as feedstock and from A\$ 1.89-2.20 per kL/day of product water using seawater. These costs only relate to direct RO costs as the costs for pre and post-treatment are very site specific. (AFFA, 2002).

RO plants are powered exclusively by electrical energy. Typical energy requirements for RO processes are:

- ▶ Electrical energy (kWh/kL) for brackish waters: 1.0 – 2.5
- ▶ Electrical energy (kWh/kL) for seawater: 3.5 – 8.5

The energy requirements for RO plants can be reduced by employing energy recovery devices, such as energy recovery turbines, energy recovery turbochargers, work exchanger energy recovery and pressure exchanger energy recovery systems. These energy recovery devices work by regaining part of the pressure energy in the brine waste stream. This regained energy is directed back into the system and utilised to power the high-pressure pumps.

### ***Advantages and Disadvantages of RO Facilities***

**Table B-4 RO Facilities – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ The construction and operation of RO plants are simple and relatively low-cost (AFFA, 2002).</li> <li>▶ The plant capacity can be increased, by simply adding extra modules.</li> <li>▶ Only part of the plant has to be shut down to facilitate maintenance, as the modules can be maintained separately.</li> <li>▶ RO processes can be designed to be compact and portable.</li> <li>▶ The efficiency can be high if brackish water is used ~ 80%.</li> </ul>	<ul style="list-style-type: none"> <li>▶ There is limited economy of scale as increasing production means adding new modules.</li> <li>▶ The most expensive equipment item (the membranes) has the lowest life expectancy 2-5 years.</li> <li>▶ Pressurized equipment items require special materials to cope with the high pressures.</li> <li>▶ RO plants are less reliable because failure can occur due to improper pre-treatment or the high pressures applied.</li> <li>▶ Pilot plants and/or good historical seasonal</li> </ul>



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used ~ 80%.

water quality data is required to guarantee a well designed plant.

- ▶ Production capacity is sensitive to water temperature. A 10% increase in temperature results in a 3% drop in production capacity (Water Corporation, 2000).
  - ▶ RO systems do not cope well with widely fluctuating raw water quality.
- 

RO plants have the potential to gain higher efficiencies than thermal plants and are less costly in their energy requirements and are specifically suited for small-scale operation. They are on the other hand more maintenance intensive and less reliable than thermal plants and the costs are strongly influenced by the TDS concentration of the feedwater.

#### ***Future Trends in RO Technology***

Significant reductions in energy costs for seawater desalination have been achieved over the last 40 years. Energy consumption has dropped from 26.5 kWh/kL to 4.5 kWh/kL. Further reductions are expected with future energy consumption rates of 2.9 kWh/kL (Water Corporation, 2000). Other improvements expected in the future include:

- ▶ Improvements in rejection and recovery rates.
- ▶ Improved flux rates.
- ▶ Greater fouling resistance.
- ▶ Increased membrane life spans.
- ▶ Improvements in pre-treatment technologies.
- ▶ Improved energy recovery options.

A High Efficiency Reverse Osmosis (HERO™) system has reportedly been developed that is capable of achieving 95% recoveries. The patented HERO process is a three step system comprising of:

1. An ion exchange system to remove scale forming ions (water softening)
2. Membrane degasification step to remove the buffering effect of carbon dioxide.
3. RO.

#### **B1.2.3            Electrodialysis (ED)/Electrodialysis Reversal (EDR)**

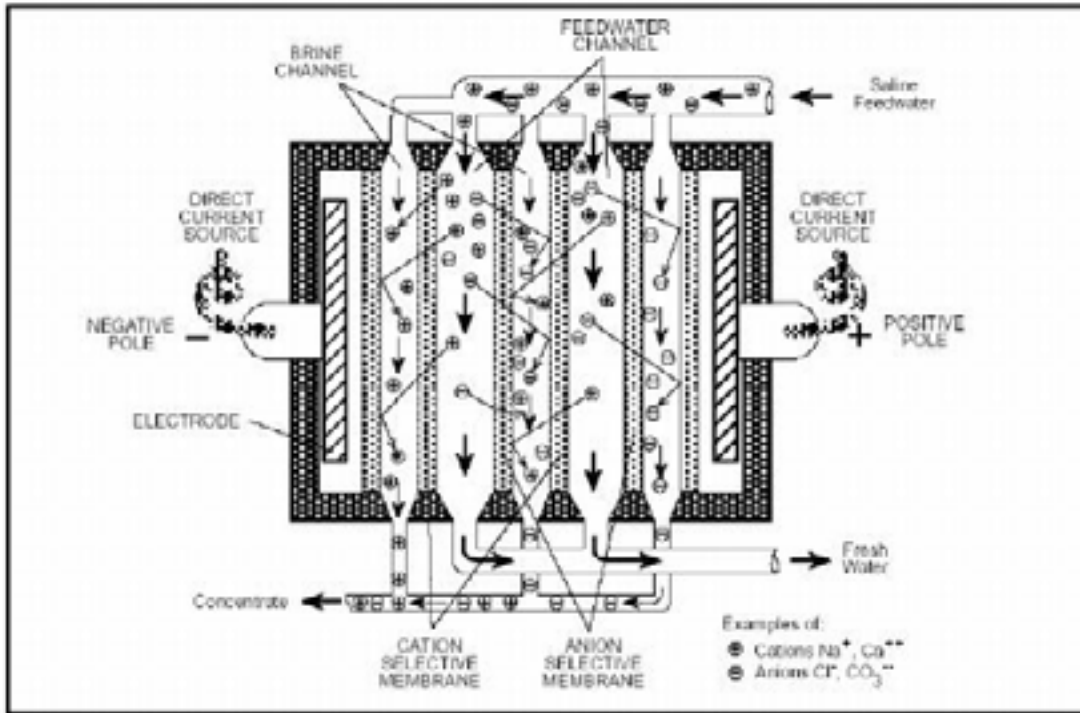
##### ***Description***

The driving force in electrodialysis (ED) desalination process is an imposed direct current (DC) electrical field rather than pressure. Most salts that contribute to salinity in water are present in ionic form:

- ▶ Positively charged cations such as  $\text{Ca}^{++}$  (calcium) and  $\text{Na}^+$  (sodium)
- ▶ Negatively charged anions such as  $\text{Cl}^-$  (chloride) and  $\text{HCO}_3^-$  (bicarbonate)

When a DC electric field is imposed on water, the positive ions are attracted to the negative pole (cathode) and the negative ions are attracted to the positive pole (anode).

In an ED cell, a series of anion and cation selective membranes are inserted alternatively between two poles, as shown below in Figure B-9.



**Figure B-9: Schematic representation of membrane stack (Buros, 2000)**

Saline feedwater is inserted into the various compartments separated by membranes. Under the influence of the DC field, anions pass through an anion selective membrane towards the positive pole. However once the anion has passed through the anion selective membrane, it is confronted by a cation selective membrane. The cation selective membrane prevents the anion from travelling further towards the positive pole, the negative pole prevents the anion from travelling back through the anion selective membrane. The anion is then trapped between the anion selective and cation selective membranes. The cations similarly follow a similar path, ending up in a cation rich compartment. The result is chambers for ion rich water (brine solution) and ion depleted water (product water).

