SMALL DESALINATION PLANTS (SDPS)

Himangshu K. Sadhukhan and Pradip K. Tewari
Bhabha Atomic Research Centre, Mumbai 400085, India

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Summary

Small desalination plants (stationary or mobile) are required for the supply of drinking and industrial water in remote areas, hotels, hospitals, offshore platforms, ships, etc. When storage capacity is available, a mobile small desalination unit can be rotated and operated periodically serving several small communities spread out over a large water scarcity area. The choice of desalination process is determined by the chemistry and physical condition of the feed water, product water quality requirement, and the energy source available to power the desalination plant.

1. Introduction

Ever since men have been sailing the seas, there has been a need for small desalination plants (SDPs). As early as 1684, the Secretary to the Board of Admiralty proposed an experimental machine for producing fresh water from seawater on one of His Majesty's ships. However, there is no further information available about this plant.

Earlier distillation desalination units of SDPs were made of cast iron shell. Steam was circulated in copper coil. The liquid entrainment in the vapor was too high, resulting in high salinity product water. The early SDPs were operated at about 110°C. About half of the feed seawater was evaporated leaving behind a precipitate of a high percentage of calcium and magnesium salts such as carbonates and sulfates on the heating surface. Scaling was very frequent and harder scales were frequently removed by chiseling and hammering (Budge 1987).

With time and experience, it was realized that SDPs would perform better at lower temperature. So vacuum pumps were used to produce and maintain a vacuum. Slowly vacuum pumps were also replaced by steam jet and water jet ejectors.

2. Single-effect and Multieffect Distillation

SDPs are normally single purpose units for producing only good quality water from saline water which is used as drinking water or process water for industrial use.

Low temperature SDPs with a submerged element or plate heat exchanger type are available for producing pure water from saline water using waste heat as the energy source. They operate at about 40°C and 710 mm Hg vacuum without any chemical pre-treatment of the feed. The units are ideally suited for locations where the waste heat is available. SDPs with a self-scale shedding heating element made of monel using low pressure steam as heating media are also popular for small-scale applications. Single-effect desalination units are preferred when space and weight are the limitations and enough waste heat is available for producing the required quantity of fresh water from seawater. Multieffect distillation (MED) units are used when water requirement is high and available quantity of heat is less. The vapor produced in the first evaporator is used as heating media for the next effect. In practice, MEDs for small desalination plants have two to four effects. Thousands of MED plants were built in the past by industries all over the world primarily for the recovery of salt. This process was also the first one to be used to produce a significant amount of fresh water from seawater (Khan 1986). It has come a long way with technological developments achieving high heat transfer coefficients at lower temperature differential for these plants. A recent development in this field is the horizontal tube thin film (HTTF) desalination evaporators which have still higher heat transfer coefficients and less maintenance problems. Some innovations such as orbital tube evaporators (OTE) for desalination are also under development. A list of a few small desalination plants based on MED process is given in Table 1.

Location	**Plant capacity (m^3 day^{-1})**	**Application**
Abu Dhabi	120[a]	To supply water in the city
Offshore, India	35	Industrial and potable use on oil offshore platform
Onboard ship, France	100	Potable use onboard ship
Farazan Islands, Saudi Arabia	140	Supply potable water in islands
Skikda, Algeria	380	Potable water
Kagawa, Japan	16[a]	Potable water production from MED using solar heat
Tortola, British Virgin Islands	1000	Potable water supply to islands

[a]Solar powered MED.

Table 1. Examples of the MED-based SDPs.

With the development of steam engines fitted in ships, the concept of SDP fulfilling the requirement of good quality water for the crew started picking up. Steam was used to generate vapor from seawater which was condensed to give pure water. The principle of distillation was used in these plants for producing fresh water from seawater.

3. Vapor Compression

The heat for seawater evaporation comes from the compression of vapor rather than direct exchange of heat from the steam produced in a boiler. Vapor compression (VC) units are built in a variety of configurations to promote heat transfer. Both mechanical vapor compressors and thermocompressors are used to drive the process. The vapor produced is compressed raising its temperature. It is used as heating media for evaporating the brine. The condensate is pumped out as product water. There are two types of VC desalination units: pressure and vacuum operation units. Pressure units operate at about 101°C and 1.05 bar. Cupronickel, titanium and monel are used as the materials of construction. The scale formation is controlled by pH control and use of suitable anti-scalants. Vacuum desalination units operate at about 70-75°C and 0.4 bar. Aluminum, copper-based alloys and titanium are used for tubes, tubesheets, etc. Anti-scalants are used for scale control. For low capacities, centrifugal compressors are used for compressing the water vapor. Such plants have high thermal efficiency as the major part of the latent heat is reused. Efficiency is further improved by recovering the heat of the blowdown brine and product water in pre-heating the incoming seawater feed. A list of a few VC-type SDPs is given in Table 2.

