RENEWABLE ENERGY AND DESALINATION SYSTEMS

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Contents

Summary

The chapter reviews the reported work on applying the renewable energy in the operation of desalination systems, which at present totally depend on burning of fossil fuels, In this respect, sustainability is defined and emphasized. A brief review of desalination technologies is presented. Desalination using solar energy is reviewed in detail.

Desalination using other renewable energies such as wind, geothermal, wave, tidal and ocean thermal energy are also reviewed.

1. Introduction

1.1 Need for Desalination

Almost 97.5% of the total global stock of water is saline. Out of the remaining 2.5%, approximately 70% is locked up in polar icecaps, whereas the major part of the remaining 30% lies in underground aquifers. Thus 0.007% of the total global stock of water is readily accessible in rivers, lakes and other reservoirs for direct use. Several regions of the world are in a grip of water scarcity with less than 1000 cu.m. of freshwater available per year per capita. As a result, desalting seawater has become a dire necessity to augment freshwater resources in many arid regions.

No surprise, there has been a 22 fold increase in desalting capacity since 1972, and this figure continues to rise. Yet desalinated water is only about 1/1000 part of the freshwater used worldwide, which costs several times more than the water supplied from conventional resources. The cumulative desalination installed capacity was about 53 million m^3/d in 2008 and as of 2008, the cumulative contracted(planned) capacity of desalination plants around the world was 62.8 million m3/d(Al Gobaisi ,2009) and this is comparable to that predicted by Water Re-use Promotion Center, Japan 2006 (Totaro Goto 2006, Table 3). The projected trend of seawater desalination in the world is expected to be 64.3 million m^3/day in 2010 and 97.5 million m^3/day in 2015. The Arab Gulf Cooperation Council Countries still remain the biggest market in the world (See Table 1).

Country	2006	2010	2015
Saudi Arabia	7,246,000	11,496,000	16,436,000
UAE	5,456,000	8,356,000	11,556,000
USA	6,616,000	7,866,000	10,566,000
China	622,000	1,972,000	5,322,000
Spain	2,379,000	3,824,000	4,954,000
Algeria	721,000	2,561,000	4,461,000
Kuwait	2,081,000	3,191,000	4,341,000
Australia	362,000	1,222,000	3,472,000

Table 1 – Present and Future Desalination Market by Country-wise,
Source: Al Gobaisi Darwish 2009, “*Sustainability of Desalination Systems – An Essential Consideration for The Future of Desalination Systems*”.

2. What Is Sustainability?

Sustainability of any manufacturing process has two basic criteria:

A product must be made by using natural resources only, with their continued availability from generation to generation.
The wastage produced in the process must be handled within the manufacturing loop or be assimilated into the natural ecosystem without building up or causing any pollution of land, air and water.

At present, the desalination practice is totally based on burning fossil fuels which obviously pollutes the atmosphere. Moreover, disposal of hot concentrated brine pollutes the oceans. The rejected brine affects the salinity and turbidity, increases temperature as well as causes water currents. Thus, the present situation is totally away from any degree of sustainability. The two papers "Energy and Water in Kuwait : A Sustainable View Point" from Darwish M.A. et.al (2007) outlines how the power production plus thermal desalination based on burning fuels are consuming the available natural resources in that country. Part II of the paper (Darwish M.A. et.al (2007) outlines some of the measures needed to save both water and energy. However, the situation cannot be fully sustainable. In an earlier paper, Afgan,N.H. et.al (1999) an attempt has been made to assess sustainability of desalination plants based on resource, environmental and economic indicators. How the desalination is affecting the environment has been outlined by Einav,R. et.al (2002). Darwish et.al (2006) provides guidelines towards achieving sustainability in desalination in the Gulf area. It is clear from the above cited work that though sustainability is receiving lot of attention, yet it can be truly achieved in desalination by shifting over to the renewable energies rather than burning fuels. Before it is discussed, a brief review of desalination technologies is given in the follow section.

3. Review of Desalination Technologies

The desalination technologies can be broadly divided into two major groups, namely,

- Those which utilize thermal energy to evaporate water with subsequent condensation to freshwater.
- Those based on the selective flow of water through semi-permeable membranes.

3.1 Thermal-Based Processes

The predominant process being applied in this category is the multistage flash (MSF) process, as shown in Figure 1, with a large quantity of brine recirculation (BR) thus referred to as MSF-BR process.