It should be noted that electrodesalination is only effective at removing ionic particles. Non-ionic particles, micro-organisms, and turbidity are not removed by the process and will still remain in the product water.

As with RO, pre-treatment is necessary. ED membranes are susceptible to scaling and fouling. Pre-treatment is also necessary to prevent clogging of the narrow channels between membranes. Should the channels clog up the residence times (or time the feedwater spends inside the chamber) increases and the feedwater will become highly desalinated. This increases the resistance of the water to current flow and increases the cost of maintaining the electrical field and decreases process efficiency. Refer to Appendix C for further details regarding pre-treatment.

ED processes were first developed in the 1960s. During the 1970's the first electrodesalination reversal (EDR) process was commercially introduced. The EDR process works on the same principles as the ED

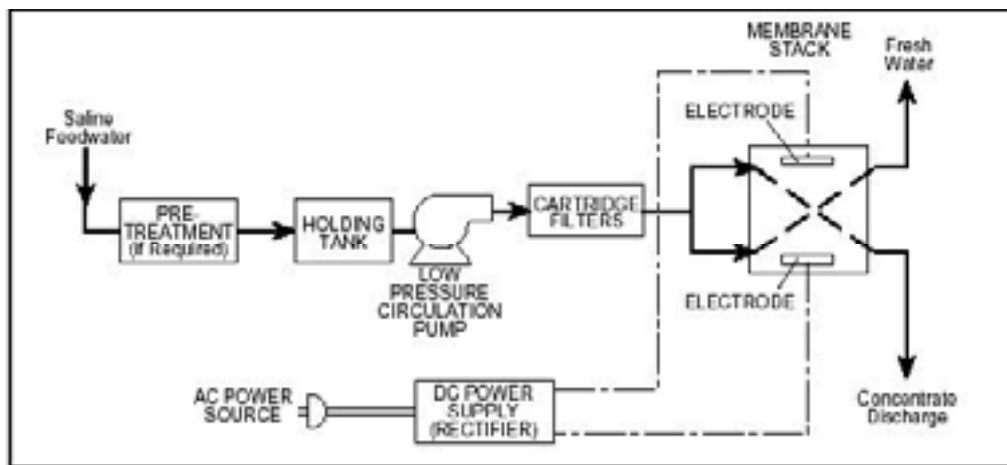
process – that is using anion and cation selective membranes to remove ionic material from saline waters. The key difference is that several times an hour, the polarity of the poles is reversed and the flow channels are switched (ie the brine channel becomes the product channel and visa versa). It takes approximately 1-2 minutes for the product water to reach adequate quality after reversal. The product water during this time is disposed of or recycled back into the process.

The reversal process of EDR aids in breaking up and flushing out scale, slimes and other deposits. When the polarity is reversed, the chemical reactions at the electrodes are also reversed. Reactions at the negative electrode include the production of hydroxide, which raises the pH of the water resulting in calcium carbonate precipitation (scale). Reactions at the positive electrode produce acid, oxygen and some chlorine. The acid tends to dissolve any calcium carbonate present. This automatic cleaning process allows the units to operate with fewer pre-treatment chemicals, minimises membrane fouling and reduces the time intervals between system disassembly for cleaning.

Post treatment for drinking water use is also necessary for both ED and EDR to remove gases, stabilise the water for corrosion control (adjust pH and recover alkalinity) and for disinfection. Appendix D provides further information regarding post-treatment requirements.

EDR membranes and electrodes need to be regularly replaced to ensure the desalination continues to function effectively. The life span of EDR membranes typically ranges from 5 to 10 years, however evidence suggests membranes can last for more than 10 years under some operating conditions (pers comm. Terry Fagg). EDR electrodes also need to be replaced every 10,000 to 20,000 operating hours.

Figure B-10 provides a schematic representation of the ED process.



**Figure B-10: Schematic representation of the Electrodialysis process (Buros, 2000)**

**Process Characteristics**

Characteristics important for comparison:

- ▶ ED(R) processes can handle most feedwaters, including seawater. Treatment of feed waters with a TDS above 2000 mg/L becomes more expensive than RO processes. The process becomes more costly than other desalination processes when a feed water TDS exceeds 12000 mg/L.



- ▶ Product water can be treated to contain TDS levels as little as 60 mg/L but it is usually most economical down to 84% removal of the source water TDS. However TDS facilities operate very well at about 60% TDS removal.
- ▶ ED(R) processes only remove ionic contaminants. Non-ionic substances and bacteria are not removed (AFFA, 2002).
- ▶ ED is actually very susceptible to scaling unless a lot of antiscalant is used. EDR's potential for scaling is considerably less. EDR is comparable with RO for waters with TDS < 3000 mg/L with high scaling potential.
- ▶ The product water TDS concentration is variable, depending on the current applied and the residence time. It is desirable for the TDS not to fall too low due to conductivity problems in the water at low TDS.
- ▶ Membrane processes operated near ambient temperatures and the pressure is ~3.5 bar (GHD, 2003). The pressure applied is only necessary to push the feed through the channels.

***Economic and Energy Considerations***

- ▶ The capital costs range from A\$ 570-3,250 per kL/day of production capacity (AFFA, 2002). The capital costs only include direct capital costs, not indirect capital costs (engineering, contingency etc).
- ▶ The operating cost range from A\$ 1.00-2.80 per kL/day of product water. Only operating costs for desalination are incorporated (AFFA, 2002).

Energy requirements of EDR processes are dependant on the quantity of salt being removed. As a rule of thumb 1kWh is required to treat 1kL of feed water containing 1500mg/L TDS. An additional 0.5kWh is required for each additional 1000mg/L of removed ions (IDA, 2002).

ED(R) becomes uneconomical with feedwater TDS concentrations above 12,000 mg/L.

***Advantages and Disadvantages of ED(R) Facilities***

**Table B-5 ED(R) Facilities – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ The capacity can be increased by simply adding extra modules.</li> <li>▶ During maintenance only part of the plant has to be shut down because the modules can undergo maintenance separately.</li> <li>▶ High efficiency ratios are possible: ~90 %</li> <li>▶ Membranes are less susceptible to fouling than RO - The presence of suspended solids does not influence the process itself, although channel clogging should be prevented. Pre-treatment is less critical as for RO but still necessary.</li> </ul>	<ul style="list-style-type: none"> <li>▶ There is virtually no economy of scale because increasing production simply means adding new modules.</li> <li>▶ The most expensive equipment items (the membranes) can last up to 10 years in a well looked after plant, but electrode life is inversely proportional to TDS removed. This is better than RO but not as good as thermal facilities.</li> <li>▶ Periodic chemical cleaning of the membranes is necessary.</li> <li>▶ The process only removes ionic salts and not</li> </ul>



- 
- ▶ Chemical consumption rates for pre-treatment are less than for RO. other contaminants.
  - ▶ The process can be operated at ambient pressure and temperature.
  - ▶ ED(R) processes are effective at treating high scalant waters with a TDS < 3000 mg/L
  - ▶ Very suitable for portable desalination units
- 

ED(R) depends on a source of electrical power and therefore is best situated near a power grid or a power generator has to be incorporated.

