Desalination Plants

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• 70 % of earth surface is covered by water:
• 97.5 % of all water on earth is salt water
• 2.5 % is fresh water of which:
  - 70% is frozen in ice caps of Antarctica and Greenland
  - 30% is in soil or deep underground, not accessible to human use
  - less than 1% of all freshwater is in lakes, rivers, reservoirs and shallow underground sources

Real issue is amount of water available:
as an example the Amazon river accounts for 15% of the global runoff, but it is currently available only to 0.4 % of the world population.
World Water Resources

- The six billion people of our planet use nearly 30% of the world’s accessible water resources.

- On current trends, by 2025, this value is expected to reach 70%
Scarcity of a valuable resource

The world's water

- Saltwater: 97.5%
- Freshwater: 2.5%

68.9% - locked in glaciers
30.8% - groundwater
0.3% - lakes and rivers

Predicted water scarcity and stress in 2025

- Scarcity
- Stress

Source: UNEP
Economic Aspects

- Desalination produces a very small portion of the total water consumption:
  - worldwide capacity 2006: 40 mio m³/day
  - targeted capacity 2010: 65 mio m³/day (+60%, investments 25 bio USD)
  - targeted capacity 2015: 100 mio m³/day (+150%, investments 60 bio USD)

- More than half of the investments will come from the private sector.

- Worldwide operating costs in the desalination industry will rise from 6.5 bio USD in 2006 to 15.0 bio USD in 2015 (on current trends)
Desalination process: main stages

Three stages:

- **Pre-treatment**: includes the seawater intake structure, the pump house and the water treatment plant (for pH adjustment, control of scaling and removal of suspended solids and organic matter).

- **Desalination**, using one of the following methods:
  - mechanical method: membrane processes which use a semi-permeable membrane to create two zones with different salt concentrations: reverse osmosis and electro dialysis, or
  - thermal methods involving heating water to produce vapour.

- **Post- treatment**: consists of water treatment before it is sent to the distribution system (pH adjustment, degasification, stabilization of water). Includes the outfall structure, the water reservoir and the brine handling.
Reverse Osmosis
Fluids are pressed through the membrane, while dissolved solids stay on the other side of the membrane. Pressure is up to 100 bars. Spiral membrane units are widely used as they can be arranged serially within a pressure vessel. This means that the feed water flows through the membrane with one tubular system multiple times.
RO membrane
In the flash evaporator, seawater is circulated through the vapour condenser tubes of the final stage where it is heated by the transfer of latent heat from the condensing vapour. The seawater passes through the vapour condensers of each stage in series, increasing in temperature. The seawater then enters the tubes of the brine heater, where a further temperature increase takes place to provide the temperature differential needed to allow flash evaporation.
Multistage Flash (MSF)

MSF distillation plants, especially large ones, are often associated with power plants in a cogeneration configuration. Waste heat from the power plant is used to heat the seawater.

This reduces the energy needed from one-half to two-thirds, which drastically alters the economics of the plant, since energy is by far the largest operating cost of MSF plants.
Multiple Effect Distillation, like the MSF process, takes place in a series of vessels (effects) and uses the principle of reducing the ambient pressure in the various effects. This permits the seawater feed to undergo multiple boiling without supplying additional heat after the first effect.
MED units are usually connected with a power plant.

The pressure in the various effects is maintained by a separate vacuum system. The thermal efficiency of the process depends on the number of effects with 8 to 16 effects being found in a typical plant.

MED plants usually operate with a temperature in the first effect of 70°C.
Other equipment

In addition to the above mentioned sections of a desalination plant, the **Balance of Plant**

includes the fire protection system, the instrumentation and the controls.
Energy Aspects – the front line of the battle

Energy requirements of the three main industrial desalination processes:

<table>
<thead>
<tr>
<th></th>
<th>MSF</th>
<th>MED</th>
<th>RO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible unit size</td>
<td>60,000</td>
<td>60,000</td>
<td>24,000</td>
</tr>
<tr>
<td>Energy consumption (kWh/m³)</td>
<td>4 - 6</td>
<td>2 - 2.5</td>
<td>5 - 7</td>
</tr>
<tr>
<td>Thermal energy in electrical equivalent (kWh/m³)</td>
<td>8 - 18</td>
<td>2.5 - 10</td>
<td>None</td>
</tr>
<tr>
<td>Total equivalent energy consumption (kWh/m³)</td>
<td>12 - 24</td>
<td>4.5 - 12.5</td>
<td>5 - 7</td>
</tr>
</tbody>
</table>

depending upon the process, temperature and source water quality, pressure / heat/ steam.