Alternatively, the MSF process can be operated in the same number of flash stages as the once through process (MSF-OT), shown in Figure 2. Compared to the MSF-BR process (Figure 1), in this process (Figure 2), the total quantity of seawater needs to be pretreated and deaerated. However, with the availability of more efficient chemical additives, the pretreatment cost is expected to be much lower. Recently, Helal and Odeh (2004) have explored the feasibility of this process for large capacity plants.

Further as suggested by El-Dessouky et.al (1998, 1999), part of the concentrated brine from the last flash stage can be recycled in the MSF-OT process. This modified process, as shown in Figure 3, is identified as (MSF-M) process.

Recently, Hussain et.al (2005) carried out simulations for the MSF-OT (Fig.2) and the MSF-M (Fig.3) processes had they been applied to three plants containing 18, 20 and 22 flash stages, respectively, which are currently in operation using the MSF-BR process (Fig.1). The results indicate that for the same input conditions, the production rates remain more or less the same in the OT and M processes. However, there is a marked saving in the steam consumption rates in case of either OT or M process applied and thus improvement in the performance ratios (PR) on average by 30%. PR is roughly defined by dividing distillate production rate by the steam consumption rate in the brine heater. Implementation of either OT or M process to the existing plants will not at all be difficult. This would result into considerable saving of energy, thus a step forward in the direction of achieving sustainability.

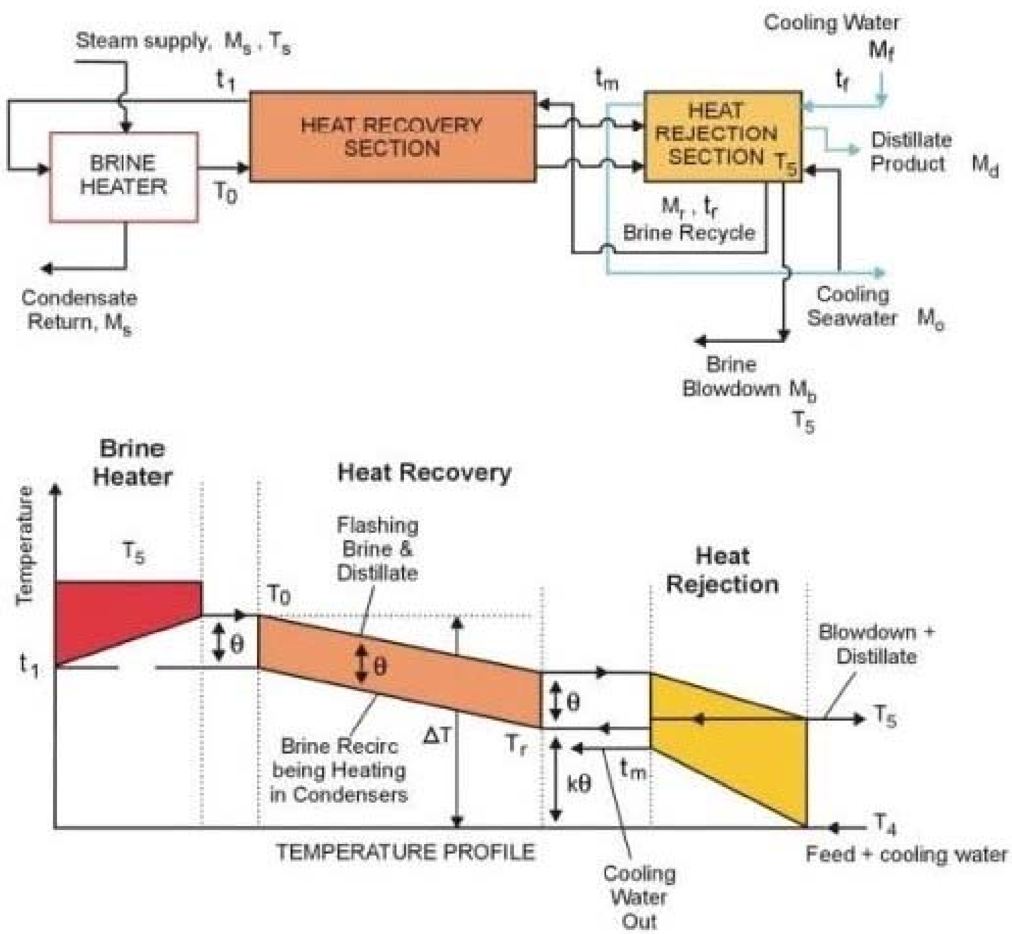

Figure 1. A Brine-Recirculation Multistage Flash Plant.

