SUMMARY OF DESALINATION METHODS USED IN COMMON PRACTICE

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1. Background

Desalination is a water treatment process that separates salts from saline water to produce a water that is low in total dissolved solids (TDS). This encyclopedia focuses on the use of desalination technology for the production of water for potable purposes although these technologies are used for other purposes - especially in industry.

As described later in this chapter, the concept of desalination has been around for several millennia. It was used only sparingly for producing potable water due to the high cost of production. The basic process used in the earliest applications was a simple boiling of saline water with condensation and recovery of the vapors (distillation). A number of units of this type were built and installed in various arid areas around the world.

A real interest in desalination for producing potable water came during the Second World War when it was necessary to provide water for troops and military installations, especially on the islands of the Pacific, locations in the Middle East and for military personnel set adrift due to the sinking of a ship or the downing of a plane. These units tended to be a form of thermal distillation for large land-based installations and ships and solar distillers for lifeboats. The military necessity gave the financial backing to allow more research and experimentation than had taken place previously.

Real progress in popularizing desalination technology on a global basis came after the war and was propelled, in part, by the enthusiasm and results of the war effort in desalting.

The result of this period of testing has been that three basic desalting processes have found commercial success in the international marketplace. These are:

- Distillation
- Electrodialysis (ED)
- Reverse osmosis (RO)

Distillation is a thermal process while both electrodialysis and reverse osmosis are membrane processes.

2. Distillation

Distillation is a process with the largest installed capacity in the world - almost two-thirds of the world's capacity. The distillation process mimics the natural water cycle in that saline water is heated, producing water vapor that is, in turn, condensed to form fresh water. In a laboratory or industrial plant, water is heated to the boiling point to produce the maximum amount of water vapor.

For this to be done economically in a desalination plant, the boiling point is controlled by adjusting the atmospheric pressure of the water being boiled. The temperature required to boil water decreases as the pressure above the water decreases. The reduction of the boiling point is important in the desalination process for two major reasons: multiple boiling and scale control.

To boil, water needs two important conditions: the proper temperature relative to its ambient pressure and enough energy for vaporization. When water is heated to its boiling point and then the heat is turned off, the water will continue to boil only for a short time because the water needs additional energy (the heat of vaporization) to permit boiling.

Once the water stops boiling, boiling can be renewed by either adding more heat or by reducing the ambient pressure above the water. If the ambient pressure is reduced, the water would then be at a temperature above its boiling point (because of the reduced pressure) and will boil with the extra heat from the higher temperature to supply the heat of vaporization needed. As the heat of vaporization is supplied, the temperature of the water will fall to the new boiling point.

To significantly reduce the amount of energy needed for vaporization, the distillation desalting process usually uses multiple boiling points in successive vessels, each operating at a lower temperature and pressure. This process of reducing the ambient pressure to promote boiling can continue downward and, if carried to the extreme with the pressure reduced sufficiently, the point at which water would be boiling and freezing at the same time would be reached.

Aside from multiple boiling, the other important factor is scale control. Although most substances dissolve more readily in warmer water, some dissolve more readily in cooler water. Unfortunately, some of these substances are found in seawater. One of the most important is gypsum ($CaSO_4$), which begins to leave solution when water approaches about 95°C (203°F).

This material forms a hard scale that coats any tubes or surfaces present. Scale creates thermal and mechanical problems and, once formed, is difficult to remove. One way to avoid the formation of this scale is to keep the boiling point of the water below that temperature. The other way is to add chemicals to reduce scale formation.

These two concepts, boiling temperature reduction and multiple boiling, have made various forms of distillation successful in locations around the world.

2.1. Processes

The three types of thermal distillation units generally used commercially are:

- Multistage flash (MSF)
- Multiple effect distillation (MED)
- Vapor compression (VC)

2.1.1. Multistage Flash

In the MSF process, seawater is heated in a vessel called the brine heater. This is generally done by condensing steam on the walls of a series of tubes that passes through the brine heater which contains the seawater to be heated (see Figure 1). This heated seawater then flows into another vessel, called a stage, where the ambient pressure is such that the water will immediately boil.

The sudden introduction of the heated water into the chamber causes it to boil rapidly, almost exploding or flashing into steam. Generally, only a small percentage of this water is converted to steam (water vapor), depending on the pressure maintained in this stage since boiling will continue only until the water cools (furnishing the heat of vaporization) to below the boiling point.