Location	**Plant capacity (m^3 day^{-1})**	**Application**
La Graciosia Canary Islands, Spain	75	Potable water supply in island
Seashore municipality, West African coast, Africa	75	Municipal water supply
African naval headquartrs, East Africa	100	Potable water for navy
Imperial Iranian Airforce, Kharg Iran	50	Mobile desalination plant for potable water supply to air force units
Offshore, Abu Dhabi	40	Industrial water supply
French Red Cross	18	Mobile desalination unit
Drilling platform, Mexico	100	Industrial and potable water supply at drilling platform
Oil offshore platform, India	30	Industrial and potable water supply at oil offshore platform
Onboard ship, France	30	Potable water onboard ship
Rak White Cement Works, Ras Al Khaimah, UAE	207×7	Industrial water supply
St John US Virgin Islands	586	Potable water supply in island
Los Banos, California, USA	190	VC concentrator
Royal Haymen Resort, Australia	270	Potable water supply to holiday resort

Table 2. Examples of small vapor compression desalination plants.

The thermocompression (TC)-based SDPs have an ejector with a venturi orifice which extracts water vapor from the main vessel. Vapor is compressed by TC and used to evaporate seawater in the evaporator. The condensate is collected as product water. TC uses motive steam at 8-10 bar to drive the unit. A number of TC-based SDPs are operating to produce good quality water from seawater for industrial and municipal use. Table 3 gives a few small-sized TC-based desalination units.

Location	**Plant capacity (m^3 day^{-1})**	**Application**
Das Islands, Abu Dhabi	125	Potable water supply in island
Les Saintees, Caribbean	40	Potable water supply
Tobruk, Libya	125	Potable water supply
Ascension Island, South Atlantic	140	Potable water supply in island
Onboard ship, France	12	Potable water supply onboard ship
Mobile unit, France	36	Mobile desalination plant for fresh water supply
Municipality of Uwa Jima, Ehime, Japan	180	Municipal water supply
Arabian Cement Co., Rabigh, Saudi Arabia	480	Industrial water supply

Table 3. Examples of a few small-sized TC-based desalination units.

4. Multistage Flash

Multistage flash (MSF)-type small desalination units are used where low pressure steam is available for driving the plant. In these type of units seawater is heated up to a desired temperature and flashed in stages at lower pressures. The vapor is condensed as product water, thereby pre-heating the incoming seawater. Although, a greater number of stages give better efficiency, only two to three stage MSF units are normally used for SDP, due to weight and space limitations as in the case of marine applications (Budge 1987). Table 4 gives a list of a few SDPs based on MSF.

Location	**Plant capacity (m^3 day^{-1})**	**Application**
Belawan, Indonesia	500	Potable water supply
Saline Water Conversion, Corporation, Yanbu, Saudi Arabia	20	Potable water production
INS *Godavari* Ship, India	60	Potable water supply in ship
Al-Murrawah, Abu Dhabi	500	Potable water

Table 4. Examples of MSF-type small desalination units.

5. Electrodialysis

Electrodialysis (ED) and electrodialysis reversal (EDR)-type small desalination units find extensive use in the desalination of brackish water. The basic separation mechanism involves the removal of salt constituents leaving the desalted water behind. It is carried out by means of two special membranes that allow the passage of only cation or anion charged ions and a direct current electric field. The mode of operation in ED is unidirectional. A modification in this process is EDR which involves periodic reversal of the DC polarity. It has several advantages over unidirectional ED. It provides a flushing operation for the deposits which controls membrane scaling and fouling. The process is widely used for producing pure water from 1000-5000 ppm total dissolved solids (TDS) brackish water. The amount of electricity required for desalting is proportional to the amount of salts removed. ED is not effective in removing silica or organic components. Several SDPs have been operating in the desert and water scarcity areas throughout the world for producing potable water from brackish water by this process. ED has also been used in Japan and Kuwait for concentrating seawater to produce common salt. Development work on high-temperature ED is also in progress (Hodgkiess 1987). At higher feedwater temperatures both the membrane and solution resistances are reduced and higher current densities can be achieved. It reduces the membrane area requirement and, thus, the capital cost. The operating temperature in high-temperature ED however should not exceed around 50°C due to increased scaling tendencies. Table 5 gives examples of electrodialysis-type SDPs located in different places

Location	**Plant capacity (m^3 day^{-1})**	**Application**
Xinjian Desert, China	140	Potable water supply in desert area
Fishing fleets, Japan	2	Potable water for fishing fleet
Maldive Islands	50	Drinking water supply for islands
Rural Water Supply, India	30	Drinking water for rural areas
US Department of Interior, USA	950	Potable water production and supply
Riyadh, Saudi Arabia	400	Potable water from bore hole water
Fine Chemical, West Germany	500	Industrial use
Moomba, Southern Australia	400	Potable water supply

Table 5. Some examples of ED-based SDPs.

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