Multiple Effect Boiling (MEB) usually operates in desalination either horizontally or vertically placed tubes through which heat transfer occurs between the vapor condensing on one side and the seawater evaporating on the other. Different designs are available involving either cocurrent or countercurrent flow of seawater and the generated vapor. A new design of vertical tower, Pepp et al (1997) has been proposed with seawater evaporating on the inside surface of the tubes and the vapor condensing on the outer surface with PR as high as 24.

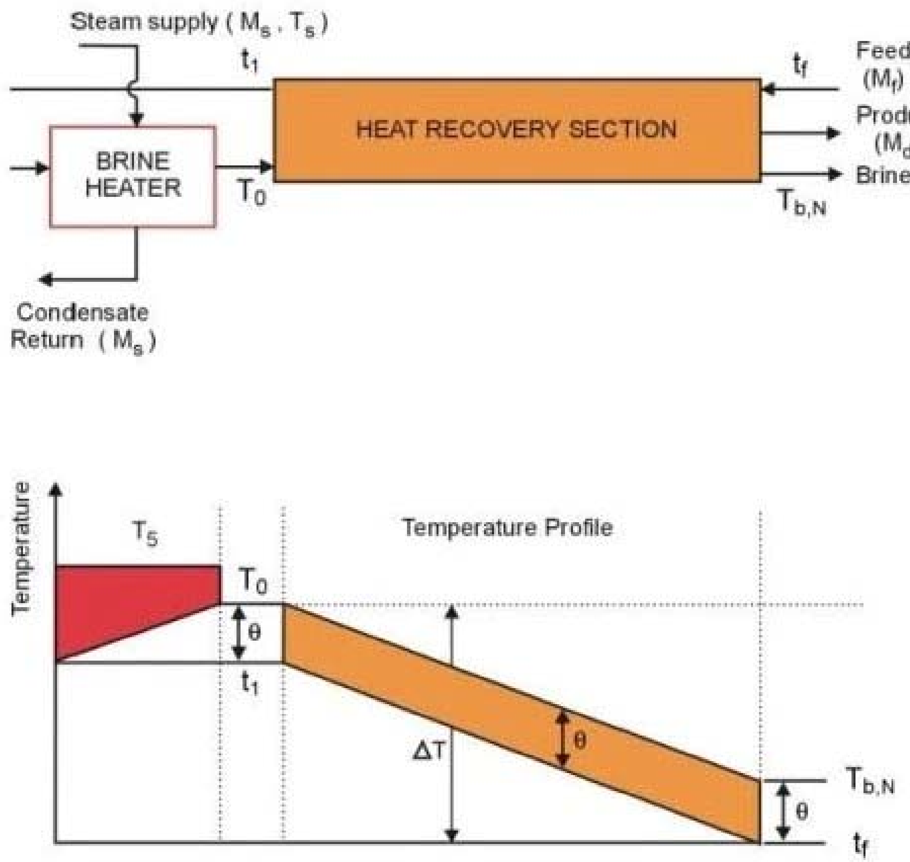

Figure 2. A Once Through Multistage Flash Plant.

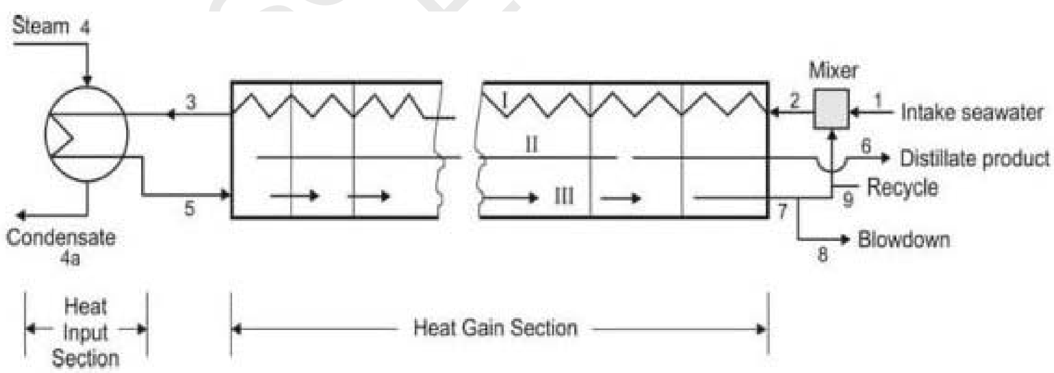

Figure 3: MSF-M Process

3.2 Membrane – Based Technologies

These technologies can be classified as follows depending upon the driving force :

- Pressure : Reverse Osmosis (RO), Filtrations – nano, ultra and micro;

- Partial Pressure : Pervaporation, Gas separation ;
- Electrical Potential : Electrodialysis (ED), Membrane Electrolysis ;
- Concentration : Membrane Extraction, Dialysis ;