## **B1.3 Other Desalination Technologies**

### **B1.3.1 Solar Humidification**

#### ***Description***

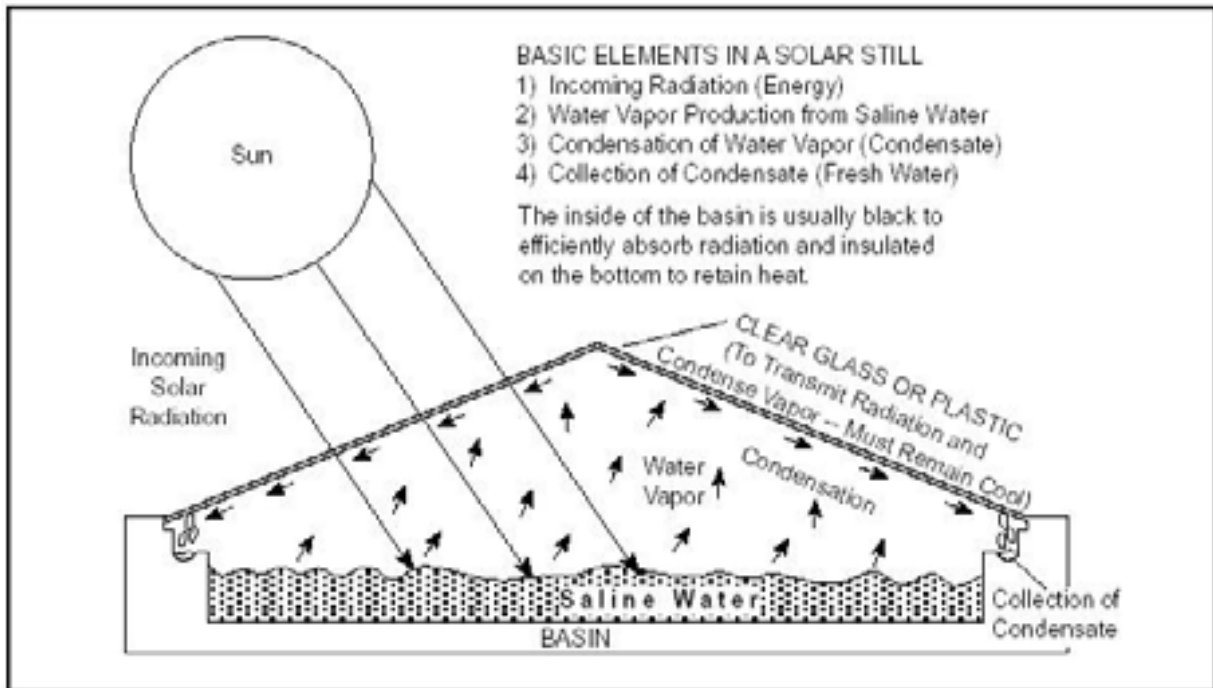
Solar humidification is probably the oldest desalination technique available. The principles of solar humidification have been adopted by a number of companies to produce various processes – one of which is called the solar still.

The solar still essentially uses the solar heat (from the sun) to evaporate pure water from a basin of saline water. The water vapour is condensed and collected under a sloping clear glass or plastic roof. The pure water (or product water) runs down the incline roof to be collected and made available. The process is best illustrated in Figure B-11.

#### ***Process Characteristics***

Characteristics important for comparison:

- ▶ In principle every feedstock can be used in this process. No pre-treatment is necessary, the basins will require cleaning and maintenance due to scaling etc.
- ▶ The recovery efficiency is variable and highly dependent on solar strength and residence time. As a rule of thumb, 1 m<sup>2</sup> of solar collection area gives 4 litres per day of fresh water production (Buros, 2000);
- ▶ The technology is best suited to small-scale plants. Larger capacity plants are often limited by the large area requirements. Using the above rule of thumb, 12.5 hectares is required to produce 500 m<sup>3</sup>/day.
- ▶ The TDS concentration of the product water is comparable to the MSF and MED processes.
- ▶ It operates at ambient temperatures and pressure.



**Figure B-11: Schematic representation of a solar still (Buros, 2000)**

***Economic and Energy Considerations***

- ▶ The capital costs are high. No special materials have to be used, but large production rates mean large glasshouse buildings or many solar stills. The amount of materials used in construction makes it capital intensive. Consideration should also be given to weather patterns in the area that may damage the solar still.
- ▶ The operating costs of solar humidification processes are high as well. Because of the large area and proneness to weather damage the maintenance requirements are high.
- ▶ Energy requirements are low, energy consumption is limited to the operation of pumps (Buros, 2000).

Because of the low technology requirements, the requirement of large land areas and the high requirement for manual labour, solar stills are ideally suited for use in developing countries.

***Advantages and Disadvantages of Solar Humidification***

**Table B-6 Solar Humidification – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ The capacity can be increased by simply adding extra solar stills.</li> <li>▶ TDS and suspended solids do not have an effect on the process itself, although increasing TDS and suspended solid concentrations does increase the</li> </ul>	<ul style="list-style-type: none"> <li>▶ There is virtually no economy of scale because increasing production simply means adding new modules.</li> <li>▶ The production capacity is dependent on the amount of sunshine available. Solar stills are only appropriate in areas with a lot of</li> </ul>



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**Advantages**

- maintenance requirements.
- ▶ Small energy requirements.
- ▶ The technology is simple.
- ▶ The process can be operated at ambient pressure and temperature.

**Disadvantages**

- sunshine.
  - ▶ They require a large surface area.
  - ▶ The manual maintenance requirement is high.
  - ▶ The installations are prone to weather damage.
- 

**B1.3.2 Freezing*****Description***

During the process of freezing ice-crystals are formed. These crystals naturally exclude salts from their structure. Cooling saline water under controlled conditions can therefore produce fresh water. A lot of research effort went into this process in the 1950's and 1960's, but did not result in an economically viable process (Buros, 2000). A number of plants were built over the years, but the freezing process as desalination process has not been an economical success.

Theoretically the freezing process is more energy efficient than distillation processes. Furthermore the corrosion and scaling problems are much reduced as compared to distillation processes (MSF, MED) (Buros, 2000).

***Process Characteristics***

Characteristics important for comparison:

- ▶ In principle every feedstock can be used in this process. There is a reduced need for pre-treatment.
- ▶ The process requires careful control and therefore skilled operators.
- ▶ The energy requirements are high.
- ▶ It operates at low temperatures.

The freezing process is more suited for the treatment of industrial waste than for the production of fresh water from saline water because of its ability to remove all harmful constituents (AFFA, 2002).

***Economic and Energy Considerations***

- ▶ Capital costs are high, mainly due to the need for specialist equipment to handle ice and water mixtures, which are considered complex materials.
- ▶ The operational costs are high as well, considering the need for skilled personnel and the high energy cost.
- ▶ Energy requirements are high (AFFA, 2002).



