DESALINATION

Desalination 194 (2006) 81–89

www.elsevier.com/locate/desal

Experimental study on a spray flash desalination (influence of the direction of injection)

Yasuyuki Ikegami[a], Hiroshi Sasaki[b*], Tomotsugu Gouda[b], Haruo Uehara[a]

[a]*Institute of Ocean Energy,* [b]*Graduate School of Science and Engineering, Saga University, 1-Honjo, Saga, Japan, 840-8502*

Tel. +81 (952) 28-8624; Fax: +81 (952) 28-8595; email: ikegami@ioes.saga-u.ac.jp

Received 31 March 2005; accepted 12 October 2005

Abstract

A comparison study of a spray flash desalination process with the direction of injection based on experimental results of upward jet flash evaporation is presented. Superheated liquid at 24.0, 30.0, and 40.0 °C was injected upward into a depressurized chamber through a stainless steel cylindrical nozzle to compare with the phenomenon of a downward jet flash evaporation method. A series of experiments were carried out to analyze the effect of the direction of injection against the spray flash evaporation phenomenon. The tube-type nozzle was used with an internal diameter of 20.0 mm and a length of 81.3 mm. The range of the mean velocity of the superheated liquid inlet was from 1.74 to 3.62 m/s. The temperature descent of the superheated liquid inlet along the nozzle axis was measured by thermal resistance. Furthermore, the data and empirical equation for the downward jet method previously reported were used to compare the experimental results on the upward jet method. As a result, a tendency that the upward jet method needs a shorter distance to complete the flash evaporation than the downward jet method was observed. Therefore, the upward jet method has the possibility of making the spray flash desalination system more compact and efficient.

Keywords: Desalination; Spray flash; Falling jet; Vertical spout jet; Non-equilibrium temperature difference; Dimensionless temperature; OTEC

1. Introduction

The water issue has occurred in every corner of the earth because of the influence of the rapid increase in population, global warming, climate change, etc., and all sectors are searching for a solution [1]. Many sectors have a keen interest in the desalination technology, which produces fresh water from almost inexhaustible seawater.

Of the several types of desalination technology, multi-stage flash (MSF) or the reverse osmosis (RO) membrane method are famous all around the world. On the other hand, spray flash desalination can utilize the relatively small

*Corresponding author.

doi:10.1016/j.desal.2005.10.026

temperature differences as the heat source. Therefore, this method can utilize the waste heat from MSF plants and others as an energy source. It is also expected to be an effective application of waste energy as a countermeasure against global warming and its related issues [2,3].

Since this method can produce fresh water only using small temperature differences, Uehara et al. [4] examined the performance analysis of the hybrid cycle with ocean thermal energy conversion (OTEC). However, it is necessary to improve the efficiency in order to enlarge the capacity of freshwater production and also to downsize the equipment towards practical use.

Miyatake et al. [5,6] injected superheated liquid at 40.0, 60.0 and 80.0°C downward directly to a decompressed chamber from a nozzle with a small diameter. In the phenomenon of flash evaporation, the temperature descent of the water jet was measured with various nozzle diameters, flow velocity and the degree of superheat. Based on the results of the measurements, an empirical formula about the dimensionless temperature of a water jet which suits the characteristics of spray flash evaporation was obtained.

Miyatake et al. [7] also conducted the experiment on the flash evaporation of the downward water jet superheated at 40.0, 60.0 and 80.0°C using a cylindrical nozzle made of glass, with an internal diameter of 3.46–8.15 mm. The results were analyzed utilizing the non-equilibrium temperature difference, which is the concept required for the design of a flash chamber and condenser.

Uehara et al. [8, 9] conducted the experiment of downward flash evaporation that focused on the influence that the shape of a nozzle gives to the temperature descent of the jet and efficiency of the plant. Nozzles such as the four-hole, cylindrical type with a diameter of 10.0 mm and a length of 81.3 mm and an elliptic-hole type were used. As a result, the four-hole type was the most efficient of those nozzles. Moreover, using 1–6 cylindrical nozzles with a diameter of 10.0 mm and a length of 81.3 mm, the effect of the number of nozzles with various degrees of superheat and flow velocity at a liquid temperature of 30.0°C was tested.

Furthermore, Uehara et al. [10] conducted an experiment of downward jet flash evaporation to measure the temperature descent of the jet and fresh water rate using a cylindrical nozzle with internal diameters of 10.0, 15.0 and 20.0 mm and a length of 81.3 mm. The temperature of the injected liquid was set at 24.0, 30.0 and 40.0°C. The mean velocity of superheated liquid and the superheat were varied. In this study, clarifying the validity of the spray flash evaporation at low temperatures, the dimensionless empirical equation for predicting the temperature descent of jet was derived.

However, research on the upward jet method [11] to increase system efficiency and to miniaturize unit size and to compare with the downward jet are almost not reported. Especially, the characteristics and validity of the upward jet flash evaporation were not fully verified, and there are no enough data to compare with each method.

First of all, this paper presents a comparison study of downward and upward jet flash evaporation using a nozzle with a diameter of 20.0 mm at a temperature of supply liquid of 24.0, 30.0 and 40.0°C. Second, the influence of the direction of the jet to the evaporation phenomenon is analyzed.

2. Experimental plant and procedures

Fig. 1 shows the flow diagram of the experimental desalination plant. An overview of the plant is shown in Fig. 2. Seawater exchanges heat with the warm water supplied from the boiler in the seawater heat exchanger, and it is heated to the target temperature. It is then pumped up to the flash evaporator (diameter of 1.7 m, height of 3.184 m, volume of 6.0 m^3) by the circulation pump. The superheated liquid is spouted upward