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Desalination 153 (2002) 25–37

DESALINATION

www.elsevier.com/locate/desal

A new seawater desalination process using solar energy

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Received 15 April 2002; accepted 30 April 2002

Abstract

This paper presents the development of a new process to desalinate seawater using solar energy. By the proposed process, the solar energy heats airflow up to a temperature between 50 and 80°C. The moderate solar heated air will be humidified by injecting seawater into the air stream. Later on, the water being free of salt will be extracted from the humid air by cooling it. Using air as a heat carrier and keeping the maximum operating temperature in the process lower than 80°C enables the use of cost effective polymers as construction material. The main feature of the present process is a successive loading of air with vapor up to a relative high humidity, such as 10 or 15 wt.%. As a result, the air volume flowing through the plant can be substantially reduced. This target will be realized by a new suggested stepwise heating/humidifying-technique. The thermodynamic background of the new process will be described. An optimizing procedure of the desalinating process by selecting of optimum process parameters will be explained. Low cost air heaters for collecting of solar energy are developed. Special designs for air humidification by evaporating of seawater has been constructed and tested. Condensing equipment has been designed to recover desalinated water out of the humidified air. This new equipment will be described and the test results of its performance will be delivered. The new collector types and the developed humidifying and dehumidifying equipment are a part of an indoor one-stage-plant consisting of a solar simulator and an air humidifying loop in Bochum, Germany. This plant is running now and serves as a pilot to provide optimum operating conditions and design guidelines for a demonstration plant. Based on these results, an engineering package for the demonstration plant will be completed.

Keywords: Desalination; Solar energy; Renewable energy; Seawater; Brackish water; Collector; Humidifier

Presented at the EuroMed 2002 conference on Desalination Strategies in South Mediterranean Countries: Cooperation between Mediterranean Countries of Europe and the Southern Rim of the Mediterranean. Sponsored by the European Desalination Society and Alexandria University Desalination Studies and Technology Center, Sharm El Sheikh, Egypt, May 4–6, 2002.

PII: S0011-9164(02)01090-1

1. Introduction

Desalination of water, especially of seawater, is effected almost exclusively by evaporating of the salty water and subsequently condensing the arising vapors being free of salt. In most cases, such desalination plants are designed as multi-stage evaporator plants using fuels as energy sources. This process is the basis for a daily production of several millions cubic meters of water [1].

For many years, efforts have been made to use solar energy for obtaining potable water from salty water. 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 subsequently cooling of the humid air delivers the needed water free of salt [4–6]. All these processes use water to collect the energy delivered by the sun.

The central issue of the actual investigation is a new process of seawater desalination using solar energy and turning away from merely heating or evaporating of the seawater itself as the main idea for water separation. On the contrary, the basic unit operation in the present case is first to use solar energy for heating of an air stream 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 collectors, humidifier, pumps and various equipment.

The second feature of the present solar desalination process is the stepwise loading of air by vapor. 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 vapor concentration in the airflow, thus reducing the airflow rate through the plant. A reduction of the power necessary for air blower and the volume of pipes and other equipment can be realized. As a result, low investment and operating costs can be achieved.

2. 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 initial temperature and initial humidity as indicated by Item 1, i.e. 25°C and 10 g water/kg 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.

In this case, the amount of water that can be gained is 20 g/kg air. The high air to water ratio (50:1) and the necessary low temperature for following condensation of the moistness are the main economic disadvantages of this procedure.

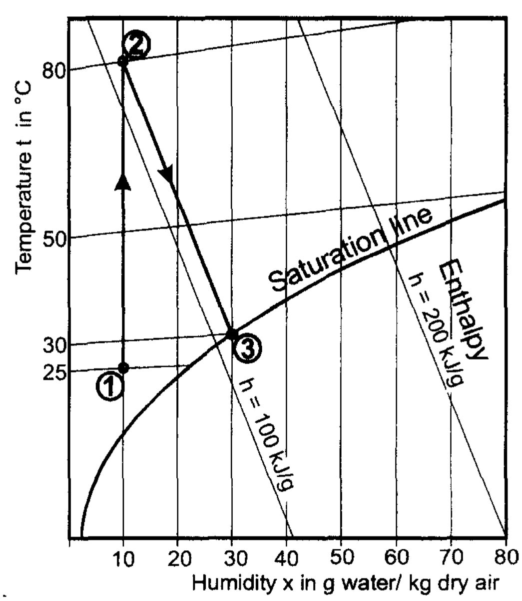

Fig. 1. Heating and humidifying process in h-x-diagram.