## ***Advantages and Disadvantages Freezing Facilities***

**Table B-7 Freezing Facilities – Advantages and Disadvantages**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>▶ It has a theoretically lower energy consumption than distillation processes.</li> <li>▶ It clears the water of all contaminants.</li> <li>▶ The TDS concentration does not have a large impact on process performance.</li> <li>▶ The corrosion and scaling problems are much smaller.</li> </ul>	<ul style="list-style-type: none"> <li>▶ The process requires careful control and skilled personnel.</li> <li>▶ The capital costs are large due to the need for special pumps to transport the mechanically complex mixture of ice and water.</li> <li>▶ Limited operating experience is available on the use of freezing for desalination.</li> <li>▶ Due to low operating temperatures required, the process is not suited for use in high temperature conditions.</li> </ul>

The process becomes more economical as the size of plant increases (like the distillation processes). Small-scale operation is considered relatively expensive.

### **B1.3.3 Membrane Distillation**

#### ***Description***

This is a novel desalination process combining distillation and membranes. Saline water is heated to increase the formation of water vapour. This vapour passes through a membrane, which is only permeable to water vapour. It condenses on a cool surface on the other side of the membrane. The fresh product water is unable to pass back through the membrane, as the membrane will only allow the passage of vapours. This enables the product water to be easily collected.

#### ***Process Characteristics***

Characteristics important for comparison:

- ▶ Membrane distillation units can treat most saline feed stocks.
- ▶ Maximum efficiencies are comparable to those of a MED plant: ~40-65%.
- ▶ TDS product water typically ~50 mg/L. Such low TDS concentrations are unacceptable for potable water and can be increased to 500 mg/L by intermixing (blending) product water with brine or other suitable water sources. Appendix D1.3 discusses this further. Blending of product and waste stream can reduce the cost per litre of product water.

To date the membrane distillation technology has only been used on small-scale plants, as it has not been proven as an economic success.

#### ***Economics and Energy Considerations***

Since the process was only implemented on small-scale there is only limited data relating to the process economics. However it can be expected, that for large-scale production, the capital cost per unit



production will be reduced with the size of the plant. The capital costs as compared to the MSF and MED process might be higher because of the use of membranes, which are expensive. The energy requirements can be low, but at low temperatures the production and the efficiency are reduced. The energy requirements will therefore only be slightly less than for MSF and MED. This process may be of interest where there is a source of low-grade thermal energy available (AFFA, 2002)

**Advantages and Disadvantages of Membrane Distillation**

**Table B-8 Membrane Distillation – Advantages and Disadvantages**

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>▶ Pre-treatment requirements are minimal. Some chemicals for scale prevention have to be added, but this is not as critical as for MSF because of the lower temperatures. It is advisable to reduce the suspended solids.</li> <li>▶ Product water quality is very high.</li> <li>▶ The process is very simple and easy to operate (Buros, 2000).</li> <li>▶ The economics improve when combined with other plants utilizing their waste heat.</li> <li>▶ The costs of the plant are relatively insensitive to the level of salinity.</li> </ul>	<ul style="list-style-type: none"> <li>▶ The capital costs are high as are the energy costs, although lower than for MSF. The energy costs are high for achieving a reasonable efficiency.</li> <li>▶ The process has not been well proven, it has only been used in a couple of small-scale plants.</li> <li>▶ The membrane increases the space necessary and increases the capital costs (AFFA, 2002).</li> <li>▶ The recovery ratio (efficiency) is at 40-65 % still low although not as low as MSF.</li> </ul>

**B1.3.4 Hybrids**

Hybrid technologies are desalination systems that combine two technologies. They can for example be the combination of a MSF system and a RO system. One benefit offered by hybrid systems is that they can better match the availability of various energy sources in the community. For example the RO system can be used when electricity needs in the community are low, and the MSF plant can be used when electrical requirements of the community rise and the electrical demand of the RO unit cannot be met. The key disadvantage however is that two different systems have to be built. In general hybrid systems are only economical in exceptional circumstances.

**B1.3.5 Co-generation**

Cogeneration is not a desalination technique as such, but rather the combination of a power plant with a desalination plant. When properly designed, the total amount of energy used by both plants will be far less than when they are operated alone. The power plant uses high-grade steam to power the generators for the production of electricity. The power plant then wastes a low-grade steam, which can be used in a MED desalination process.

The advantage of this set-up is the higher thermal efficiency that can be gained. A disadvantage however is that the power plant has to run all the time to provide power to the MED process. When there is no need for electricity the power plant will slow production or shut down, which also means the desalination plant will stop operation. This intrinsic link between electricity production and water



production can cause problems. Another obstacle that often needs to be overcome is the fact that different agencies govern the generation of electricity and the production of water.

In practice cogeneration plants are not frequently utilised (Buros, 2000).

Appendix C  
Pre Treatment



## C1 Pre Treatment Methods

Pre-treatment plants typically precede desalination systems to improve the quality of water being fed into desalination systems, protect desalination equipment and increase the overall desalination efficiency.

This has flow on effects in terms of reduced capital and operation and maintenance costs.

This section describes typical pre-treatment requirements for thermal and membrane processes.

## C2 Characterising the Feedwater

Source (feed) water analysis is necessary to characterise key contaminants that will impact on desalination performance and therefore determine pre-treatment requirements. At a minimum, the most common elements for which water quality data is required for the assessment and design of membrane systems are total dissolved solids (TDS), pH, alkalinity, hardness, free carbon dioxide, silica (SiO<sub>2</sub> – total and reactive), sludge density index (SDI), total organics (TOC), temperature; colour, turbidity, suspended solids, metals (iron, manganese, aluminium), hydrogen sulphide (in some ground waters) and the following anions and cations

**Table C-1 Ions of Concern**

Cations		Anions	
Calcium	Ca <sup>++</sup>	Hydroxide	OH <sup>-</sup>
Magnesium	Mg <sup>++</sup>	Carbonate	CO <sub>3</sub> <sup>-</sup>
Sodium	Na <sup>+</sup>	Bicarbonate	HCO <sub>3</sub> <sup>-</sup>
Potassium	K <sup>+</sup>	Chloride	Cl <sup>-</sup>
Barium	Ba <sup>++</sup>	Sulfate	SO <sub>4</sub> <sup>-</sup>
Strontium	Sr <sup>++</sup>	Nitrate	NO <sub>3</sub> <sup>-</sup>
		Fluoride	F <sup>-</sup>
		Phosphate	PO <sub>4</sub>

The sampling program used to characterise the feedwater must be designed such that the analytical results accurately reflect the feedwater source. The following points should therefore be considered:

- ▶ The sampling program should be designed such that seasonal variations in feedwater quality are identified.
- ▶ Care should be taken to ensure that samples of groundwater sources represent operating conditions (i.e. make sure that the pump well has been adequately flushed before samples are collected).
- ▶ Care is also required to ensure that the water samples are accurately preserved and the analytical results are representative of the actual feedwater quality.

Characterisation of feedwaters also aids in the most appropriate selection of desalination equipment.



