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Heat pump seawater distillation system using passive vacuum generation system

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HIGHLIGHTS

- Passive vacuum system helps seawater distillation using traditional refrigerant heat pumps.
- Passive vacuum system reducing the saturation temperature of seawater.
- The system is suitable for remote areas and could be designed and installed in different sizes.
- The system gives promising competitive energy consumption with other techniques.

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ABSTRACT

The passive system that generate vacuum is a reliable systems and could allow heat pumps that uses traditional refrigerant to be used in seawater distillation process. This could be done by reducing the saturation temperature of seawater to be matched with the operating temperature ranges of these refrigerants. A proposed system uses heat pump for seawater evaporation and condensation. The suggested system is suitable for remote areas and could be designed and installed in the various sizes. Also the compressor could be run with solar PV panels. The followings are a detailed description of system with thermal analysis and energy consumption. It also represents an energy comparison of the proposed system with the other desalination methods. The comparison shows that the system gives promising competitive energy consumption.

1. Introduction

One of the main advantages of heat pump system is that a large amount heat added or removed versus natural process of heat transfer by temperature difference. This process is performed by doing work on working fluids (almost refrigerant). This work almost is several times lower than the quantity of heat removed or added. That means the quantity of heat removed or added by the heat pump system is not actually considered as a cost indicator but the work done through the compressor is the indicator. It is well known that the thermal distillation process of sea water to produce fresh water consumes a large quantity of energy in the form of heat [25]. The combination of heat pump and distillation systems to desalinate seawater may be promising and simple economic method compared with traditional desalination techniques.

V.V. Slesarenko Ref. [1,2], used a heat pump system for waste heat for reducing power consumption in small capacity thermal desalination plant to produce fresh water. An analysis of a vacuum desalination system was provided by R. Senthil Kumar, et al. [3]. Validation was made for experimental data available in the literature. A heat pump work with absorption system instead of vapor compression system was used experimentally for water purification by J. Siqueiros [4]. The main advantage of these units is the ability to be designed as small scale or mobile units. This will allow using it in disaster areas. The cost is competitive compared to the reverse osmosis and the electro dialysis technologies. Warren Rice, [5] used a hydraulic refrigerant compressor to eliminate problems that have been experienced with conventional vapor compression refrigerant compressors used on freeze desalination plants. J.R. Lara, et al. [6], represented a detail economics analysis of MVC. Also Yasu Zhou et al., [8] represents a comprehensive design model of single-effect mechanical vapor recompression (MVR) system. Hisham Ettouney [9] represented a detailed model of the MVC process, including several new design features. D. Yogi Goswami [10] uses the natural forces of gravity and atmospheric pressure to create a vacuum in the solar driven flash desalination system. S. Al-Kharabsheh, [11,13] experimentally studied the operating parameters for solar desalination system based on an innovative passive vacuum concept and compared

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results with theoretical results. The system utilizes natural means (gravity and atmospheric pressure) to create a vacuum. A solar-powered barometric desalination system consists of an airtight barometric chamber positioned to the altitude experimentally studied by I.W. Eames, [12]. W.M. Yang et al., [14] introduced a various methods of enhancing the performance of heat pumps which followed by a review of major hybrid heat pump systems suitable for application with various heat sources. Nominee H., [15], concluded that the production rate increases by increasing the operating temperature, evaporator design temperature for MVC system.

S. Iniyan, [16], supplied a review for solar thermal technologies. Performance analyses of existing designs (study), mathematical simulation (design) and fabrication of innovative designs with suggested improvements (development) have been discussed. Kyaw Thu, et al., [17], developed a system operates at sub-atmospheric pressures and temperature. The system is a combination from a Multi-Effect Distillation (MED) and an adsorption (AD) cycle. Chennan Li, et al. [18] proposed a new combined power and desalination system. This system combines a supercritical organic Rankine cycle (SORC), an educator and a multi-effect distillation (MED) desalination system. Jingwei Hou, et al. [19], introduce a novel process to optimize the utilization of energies. The distillation unit was driven by the waste heat of the spray system. K. Sampathkumar, [20], provide a detailed review of different studies on the active solar distillation system over the years. Mario Reali [21], concerns on design aspects for the recently proposed solar barometric distillation technology for seawater desalting via underground barometric layout. The proposed desalting technology has good energy efficiency and promising technical economic features. Also Zakaria [23,24] uses heat pump to supply a sea water desalination system with low grade heat energy. Heat pump uses R-134a as working fluid. The heat pump C.O.P. reached to be 8 and production rate 1.38 kg/h.

