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Desalination 179 (2005) 345–354

DESALINATION

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# Analysis of a jet-pump-assisted vacuum desalination system using power plant waste heat

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Received 30 September 2004; accepted 22 November 2004

**Abstract**

With ever-increasing population and rapid growth of industrialization, there is a great demand for fresh water, especially for drinking, as natural resources are becoming limited. In view of the above, different desalination technologies are evolving with a thrust for utilization of renewable energy sources like solar energy, ocean thermal energy, geothermal energy and waste heat. Vacuum desalination is one such technology in which fresh water is produced from brackish water by evaporation and subsequent condensation. This desalination technique involves different processes like pressurization of brackish water by a pump, creation and maintenance of a vacuum using jet pumps, and evaporation of brackish water at reduced pressure using waste heat from a power plant such as water from condenser. In this paper an analysis of a vacuum desalination system is presented. By applying the mass, momentum and energy balances across the various components, the governing equations are obtained for the analysis. These equations are solved using simulation. Validation of the simulated performance is made with the experimental data available in the literature. The study was carried out by varying operational parameters such as evaporator temperature, condenser temperature, evaporator flow rate, condenser flow rate and chamber pressure. Yield of fresh water obtained from the system increased as condenser temperature decreased and the evaporator temperature increased. Further, the yield increased as chamber pressure decreased.

*Keywords:* Desalination; Jet pump; Vacuum; Seawater

## 1. Introduction

The world is becoming more and more aware of its shortage of fresh water. In more than 50 countries in the world, the shortage of water is already creating a critical situation. A dramatic increase of the world's population will worsen this scenario. In order to overcome this problem, new economical ways for production of potable water at socially acceptable costs have to be

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*Presented at the conference on Membranes in Drinking and Industrial Water Production, L'Aquila, Italy, 15–17 November 2004. Organized by the European Desalination Society.*



doi:10.1016/j.desal.2004.11.081

established. A techno-economic evaluation of the available desalination technologies shows that more advanced desalination systems to reduce investment and maintenance costs are needed. Growing industrialization of the arid zones does not only mean a steady increase of water consumption, but also new sources of energy that can be used for desalination of seawater. For this reason, some are trying to reclaim waste heat for industrial use while others, located near coastlines, may obtain their water through desalination of seawater using solar energy, although costs can be high.

Converting seawater into potable water is an energy-intensive process. It is only viable if the source of energy is practically free, such as from celestial sources, geothermal sources or industrial waste heat. On the energy side, safe, jet-pump-assisted vacuum desalination system can be coupled with a thermal power plant for utilizing waste heat, and this might be less expensive and viable.

There is an abundant amount of waste hot/warm water available from thermal power stations. The process reported here is vacuum desalination. This technique takes advantage of a drop in the water boiling point at reduced pressure. This vacuum is created by a jet pump. By dropping the saturation pressure exerted on the seawater to about 0.05622 bar, a condenser outlet temperature could be used as an external heat source for boiling the seawater, and the condenser inlet temperature could be used for condensing water vapour. This paper presents a comprehensive review and description of design, logistics and installation aspects of the desalination system in a power station together with an evaluation of capital costs. Table 1 shows major flow rates and temperatures of the system.

Tay et al. [1] conducted a pilot study on a laboratory-scale system and concluded that the system performance depends on how efficiently the losses of heat are eliminated. Utilization of waste heat from a steam turbine for production of fresh water through a vacuum desalination process was first reported by Low and Tay [2]. A detailed experimental study was made by Mani [3,4] to probe to the effect of water depth and slope of a single-sloped solar still. Mani et al. [5] reported on the utilization of an ocean thermal gradient for production of fresh water through a vacuum desalination process and presented the design details of the system. Simulation of the desalination system was also carried out by Kudish et al. [6], and their work was validated with experimental measurements. The development of a desalination system using solar energy was discussed by Chafik [7]. Experimental performance for a typical operating condition for the vacuum desalination plant was given by Senthil Kumar et al. [8].

Table 1
Major flow rates and temperatures

| Sl. no. | Stream | Flow rate (lps) | Temperature (°C) |
|---|---|---|---|
| 1 | Seawater through evaporator | 3333.33 | 44 |
| 2 | Seawater through condenser | 3333.33 | 33 |
| 3 | Seawater through jet pump | 0.56 | 43 |

Hoefer [9] discussed the application of the liquid jet gas (LJG) pump for evacuation of steam condensers. A number of similar application references were included in the British Hydromechanics Research Association's literature survey of jet pumps, but in many cases the information provided has been inadequate to describe pump operation. Rammingen [10] first reported the rapid mixing phenomenon and sudden rise in throat pressure within a few times diameters distance that was noted by most investigators in subsequent years. A one-dimensional analysis of the LJG pump mixing process in a