KEY POINT: Thermal processes may be advantageous when there is a readily available source of low–cost energy and/or “waste heat” (e.g. power plant co-location)

SUMMARY OF ISSUES

- Multi-stage flash distillation (MSF) and multiple-effect distillation (MED) thermal processes demand both thermal energy (typically steam) and electrical energy. The mechanical vapor compressor (MVC) is usually electrically or diesel driven. Thermal vapor compression (TVC) uses high-pressure steam.

- MSF and MED processes have electrical requirements that approximate or exceed SWRO plants while MVC plants usually have electrical requirements more than four times higher than SWRO plants.

- Thermal processes are configured to use and reuse the energy required to evaporate water, known as the latent heat of evaporation (about 2,326 kJ/kg of water or 644 kWh/m$^3$ at normal atmospheric conditions) (NRC 2008). How efficiently the latent energy is reused is a function of project-specific economics, considering capital and operating costs.

- Ettouney (2002) reports that the energy costs of thermal desal using MED or MSF account for nearly 55% of the annual cost of product water (including costs of amortized capital investment, electric and thermal energy, labor and chemicals). Because MVC plants use electricity to power the desal plant, energy costs of MVC desal can account for up to 70% of total annual costs the (Ettouney et al. 2002)

- Thermal processes are most economical in the context of power plant co-generation. (i.e., with the availability of waste heat and inexpensive power).

- Thermal processes continue to dominate the Middle East. In other parts of the world, where integration of power and water generation is limited and where oil or other fossil fuels must be purchased at market prices, thermal processes are generally prohibitively expensive (IDA 2008).
In the US, almost all seawater desal applications utilize RO membrane technology. Thermal desal is virtually unused in the municipal treatment market. This trend is largely driven by the lower capital and operating costs of RO relative to thermal processes (Watson, Jr. and Hentrone 2003).

**STRATEGIES**

Table 1 summarizes the power consumption of thermal technologies for desal.

**Table 1. Power consumption for thermal desal technologies.**

<table>
<thead>
<tr>
<th>Thermal Process</th>
<th>MSF</th>
<th>MED</th>
<th>MVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption (kWh/kgal)</td>
<td>11-21*1</td>
<td>11*2</td>
<td>27*2</td>
</tr>
<tr>
<td>Thermal energy (million Btu/kgal)</td>
<td>0.83*1</td>
<td>0.71*1</td>
<td>N.A.</td>
</tr>
<tr>
<td>Total power consumption (kWh/kgal)</td>
<td>70-112*1</td>
<td>31-45*3</td>
<td>27*2</td>
</tr>
</tbody>
</table>

*Source: *1 CCC 1993; *2 Ettouney et al. 2002; *3 Darwish, Al Asfour, and Al-Najem 2003

As noted above, thermal processes are typically only economical in the context of power plant co-generation. (i.e., with the availability of waste heat and inexpensive power). With cogeneration, desal plants are built along with power plants and use the low-temperature steam exhausted from the power plant steam turbines. This approach combines water production with the generation of electric power (using the same fuel), thereby improving the energy efficiency of the desal process.

Large MSF distillers dominate desal processes in the Middle East largely because of cogeneration. However MSF technology continued to lose its share (27%) to RO (59%) and MED (9%) in 2008, due to the improvement of membrane technologies and the cost advantage. MED capacity has increased 90% since 2004; with nearly 0.7 billion gallons per day (2.7 million m³/d) of MED capacity contracted between the end of 2004 and mid-2008 (IDA 2008).

Unlike membrane processes, the energy required to accomplish desal via thermal processes does not vary substantially with the TDS concentration. Therefore, thermal processes are much less energy efficient for lower-TDS brackish water desal.
BENEFITS & COSTS

- Thermal processes have a larger footprint, require more feedwater, and have higher capital and operating costs than membrane plants.

- Thermal plants are only economically justifiable when designed and constructed in conjunction with an electric power plant employing once-though cooling, and/or where a large quality of low TDS (<25 mg/L) water is required. Thus, thermal processes are virtually unused in the United States for municipal desal.

KEY UNCERTAINTIES

As discussed above, thermal seawater desal plants are best–suited for co–location at steam electric power plants equipped with once–through cooling (OTC) systems. To be economically viable, the desal plant must be integrated within the steam cycle of the power plant at the time of its design. Current environmental requirements that severely limit the use of OTC power plants mean that thermal desal technology is unlikely to be employed in the United States.

ADDITIONAL RESOURCES