RO is very successfully applied in producing potable water from the seawater. It is also being used for producing ultrapure water required in the semi-conductor industry. Table 2 compares the energy consumption in the major processes for seawater desalination for typical unit sizes :

Process	Cu.m./day Product	Energy Consumption KWH/cu.m. Product
RO	24,000	5 – 7
MEB	60,000	4.5 – 12.5
MEB/VC	24,000	7 – 9
MSF	60,000	12 – 24

VC : Vapor Compression

Table 2: Energy Consumption of Desalination Processes

Voutchkov (2004) describes how co-location of RO plant with large power generation station is beneficial in reducing the cost of producing pure water and minimizing the impact of RO plant discharge on the aquatic environment.

Membrane Distillation (MD) involves transporting water vapor through the pores of a hydrophobic microporous membrane. Using a sweeping gas stream, the water vapor from the permeate side of the membrane is flushed out by maintaining a pressure gradient for mass transfer. The SAND Report, Evans and Miller (2002) describes the problems involved in sweeping gas MD using commercially available hydrophobic hollow fiber membranes in making a viable technology for desalting seawater.

According to Ettouney et al (2002), the RO is the optimum choice for low salinity water regardless of plant capacity. The unit product cost has approximately equal contributions of fixed charges, power cost and membrane replacement cost.

3.3 Renewable Energies

Presently the practice of desalination is totally away from any degree of sustainability. In order to correct this situation, the only option is to switch over as far as possible to *renewable energy* driven desalination, away from the influence of conventional economics being myopic in its vision of the future. A more enlightened vision of economics has to be adopted with a strong sense of ecological security as well as continuity of resources.

As the term indicates, the resources of renewable energy are natural, long lasting and do not deplete with the passage of time along with their usage. These can be broadly classified as given below :

- Solar

- Wind
- Geothermal
- Waves
- Tides
- Hydraulic
- Biomass

4. Desalination Using Solar Energy

Thermonuclear processes occurring in the Sun produce electromagnetic radiation. The part of this radiation received by the Earth can be converted to heat, electricity as well as mechanical energy. Thus, the solar energy is clean, silent and available in majority of the places on the Earth. However, it has disadvantages of being low intensity having wide variations diurnally and annually. The diffuse nature of sunlight needs large areas for concentration (Howe, 1974). Thus, a fraction of the energy reaching the Earth's surface can be converted into useful forms by the means and objectives as shown in Figure 4.

The various angles formed between the site and the radiation beams are important parameters for evaluating solar plant efficiencies. Thus to harvest the optimum solar energy, variations in the incident radiation and changes of the beams in relation to a random surface under observation has to be known. Belessiotis and Delyannis (2000) have reviewed several models to estimate the availability of solar radiation at a particular location.

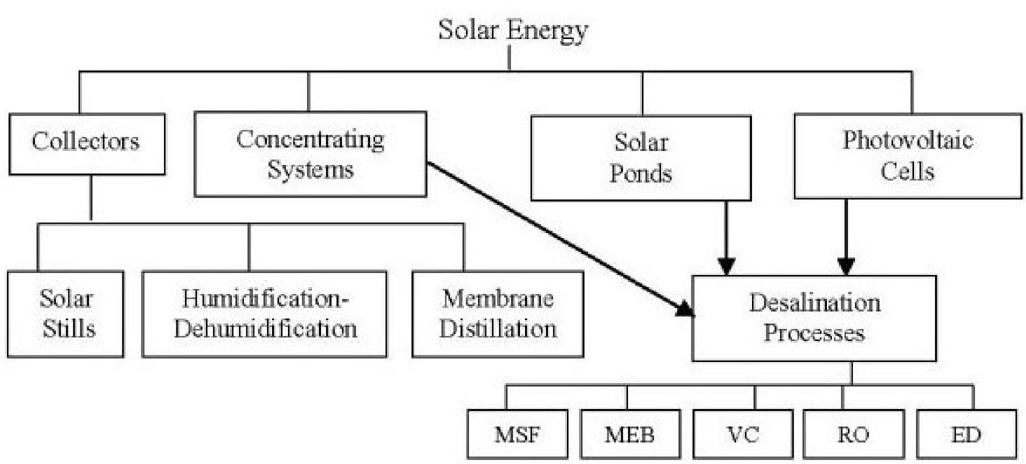

Figure 4 : Utilization of Solar Energy

The solar energy can be directly utilized for desalination in a solar still or indirectly by converting into heat or electricity in order to drive a conventional desalination system. These are reviewed in the subsequent sections.

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