## C3 Thermal Desalination

The most common reason for pre-treatment in thermal desalination system is the prevention of scale. Scale formation reduces desalination efficiency by increasing the resistance to heat transfer, and also increases the frequency of cleaning.

Scale formation can be minimised by operating the thermal process at a low top brine temperature. Reducing the top brine temperatures however reduces the performance ratio. The dosing of anti-scalants is therefore widely used in thermal processes to ensure the plants are operated at optimal levels.

Depending on the quality of the feedwater, filtration may also be carried out prior to the thermal process. However filtration is rarely used in thermal plants as biological and organic matter does not significantly interfere with thermal desalination processes.

## C4 Membrane Desalination

Pre-treatment is considered very important for membrane processes, as the membranes are highly susceptible to fouling, which in turn affects their performance. The type and level of pre-treatment required will depend on the quality of the feed water, membrane type and configuration.

Depending on the feedwater quality, membrane systems may employ a combination of the following pre-treatment processes:

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Chemical Treatment	Coagulation pH adjustment Scale inhibition
Degasification	Vacuum Degasification Forced Draft Degasification Membrane Contactor Degasification
Filtration	Media Filtration Membrane Filtration
Secondary Filtration	Cartridge Units Ultra Filtration units
Disinfection	Ultraviolet irradiation Oxidants

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These pre-treatment technologies are discussed in further detail below.

Table C-2 below details contaminants commonly found in desalination feed waters. Concentrations specified indicate levels at which the contaminant have a high scaling potential and may cause membrane fouling. These levels are likely to reduce plant efficiencies and increase operating and



maintenance costs. Pre-treatment methods available to reduce the contaminant impact are recommended.

Contaminants not removed from feed water prior to desalination may reduce the lifespan of the facility and/or its components, shortened operating periods and increased levels of maintenance.

## **C5 Chemical Treatment**

Chemical dosing can be used to improve the effectiveness of pre-treatment processes and reduce scale formation.

### **C5.1 Coagulant Dosing**

Dosing of coagulants improves the efficiency of filtration processes. Colloidal material such as clay, silica, iron, heavy metals, colour and organic solids are often either defined as soluble or are too small to settle out by conventional filtration. When coagulants are added to the water the colloidal material effectively grows to a size that allows removal by filtration.

Chemical coagulants include lime, alum, ferric salts and polyelectrolytes. It is recommended that an evaluation be undertaken to determine the most appropriate coagulant for a particular feedwater and desalination process. For example, calcium, present in lime can cause an increase in scale formation in distillation/condensation processes, while iron present in ferric salts can cause excessive fouling in membrane desalination systems.

### **C5.2 pH Adjustment**

pH adjustment is required to either:

1. neutralise impact of coagulant chemicals
2. reduce the pH of feed water to increase solubility of scale forming chemicals

Coagulants typically increase the pH level of the feed water. RO processes typically prefer feedwater with a low pH, therefore acids are commonly added after coagulation/filtration.

Chemicals commonly used to lower the pH include carbon dioxide, sulphuric and hydrochloric acid.



**Table C-2 Concentrations for potential Membrane fouling**

<b>Feed Water Characteristics</b>	<b>Concentration</b>	<b>Description</b>	<b>Impact</b>	<b>Recommended Method of Pre Treatment</b>
Aluminium (colloids)	0.1 - 1.0 ppm	Hydrated aluminium ions react with water to form a number of complex hydrated aluminium hydroxides which polymerise and start absorbing negatively charged colloids.	Membrane fouling by aluminium-based colloid carryover can occur.	Antiscalant <sup>5</sup>
Barium (Ba)	> 6000% concentrated <sup>1</sup>	BaSO <sub>4</sub> solubility is lower with increasing sulphate levels and decreasing temperatures.	Solubility of barium sulphate (BaSO <sub>4</sub> ) is low and can cause membrane scaling problems.	Antiscalant <sup>5</sup>
Calcium Sulphate (CaSO <sub>4</sub> )	> 230% concentrated <sup>1</sup>	Commonly known as Gypsum (CaSO <sub>4</sub> )	The solubility of calcium sulphate is low and can cause membrane fouling problem.	pH adjustment Antiscalant <sup>5</sup>
Calcium Carbonate (CaCO <sub>3</sub> )	1.8 – 2.5 LSI <sup>2</sup>	Calcium carbonate solubility is measured using the LSI <sup>2</sup> index for brackish waters. A variation on the LSI index, the SDSL index is used for high TDS seawater. A recommended target LSI in the RO concentrate is negative 0.2 (which indicates that the concentrate is 0.2 pH units below the point of calcium carbonate saturation)	The solubility of calcium carbonate is low and can cause membrane fouling problem.	pH adjustment Antiscalant <sup>5</sup>
Carbon Dioxide (CO <sub>2</sub> )	> 1600 ppm, pH 4	CO <sub>2</sub> and the bicarbonate ion are in balance. CO <sub>2</sub> is calculated based on the bicarbonate level and pH of the water. CO <sub>2</sub> being a gas is not rejected or concentrated by the desalination process. Therefore its concentration will be the same in the feed, permeate and concentrate.	CO <sub>2</sub> is a gas that when dissolved in water reacts with the water to form weak carbonic acid (H <sub>2</sub> CO <sub>3</sub> ) which lowers the water pH	pH adjustment or Leave CO <sub>2</sub> in its gaseous form and treat the permeate for its removal (degasification)



Feed Water Characteristics	Concentration	Description	Impact	Recommended Method of Pre Treatment
Hydrogen Sulphide (H <sub>2</sub> S)	3 – 5 ppm	H <sub>2</sub> S is a gas that causes noticeable “rotten egg” smell in the feed waters. High H <sub>2</sub> S concentration is best removed during post treatment processes	Odour issues	Leave H <sub>2</sub> S in its gaseous form and treat the permeate for its removal
Iron (Fe <sup>++</sup> )(Fe <sup>+++</sup> )	0.05 ppm	Iron is a water contaminant that takes two major forms. The water soluble form is known as the ferrous state and has a +2 valence state. The water insoluble form is known as the ferric state and has a +3 valence state.	In some cases, the presence of iron can create a bio-fouling problem by being the energy source for iron reducing bacteria.  Iron foulant will quickly increase the RO feed pressure requirements and increases permeate TDS	Dispersant chemicals or iron filters or softening  Ultra/multimedia filtration or polyelectrolyte
Manganese (Mn)	0.05 ppm	Manganese like iron can be found in organic complexes in surface waters. In oxygen free water, it is soluble. In its oxidised state, it is insoluble and usually in the form of manganese dioxide (MnO <sub>2</sub> )	Manganese can cause staining of the cloths and plumbing fixtures and cause scaling throughout the desalination unit	Iron dispersant chemicals
pH	5 > pH > 7.5	The pH scale ranges from 0-14, with 0 being the most acidic, and 14 being the most alkaline. The pH can be manipulated through the use of phosphate, bicarbonate, and other buffers.	Feed pH affects the fouling potential of silica, aluminium, organics and oils. Feed pH also affects the rates of flocculation.	pH adjustment (acid addition, degasification)



