

INTRODUCTION AND DEFINITIONS

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1. Basic Principles

Multiple-effect (ME) and vapor compression (VC) evaporation have been described in very general terms in Section 1.1. That treatment was limited and general and the diagrams simplified and stylized so as not to confuse the first-time reader. In contrast, the present chapter explores the innermost workings of the theory behind these processes and particularly those designs and configurations that have been used successfully in the desalination of seawater.

However, before venturing into the mathematics and design details of these processes, one must understand subjectively the most basic functional steps and goals of all evaporative desalination processes. One way to view these is as follows.

1.1. The Evaporating Zone

In any working apparatus, there must exist one surface (or set of surfaces) in which salt solution and water vapor co-exist, but not in equilibrium. Here the rate of evaporation from the surface exceeds the rate of condensation onto the surface, with a net transfer of water to the vapor phase. That is to say, the water vapor pressure of the solution exceeds the water vapor pressure of the gas phase above it. This is the goal of the evaporative zone.

To achieve this imbalance in vapor pressures, it is easy enough to increase the water vapor pressure of the solution by increasing its temperature somewhat. However, as the water evaporates from the solution, it absorbs its heat of vaporization from the remaining solution, thus reducing the temperature of that solution and, hence, its vapor

pressure. In addition, the solution becomes more concentrated in salt, lowering its water vapor pressure still further. At the same time, an increase in the amount of water vapor in the gas phase, if confined, will lead to a build-up of vapor pressure in the gas phase. Thus, the desired vapor pressure imbalance is reduced and the process slows down, seeking a new equilibrium state.

One may also achieve the initial vapor pressure imbalance by drawing off some of the water vapor in the gas phase, creating a partial vacuum. However, once again, the solution is cooled by losing the heat of vaporization of the water evaporated, its concentration increases, and its vapor pressure falls. The new water vapor formed increases the pressure in the gas phase and once again the process slows down.

Thus in order to maintain a continuous evaporative process, it is necessary to consider three factors: (a) the addition of heat to the evaporating solution, (b) the replenishment of this solution, which is slowly becoming more concentrated, and (c) the removal of produced water vapor from the gas phase.

1.2. The Condensing Zone

Similarly, in the condensing zone one seeks to maintain an imbalance, with the gas phase water vapor pressure being higher than that of water in the liquid state. As vapor condenses, the vapor pressure in the gas phase decreases. At the same time, as vapor condenses into the liquid phase, it releases its heat of vaporization to the liquid phase, increasing its temperature and, thus, the vapor pressure of the liquid. So again the process slows toward equilibrium. To maintain the process one must (a) remove heat from the liquid state and (b) introduce additional water vapor to the condensing zone.

1.3. Vapor Transport

In a practical desalting process, not only must there be an evaporation zone and a condensing zone, these must be connected by a means for transporting water vapor from the former to the latter. This can be accomplished by natural convection and diffusion or mechanically by fan or pump.

1.4. Energy Input

The energy needed to drive the system may be added to the liquid phase through the addition of heat and/or to the gas phase through the use of a compressor that both extracts vapor from the evaporation zone and supplies it at increased pressure to the condensing zone.

1.5. Energy Efficiency

The earliest and simplest desalination systems (see Section 1.2) consisted basically of a heated vessel of salt water connected to an air or water cooled metal pipe that served as a condenser. One drawback of such systems is that the energy added to the evaporator (the energy of vaporization of the product water plus some sensible heat) is lost to ambient in the condenser. This leads to a level of energy consumption (and cost) that is

often difficult to justify. Although some improvement in energy efficiency may be obtained by letting the condenser serve as a pre-heater to the make-up feedwater, this alone is only an incremental improvement.

It was not until the nineteenth century that technologies were developed to reduce the energy consumption of evaporative processes several-fold. These were ME and VC evaporation. Their early development is also described in Section 1.2 and their most common present embodiments are explained in Section 1.1. In both cases, the energy of vaporization is, in a sense, recycled within the system to cause further evaporation.

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