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A new type of seawater desalination plants using solar energy

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Abstract

This paper presents a new water desalination process. The basic unit operation in this process is to use solar energy for heating of an air stream and in the second step to add seawater into the hot air in order to humidify it. It follows a cooling step of the humid air providing potable water as a condensate. On the base of this solar desalination process, a desalination plant is predicted and designed to provide 10 m^3 of potable water daily. The main feature of the new process is the stepwise loading of air by vapour. The process consists of several steps for air heating, each followed by a humidification stage. This manner of operating makes it possible to obtain high vapour concentration in the air flow, thus reducing the air flow rate through the plant. The power necessary for air blower and the size of pipes and other equipment decrease. Experimental and computational work has been conducted to realise the application of that new desalination idea. New collectors for solar heating of air and humidifying equipment to moisten that heated air are developed. Heat exchanger for recovery of water by dehumidifying of the humid air could be designed and tested. Using this new equipment, a small pilot plant could be constructed and run to test the new process under different operating conditions. The results of these tests will be presented. A dynamic simulation program to predict, to optimise and to design solar desalination plants according to the new process has been developed. The program includes also an economic part, which enables the optimisation of the process under consideration of thermodynamic aspects as well as from the economic point of view. Applying the dynamic simulation program and the developed economic optimisation procedure, it is possible to design and to optimise any desired plant using the new process. As a demonstration, a plant with a capacity of 10 m^3 of potable water per day is designed and optimised according the developed planning and optimisation procedure. For this plant the size and the optimum operating conditions of each kind of equipment are determined. The process flow sheet of this desalination plant is provided. The required investment costs are determined under variation of some plant design parameter.

Keywords: Desalination; Solar energy; Seawater; Brackish water; Collector; Humidification; Dehumidification

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1. Introduction

The conventional method for desalination of seawater is to evaporate the salty water and subsequently to condense the arising vapour being free of salt. In the majority of cases, such desalination plants are designed as multi-stage evaporator plants using fuels as an energy source. This process is the basis for a daily production of several millions cubic meters of water [1].

The use of solar energy to fulfill the task of seawater evaporation and to obtain potable water is a subject of many investigations done during the last years. The solar desalination process offers the advantage of doing practically no ecological damage and creating minimum energy cost. Solar water evaporation plants use collected solar energy for direct heating and evaporating of salty water to gain distilled water [2,3]. In other cases, solar energy has been used to heat seawater and later to inject the warm water into air to humidify it. The subsequent cooling of the humid air delivers the needed water free of salt [4–6]. In all these processes the salty water is directly heated by the sun.

The target of the actual investigation is to develop a new process for seawater desalination using solar energy and turning away from merely heating or evaporating of seawater itself as the main idea for water processing. The basic idea in the present research is first to use solar energy for heating an air stream up to maximum 80°C and in the second step to inject seawater into the hot air to evaporate it using the energy initially provided by the sun. Air, as a heat carrier at temperatures less than 80°C, allows the use of economic structure materials for collecting of solar energy. No corrosion, scaling or plugging can occur in the solar collecting system. The low operating temperature allows the use of low-cost polymers for air heaters, humidifiers, pumps and other equipment.

One main objective of the present solar desalination process is to minimise the air volume which flows through the plant, that means, a maximum concentration of vapour in the air should be appointed. This target will be achieved by a stepwise accumulation of vapour in the solar-heated air flow and subsequently by an intermediate heating of the humid air.

The process consists of several steps for air heating accompanied by humidifying stages. This manner of operating makes it possible to obtain high vapour concentration in the air flow, thus reducing the air flow rate through the plant and decreasing the power necessary for air blower. The volume of pipes and other equipment can be reduced, low investment costs can then be achieved.

1.1. Thermodynamic background of the process

Heating and humidifying of air can be described using the psychometric chart, also called *h-x*-diagram shown in Fig. 1 [7,8].

An air flow with the initial temperature and initial humidity as indicated by Item 1, i.e. 25°C and 10 g water per kg of dry air, can then be heated up to 80°C (Item 2) and humidified by adiabatic injection of water to increase its humidity up to 30 g/kg (Item 3) accompanied by a temperature decreasing to approximately 30°C.

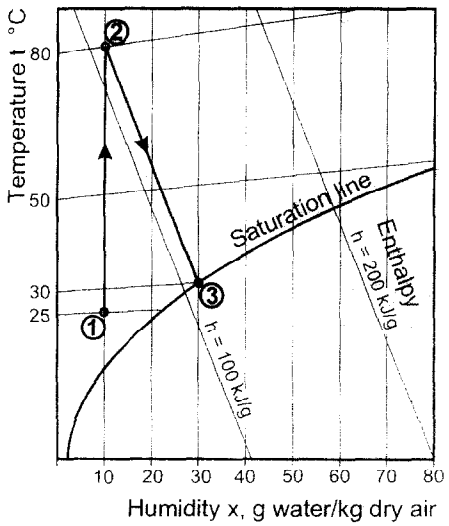

Fig. 1. Heating and humidifying process in *h-x*-diagram.