Feed Water Characteristics	Concentration	Description	Impact	Recommended Method of Pre Treatment
Silica (SiO <sub>2</sub> )	Unreactive Silica: 4.0 SDI <sup>3</sup> Reactive Silica: 200-300%	Reactive silica (SiO <sub>4</sub> ) is the preferred form of total silica in desalination processes. Its solubility is restricted to 200-300% with use of a silica dispersant. Unreactive Silica (colloidal silica) acts more like a solid that a dissolved ion, with sizes as small as 0.008 microns. Only portions larger than 0.045 microns can be measured using the SDI <sup>3</sup> test.	Silica in the colloidal form can cause fouling of the front end of the membrane. Reactive Silica contributes to total TDS and can increase the membrane operating pressures.	Flocculants Antiscalant <sup>5</sup> Sand Filtration Nano Filtration
Total Dissolved Solids (TDS)	< 100,000 ppm	TDS is calculated as the sum of the cations, anions and the silica ions. Osmotic pressure results from the difference in salt concentration across the membrane. Increase TDS levels increase the osmotic pressure.	Larger energy requirements are needed to overcome osmotic pressures. Generally 1000 ppm TDS equates to 11 psi osmotic pressure.	Flocculants Antiscalant <sup>5</sup> Sand Filtration Micro/Ultra/Nano Filtration
Temperature (°C)	25 °C < temp < 28 °C	Temperature is a critical design parameter. Generally, every 5°C decrease in feed temperature, increases the feed pump pressure requirement by approximately 15%.	Temperature has significant effects on feed pump pressure requirements, hydraulic flux balance between stages, permeate quality and solubility of sparingly soluble salts.	Cooling ponds Heating units
Total Organic Carbon (TOC)	> 3 ppm	Organics are compounds that contain carbon (except CO <sub>2</sub> , HCO <sub>3</sub> , CO <sub>3</sub> ). Naturally occurring organic matter are typically negatively charged colloids or suspended solids.	TOC can be a foulant for RO membranes. Generally, alert levels for potential organic fouling in natural water sources are TOC= 3 ppm, BOD= 5 ppm and COD= 8 ppm.	Flocculants Antiscalant <sup>5</sup> Sand Filtration Micro/Ultra/Nano Filtration



Feed Water Characteristics	Concentration	Description	Impact	Recommended Method of Pre Treatment
Turbidity	> 1.0 NTU <sup>4</sup>	Turbidity is the suspension of colloidal particles that do not settle out in solution.	High turbidity levels increase operating costs, scaling potential and maintenance requirements.	Flocculants Antiscalant <sup>5</sup> Sand Filtration Micro/Ultra/Nano Filtration

<sup>1</sup> With the addition of antiscalants, compounds can become supersaturated. Supersaturation occurs where a compounds concentration in water exceeds its saturation level.

<sup>2</sup> Langlier Saturation Index (LSI): A method of reporting the scaling potential of low TDS brackish water based on temperature, calcium hardness, alkalinity and background total dissolved solids. The LSI value is calculated by subtracting the calculated pH of saturation of calcium carbonate from the actual feed pH. If this number is greater than 0 it is assumed that there is a tendency for calcium carbonate to precipitate.

<sup>3</sup> Silt Density Index (SDI): An empirical test developed for membrane systems to measure the rate of fouling of a 0.45-micron filter pad by the suspended and colloidal particles in the feed water. Typical RO element warranties list a maximum SDI of 4.0 at 15 minutes of the feed water.

<sup>4</sup> Nephelometric Turbidity Units (NTU)

<sup>5</sup> Software produced by Antiscalant manufacturers is a reliable method for providing appropriate dosing rates.



### **C5.3 Scale Inhibition**

Scale inhibiting chemicals increase the solubility of chemicals within feed waters, reducing the potential for scaling. The precipitation of calcium carbonate, magnesium hydroxide and calcium sulphate can be prevented through the addition of antiscalent chemicals. These chemicals typically fall into two groups:

1. Chemicals bought from a general purpose chemical supplier (e.g. sodium hexametaphosphate). The amount of chemical used is generally based on experience and trial and error. Pilot plant testing can also assist in the selection of inhibitors and appropriate dosage rates.
2. Chemicals bought from the membrane supplier company. Application rates are accurately predicted based on complex formulae. Software produced by the supplier company utilises these formulae and is a reliable method for determining the required dose rates for antiscalents.

### **C5.4 Degasification**

Degasification can be used during pre-treatment processes as a method to control the feed water pH. CO<sub>2</sub> is a gas that when dissolved in water reacts to form weak carbonic acid (H<sub>2</sub>CO<sub>3</sub>) lowering the water pH. Removal of the CO<sub>2</sub> gas is an effective method to control the pH of the feed water.

The degasification process is discussed further in Appendix D1.2

Degasification is generally undertaken as a post treatment process to remove H<sub>2</sub>S. H<sub>2</sub>S does not negatively impact on the desalination process and is removed to avoid odour issues associate with the product water.

## **C6 Filtration**

Filtration is the physical separation process used to remove particulate matter from the feed water. Filtration can be achieved by sand, membrane and cartridge filtration.

Sand filtration has historically been the filtration method of choice. However as membrane filtration technologies such as MF, UF etc become cheaper they have become more popular. Benefits to be gained by membrane filtration include: improved particulate removal, which in turn increases membrane life and improved recovery rates. The benefits however are offset by higher capital and operating costs.

Cartridge filters act as the final barrier prior to RO. Cartridge filters are easily replaced and the filter mesh can be sized to remove from 20 micron to 0.05 micron particles. Some cartridge filters can be backwashed but are commonly replaced when high head losses are reached.

Micro/Ultra/Nano filtration units remove particles in the size range 0.03 – 10, 0.002 – 0.1 and approximately 0.001 microns respectively from the feed water by passing the water through a synthetic membrane and imposing high pressure. In this way microorganisms, macromolecules and oil emulsions can be separated. Membrane filtration units are usually formed from polymers, such as PVC and cellulose acetate. Ceramics and metallic oxides can be used to form more robust constructions. The membranes are usually tubular, capillary or spiral wound and ultrafiltration units may be composed of a series of bundles of the hollow membranes.



## **C7 Disinfection**

Biological material can seriously interfere with membranes, resulting in increased maintenance, increased pressure requirements and lower life spans. Seawater is particularly prone to biological material and often requires disinfection prior to desalination. Disinfection methods commonly used include:

### **C7.1 Ultraviolet Irradiation**

Raw water is exposed to ultra violet light. When UV radiation penetrates the cell wall of an organism, it destroys the cells ability to reproduce. UV disinfection is a physical process rather than a chemical disinfectant and eliminates the need to generate, handle, transport and store hazardous or corrosive chemicals. The process is effective at inactivating most viruses, spores and cysts and has no residual effect.

### **C7.2 Oxidants**

The addition of oxidants such as chlorine, bromine iodine or ozone provides biological disinfection and protects desalination facilities from biological and microbial build-ups. Oxidants such as chlorine however have a detrimental effect on membranes and must be removed completely following the disinfection process. Free available Chlorine in membrane feed waters must be reduced to less than 0.05 ppm (as  $\text{Cl}_2$ ) to ensure no damage is sustained. The two most common pre-treatment methods for reducing chlorine levels are by absorption into activated carbon media or by the use of a chemical reducing agent such as sodium bisulphite.