Finally, it could be concluded that seawater desalination techniques still need to be more simple and sustainable and less in energy usage. The main problem, which prevents using heat pumps that uses traditional refrigerants, in seawater distillation, is that the refrigerant maximum operating temperature is much lower than the seawater saturation temperature at atmospheric conditions. V.V. Slesarenako, [1] tried to solve this problem by using pure water as working medium in the heat pump.

In the following a trial to solve this problem by reducing the pressure applied on seawater surface. This will consequently reduce the saturation temperature of seawater. This reduction will make the operating temperature of used heat pump consistent with a heat pump that uses a traditional refrigerant range. The techniques of vacuum pressure

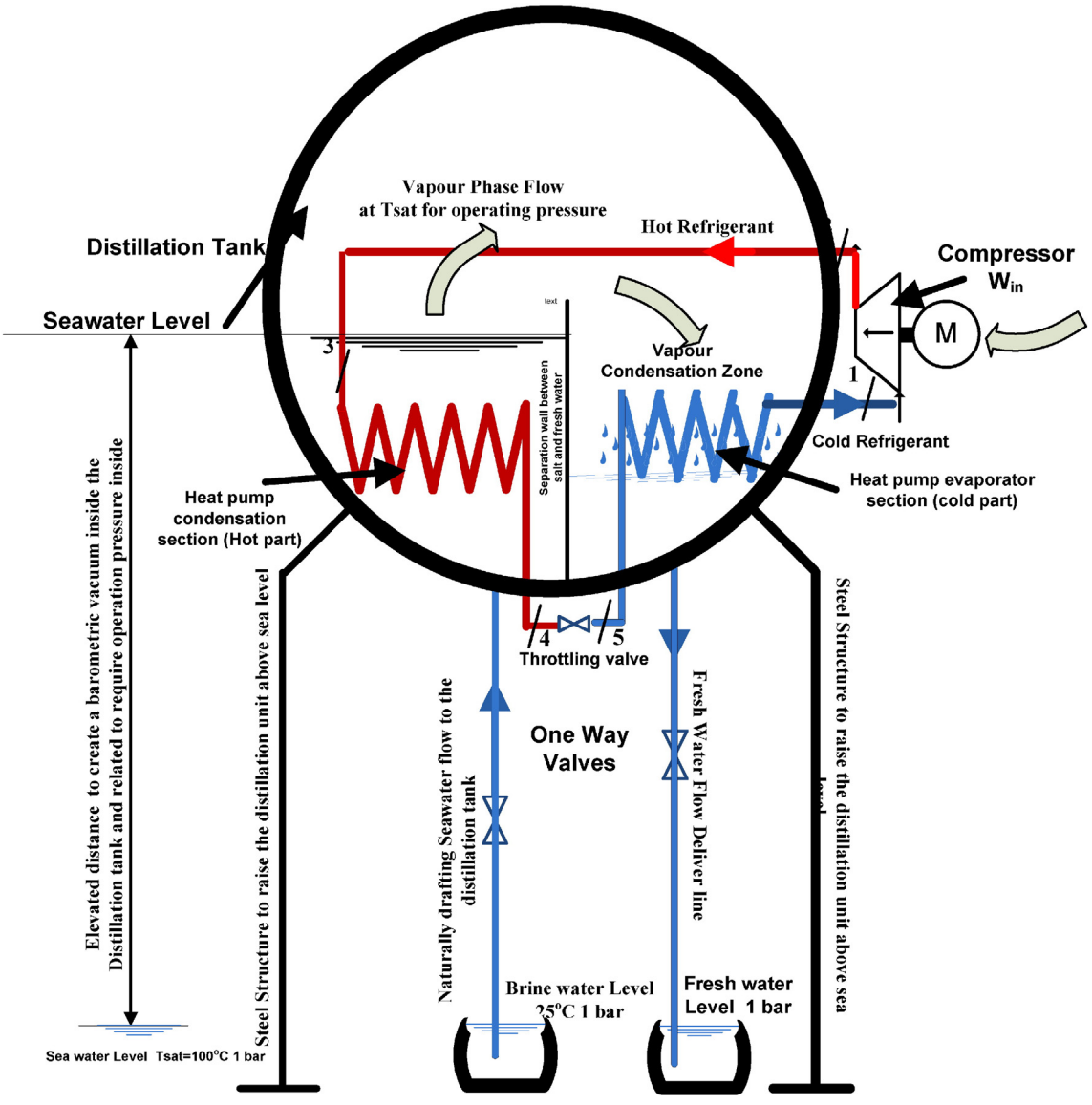

Fig. 1. Layout of the proposed water distillation system.