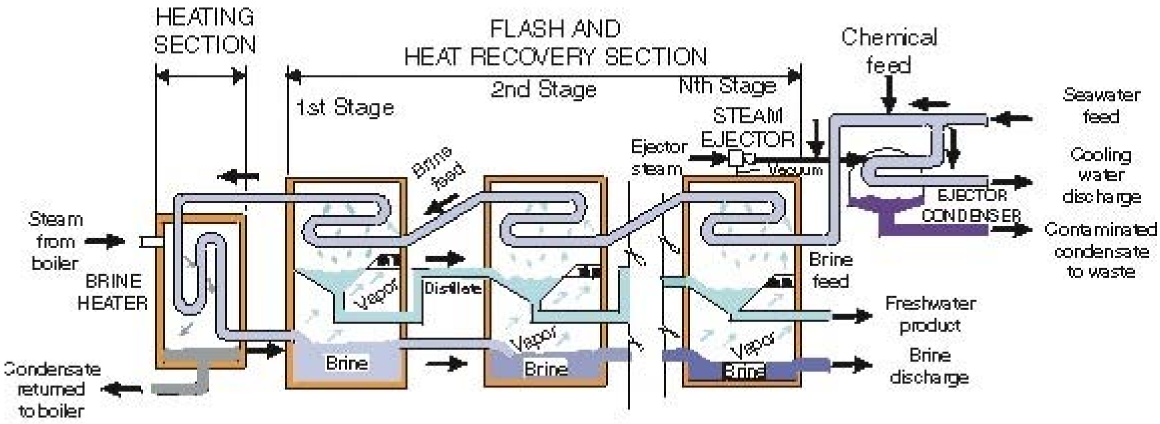

Figure 1. Diagram of a multi-stage flash distillation plant.

The remaining heated seawater passes to another stage which is at a lower atmospheric pressure causing it to boil again. This is repeated so that the feed water passes from one stage to another and is boiled repeatedly without adding more heat. Typically, an MSF plant can contain from 4 to about 40 stages, with 20 to 30 being normally used.

The steam generated by flashing is converted to fresh water by being condensed on tubes of heat exchangers that run through each stage. The tubes are cooled by the incoming feed water going to the brine heater. This, in turn, warms up the feed water so that the amount of thermal energy needed in the brine heater to raise the temperature of the seawater is reduced.

2.1.2. Multiple Effect Distillation

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. In an MED plant, the seawater enters the first effect and is raised to the boiling point after being preheated in tubes (see Figure 2). The seawater is either sprayed or otherwise distributed onto the surface of evaporator tubes in a thin film to promote rapid boiling and evaporation. The tubes are heated by steam from a boiler, or other source, which is condensed on the opposite side of the tubes. The condensate from the boiler steam is recycled to the boiler for reuse.

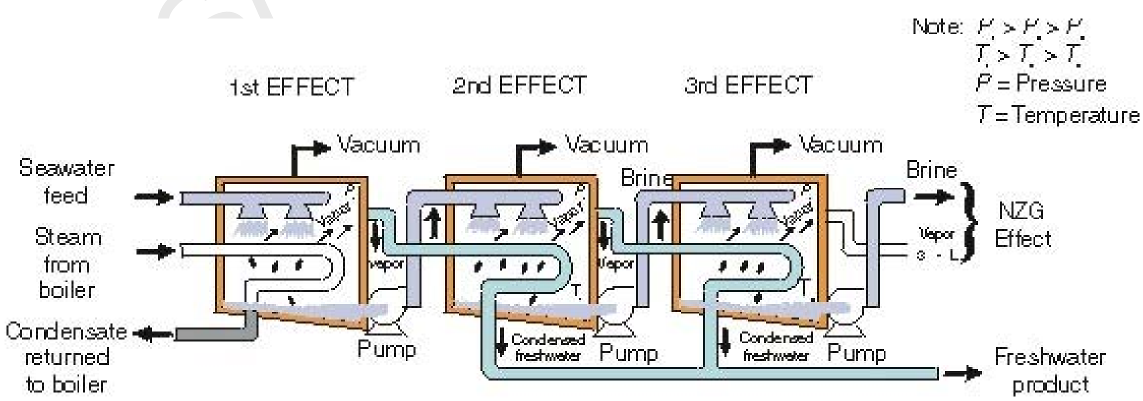

Figure 2. Diagram of a multiple effect plant.

Only a portion of the seawater applied to the tubes in the first effect is evaporated. The remaining feed water is collected and fed to the second effect, where it is again applied to a tube bundle. These tubes are, in turn, being heated by the vapors created in the preceding effect. This vapor is condensed to fresh water product, while giving up heat to evaporate a portion of the remaining seawater feed in the next effect. This continues for several effects, with 8 or 16 effects being found in a typical large plant.

Usually, the remaining seawater in each effect must be pumped to the next effect so as to apply it to the next tube bundle. Additional condensation takes place in each effect on tubes that bring the feed water from its source through the plant to the first effect. This warms the feed water before it is evaporated in the first effect.

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Bibliography and Suggestions for further study

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