Disinfection should be undertaken prior to filtration as filtration is required to physically remove the bio matter. Chlorination must be followed by dechlorination.

Appendix D  
Post Treatment



## D1 Post Treatment Methods

Desalination can and most often does produce water so free of dissolved material that corrosion and aesthetic problems can arise. Post treatment method selected will depend on the quality of the product water and its intended use.

Post treatment may include: pH correction and alkalinity recovery for stabilisation and corrosion control, degasification to remove carbon dioxide and other gases (eg hydrogen sulphide) and a final disinfection stage to create residual chlorine levels.

### D1.1 Corrosion Control (pH Adjustment and Alkalinity Recovery)

When water is neither scale forming nor corrosive it is said to be stable. As far as corrosivity issues are concerned, the most important water quality parameters are pH, alkalinity, calcium and TDS.

High CO<sub>2</sub> content and low pH in product waters contributes to corrosion. CO<sub>2</sub> is produced (lowering the pH) in water when alkalinity is consumed. This is particularly true when acid is used for scale control or coagulant cations (e.g. alum) are added to water during pre-treatment processes. The addition of lime (Ca(OH)<sub>2</sub>) or soda ash (Na<sub>2</sub>CO<sub>3</sub>) to raise the pH or acids (e.g. sulfuric acid) to lower pH is an effective post treatment process to adjust final pH of the water and control corrosion.

Lime and soda ash utilise CO<sub>2</sub> in water as part of the stabilisation process resulting in a less corrosive buffered solution. Lime can also add both alkalinity and calcium (hardness) to soft water. If residual harness and alkalinity in product water is enough for corrosion control, soda ash to raise pH may be sufficient.

Table D1 below outlines some further advantages and disadvantages of Lime and Soda Ash.

**Table D-1 Lime and Soda Ash Comparison**

	<b>Advantages</b>	<b>Disadvantages</b>
Lime (Ca(OH) <sub>2</sub> )	<ul style="list-style-type: none"> <li>▶ Low cost</li> <li>▶ Widespread availability</li> <li>▶ Adds both alkalinity and calcium (hardness) to soft water</li> </ul>	<ul style="list-style-type: none"> <li>▶ Slow reaction time</li> <li>▶ Handling and storage (wet or dry) issues</li> </ul>
Soda Ash (Na <sub>2</sub> CO <sub>3</sub> )	<ul style="list-style-type: none"> <li>▶ Transportable in a dry state and easy to mix into solution</li> <li>▶ Economical method to raise pH</li> <li>▶ Imparts buffering capacity</li> </ul>	<ul style="list-style-type: none"> <li>▶ Higher reagent cost (relative to lime)</li> <li>▶ High dosage required</li> <li>▶ Increases TDS of the water</li> </ul>



## D1.2 Degasification

Degasification may be used to obtain equilibrium with atmospheric CO<sub>2</sub> and assist in pH adjustment. Several methods of degasification are available, and are discussed in Table D-2.

**Table D-2 Degasification Technologies**

Vacuum Degasification	Vacuum Degasifier are typically tall columns filled with packing or trays and are used to bring a liquid phase in contact with a gas phase for the purpose of removing dissolved gases from the liquid. The liquid runs from the top of the column down around the packing. The packing creates a large surface area for the gas phase to contact the liquid phase.
Forced Draft Degasification	Device to remove dissolved gases (CO <sub>2</sub> in particular) from solution by blowing an air stream through a packed column counter current to down flowing water.
Membrane Contactor Degasification	The membrane contactors utilise a hydrophobic porous membrane to remove dissolved gasses. The membrane acts as a support to prevent dispersion of the water while allowing the water to come to contact with the gas phase. A vacuum is applied to reduce the partial pressure of the gas phase. And as the partial pressure of the gases on the gas phase is reduced the concentration of the gases remain dissolved in the water is reduced in proportional to the partial pressure.
Steam deaerator	On high temperature distillation systems, a steam deaerator may be used. On most distillation desalination systems, the only economical method of deaeration of the water is to lower the pressure with a vacuum pump or venturi eductor to produce water vapour to strip away all the dissolved gasses.

The degasification process removes any residual hydrogen sulfide in addition to stripping carbon dioxide. Carbon dioxide is indicative of corrosive water and results when the pH of the feedwater is lowered and carbonate changes to bicarbonate and then ultimately to carbon dioxide and water.

## D1.3 Remineralisation

Blending desalinated product water low in minerals with another water source water, brine or other sources of treated water is a very useful method for water stabilisation. Reblending product water with other water sources results in savings in treatment costs and minimises the use of water stabilising chemicals. Care must be taken when reblending with brine solutions to ensure that no backwash or chemical contamination exists in the waste stream.

Blending ratios need to be determined on a case-by-case basis, as the quality of water sources used to stabilise the desalinated product water will vary from site to site.

## D1.4 Post Treatment of Electrodialysis Product Water

ED(R) product water is usually less aggressive than the RO product as acid addition for scale control is generally not required for ED(R) processes. In addition ED(R) can be controlled such that only certain



salts are removed unlike RO where on average 98% of salts are removed. This also reduces post treatment requirements. Post-pH adjustment is not always required. (AWWRF, 1996)

The ED(R) process however is ineffective at removing nuisance matter such as silica, particulates, bacteria, viruses and organic material. Depending on the final product water requirements it may be necessary to remove these nuisance materials by pre or post treatment steps. ED(R) designers generally prefer removal of suspended solid material to be carried out in a pre-treatment step (as this provides added length of protecting the ED(R) membranes). Disinfection is almost always carried out as a post treatment step in ED(R) systems. Common disinfectants include chlorine or chloramines.

### **D1.5 Residual Disinfection**

While desalinated water is being fed into a water reticulation system, disinfection can also be undertaken. While most of the desalination technologies (except ED(R)) will produce highly disinfected water, it is often necessary to provide a residual Cl level to prevent re-contamination within the reticulation system.

The use of chemicals such as chlorine or chloramine creates a residual chlorine concentration throughout the potable reticulation system ensuring that no bacterial contamination exists in the potable water at its final destination.

It should be noted the disinfection by oxidants such as chlorine must be carried out downstream of membrane processes as membranes cannot tolerate chlorine.