Source: International Atomic Energy Agency 1992

• Pumps are the biggest power consumers: up to 75 percent of operating costs
• RO has the lowest energy demand
• In theory, about 0.86 kWh of energy is needed to desalinate 1 m³ of salt water assuming a salt concentration of 3.45% at a temperature of 25°C. In practical life 5 to 26 times as much is needed depending on the type of process used.
• Any prototype consideration may be related to cutting energy needs !!
Design of desalination plants

Main parameters:

- Production capacity
- Characteristics of water to be produced
- Materials:
  - resistant to corrosion, chemical reaction
  - resistant to pressure, vibrations and changing temperatures:
    - for low pressure parts (< 10 bar) such as in membrane elements and pressure vessels → use of non-metal: PVC and fiberglass
    - for high-pressure parts (10 to 70 bar) such as pumps, drains and lids mainly → use stainless steel.

- Location and salt concentration
- Maintenance needed and respective costs involved
- Capital and operating costs
- and LAST but not LEAST: energy – availability and costs
• All proven electrical and mechanical equipment
• Complex in terms of Process technology
• Low tech in terms of equipment
• Specific know how needed for construction of watertight tanks
• All other civil works – common civil structures
• No rocket science
• Maintenance is important
• Every project is unique – check prototype aspects
• Complex operations, involve interactions between many different parties
• Internal Exposures
  o Chemical Reactions
  o Machinery Breakdown
• Steam Production by Co-generation plant
Underwriting Considerations – During Construction 2

• External Exposures
  • Natural Perils
  • Location (coast line) → Flooding
  • Design, Materials and Workmanship
  • Ground Conditions, Location at sea, river (wadis often underestimated), lakes etc.
  • Wet Works – see separate IMIA paper
  • Quality of labour; i.e. welding
  • Heavy Lifts
  • TPL Exposures– see separate IMIA Paper
  • Financial Exposures
  • Political Risks
Underwriting Considerations – During Operation

- In addition to the construction risks
  - Maintenance
  - Experience of staff
  - Water Quality
    - Flooding
      - direct infiltration
    - Act of terrorism
      - substantial investments needed for security measures
Waste management:

Wastes includes concentrated brine, backwash liquids containing scale and corrosion salts and antifouling chemicals, and pre-treatment chemicals in filter waste sludges.

Depending upon the location and other circumstances including access to the sea and sensitive aquifers, concentrations of toxic substances etc., wastes can be discharged directly to the sea, mixed with other waste streams before discharge, discharged to sewers or treated at a sewage treatment plant, lagooned and dried and disposed of in landfills or salt piles.

Assuming an average salinity of 3.5%, every cubic meter of desalinated water produces 35kg brine water to be treated. Taking an average plant in the Middle East with a daily production of 200’000 m³ of water, an amount of approximately 7’000 tons of brine water per day has to be handled.
„Normal“ losses - independent from type of plant

Construction:

ground conditions, excavation, foundation,

example – slope collapse, hang slide (Caribbean)
Losses during construction:

Due to location near sea – flooding

Example North Africa

A RO desalination plant was constructed in a bay at the Mediterranean Sea

Due to heavy rain falls with peak precipitation a dry wadi behind rapidly turned into a violent torrent and caused heavy damage to works under construction.
During commissioning / testing and later also during maintenance/operation:

Special equipment such as tanks, tubes, membranes, pumps
Loss examples given in the paper:

Example 1
Shuaiba
Human error during maintenance / pressure test of a tank
Operation

Example 2

Machinery Breakdown in a RO desalination plant due to entrance of fine particles

Unclear whether fine particles entered during maintenance or had been there from construction and were flushed into the pressure pump as a consequence of the restarting and the corresponding turbulence.

In spite of filter systems working correctly foreign objects may enter the system during construction or during temporary removal of elements.
Loss of cooling oil in transformer

RO Plant at Mediterranean Sea

Sudden standstill due to power stoppage of the high pressure pumps. Cracks were detected in the ceramic isolation of the 3150 KVA transformer near the clamps at the high-tension entrance.

Overheating and magnetic turbulences (thunderstorm) had not occurred. It was finally concluded that sudden changes in the electric power supply – apparently frequent in this area – must have caused high-voltage peaks in the tension and caused the isolators to crack.
Conclusions

Most losses so far „standard“ i.e. cat nat, design, material, workmanship, human error etc.

Frequency may be compared to similar industries, taking into account the location at the sea.

Losses due to special technology so far rare. Most failures such as pumps, membranes etc. are usually handled on the basis of purchase contracts and the resp. warranties.

However, desalination processes are in permanent development and may therefore imply in many cases certain prototype exposures.

Experienced underwriters will carefully follow up these developments and take them into consideration.
Thank You