Appendix E  
Desalination Equipment Suppliers



## Desalination Equipment Suppliers

Company	Contact Details	Range of Equipment Supplied
<b>Electrodialysis (ED)</b>		
Ionics Watertec	Contact	Peter West
	Phone Number	07 3279 1888
	Fax Number	07 3279 1790
	Email Address:	<a href="mailto:pwest@ionwater.com.au">pwest@ionwater.com.au</a>
	Internet:	<a href="http://www.ionics.com">www.ionics.com</a>
Osmoflo	Contact	Jenny Trimboli
	Phone Number	08 8159 8999
	Fax Number	08 8234 7066
	Email Address:	<a href="mailto:jenny.trimboli@osmoflo.com.au">jenny.trimboli@osmoflo.com.au</a>
	Internet:	<a href="http://www.osmoflo.com.au">www.osmoflo.com.au</a>
PEX Industries	Contact	John Lebowitz
	Phone Number	02 9371 6688
	Fax Number	02 9388 1147
	Email Address:	<a href="mailto:lebowitz@pex-ind.com.au">lebowitz@pex-ind.com.au</a>
QED OCCTECH	Contact	Tom McCrisken
	Phone Number	08 9388 8766
	Fax Number	08 9228 1544
	Email Address:	<a href="mailto:tmccrisken@qedocctech.com">tmccrisken@qedocctech.com</a>
	Internet:	<a href="http://www.occtech.com.au">www.occtech.com.au</a>
<b>Multi Effect Distillation (MED)</b>		
PEX Industries	Refer to "Electrodialysis" section	1.5 to 48ML/d
Thames Water Projects	Contact	David Middleton
	Phone Number	03 9239 4196
	Fax Number	03 9239 4200
	Internet:	<a href="http://www.thameswaterprojects.com">www.thameswaterprojects.com</a>
VA Tech WABAG	Contact	Colin Nash
	Phone Number	03 9264 9912
	Fax Number	03 9574 9556
	Email Address:	<a href="mailto:cnash_wabag@bigpond.com">cnash_wabag@bigpond.com</a>



Company	Contact Details	Range of Equipment Supplied
	Internet: <a href="http://www.wabag.com">www.wabag.com</a>	
<b>Multistage Flash Distillation (MSF)</b>		
Inteleco	Contact David Murdoch Phone Number 02 4351 9200 Fax Number 02 9512 2473 Email Address: <a href="mailto:inteleco@h2.au.com">inteleco@h2.au.com</a> Internet: <a href="http://www.h2.au.com">www.h2.au.com</a>	0.005 to 0.05ML/d
Thames Water Projects	Refer to "Multiple Effect Distillation" section	Unknown
VA Tech WABAG	Refer to "Multiple Effect Distillation" section	1 to 25ML/d
<b>Reverse Osmosis (RO)</b>		
CRS Industrial Wastewater Treatment Systems	Contact Chris Pocock Phone Number 02 9899 7811 Fax Number 02 9899 7336 Email Address: <a href="mailto:cpocock@watertreatment.net.au">cpocock@watertreatment.net.au</a> Internet: <a href="http://www.watertreatment.net.au">www.watertreatment.net.au</a>	0.0005 to 1ML/d
ICES	Contact Robert Drane Phone Number 0419 879 846 Email Address: <a href="mailto:robert.drane@icespl.com">robert.drane@icespl.com</a>	0.001 to 4.8ML/d
Ionics Watertec	Refer to "Electrodialysis" section	From 1ML/d
Normach	Contact Phil Norman Phone Number 08 9336 6969 Email Address: <a href="mailto:phil@normach.com.au">phil@normach.com.au</a> Internet: <a href="http://www.normach.com.au">www.normach.com.au</a>	0.0018 to 2ML/d
O'Donnel Griffin	Contact Ian Blinco Phone Number 08 8347 2970 Email Address: <a href="mailto:iblinco@tycoint.com">iblinco@tycoint.com</a> Internet: <a href="http://www.odg.com.au">www.odg.com.au</a>	0.04 to 12ML/d
Osmoflo	Refer to "Electrodialysis" section	0.05 to 20ML/d
PEX Industries	Refer to "Electrodialysis" section	10 to 330ML/d
QED OCCTECH	Refer to "Electrodialysis" section	1 to 8ML/d



Company	Contact Details	Range of Equipment Supplied
Sharplift Marine and Industrial Equipment	Phone Number	07 4035 1981
	Fax Number	07 4035 1065
	Internet: <a href="http://www.sharplift.com.au">www.sharplift.com.au</a>	
Surewater Australia	Contact	Denver Irwin
	Phone Number	07 3378 2984
	Fax Number	07 3378 2503
Thames Water Projects	Refer to "Multiple Effect Distillation" section	2 to 36ML/d
VA Tech WABAG	Refer to "Multiple Effect Distillation" section	5 to 150ML/d
Wendouree Water Treatment	Contact	Bob Ward
	Phone Number	07 4634 3006
	Fax Number	07 4634 2448
	Email Address: <a href="mailto:wendouree@bigpond.com">wendouree@bigpond.com</a> Internet: <a href="http://www.wendoureewater.com.au">www.wendoureewater.com.au</a>	
<b>Vapor Compression Distillation (VC)</b>		
AquaDyne	Contact	Gregory Paxton
	Phone Number	07 3804 7119
	Fax Number	07 3804 7922
	Email Address: <a href="mailto:gpaxton@globalpowerwater.com">gpaxton@globalpowerwater.com</a> Internet: <a href="http://www.aquadyne.us.com">www.aquadyne.us.com</a>	
Inteleco	Contact	David Murdoch
	Phone Number	02 4351 9200
	Fax Number	02 9512 2473
	Email Address: <a href="mailto:inteleco@h2.au.com">inteleco@h2.au.com</a> Internet: <a href="http://www.h2.au.com">www.h2.au.com</a>	
KBA (Karla Bell & Associates)	Contact	Karla Bell or Jeff Carrier
	Phone Number	02 9665 2049 or 07 3378 8814
	Email Address: <a href="mailto:karla.bell@bigpond.com">karla.bell@bigpond.com</a>	
PEX Industries	Refer to "Electrodialysis" section	0.5 to 17ML/d
Thames Water Projects	Refer to "Multiple Effect Distillation" section	1 to 25ML/d
VA Tech WABAG	Refer to "Multiple Effect Distillation" section	Unknown



Company	Contact Details	Range of Equipment Supplied
<b>Brine Disposal – Value Adding</b>		
Geo – Processors	Contact Lance Stapleton Phone Number 02 9630 0804 Fax Number 02 9630 0603 Email Address: <a href="mailto:admin@geo-processors.com.au">admin@geo-processors.com.au</a> Internet: <a href="http://www.geo-processors.com.au">www.geo-processors.com.au</a>	Unknown
<b>Other Process</b>		
AWA Hydroflo	Contact Keith Mason or Stephen Reid Phone Number 07 3807 0554 Fax Number 07 3807 3177 Email Address: <a href="mailto:hydroflo@bigpond.com">hydroflo@bigpond.com</a>	0.0072 to 100 ML/d
Ionics Watertec	Refer to “Electrodialysis” section	From 1 ML/d
Osmoflo	Refer to “Electrodialysis” section	0.05 to 20 ML/d
PEX Industries	Refer to “Electrodialysis” section	Unknown
VA Tech WABAG	Refer to “Multiple Effect Distillation” section	Unknown



**GHD Pty Ltd** ABN 39 008 488 373

201 Charlotte Street Brisbane Qld 4000

GPO Box 668 Brisbane Qld 4001 Australia

T: (07) 3316 3600 F: (07) 3316 3333 E: bnemail@ghd.com.au

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#### **Document Status**

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