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Design of low Temperature Flashing System Desalination Plant using Brine Solution Heat Load

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Abstract

It is well known that the usage of the distillate water increase day-by-day and large capacity can be produced by the principle of flashing system. Total money spend on the flashing system can be reduced by the solar thermal system compared to other thermal system. The main objective of the paper is to utilize the high temperature unit exit brine solution heat load to the low temperature flashing system and the heat load is reduced step by step. The low temperature the stages are designed up to the last level at which the brine solution heat load is not useful. At 120 ⁰C of thermic fluid temperature the brine solution delivered heat load of 71.650 kW in the high temperature unit and 15.25 kW in the low/medium temperature unit respectively and it is used for the desalination process. The 1kg of mass flow rate of sea water produces 0.143 kg/s distilled water and low temperature unit produces additional distilled water of 0.032 kg/s. The production of distilled water is limited by thermic fluid temperature and brine solution concentrations.

Keywords: Flashing system, solar thermal, distilled water, seawater concentration etc.

Introduction

In the proposed step by step reduced desalination system is worked under the principle of flashing system and the flashing system can able to produce large the amount of distilled water by the multistage flashing system[1]. It is well known that more water is used for the cooling of the of nuclear power plant and the heat load for the desalination system is minimized by integrating the nuclear plant cooling exit water and desalination system.lso made by heat recovery system like power plant cooling system, i.e. the heat load used for cooling the nuclear power plant is enough for making the flashing of vapour[2]. The detail simulation of brine solution heat load at various condensed fluid temperatures and no of possible stages is discussed[3] for the large production of distilled water. The present paper made design of low temperature flashing system by using the exit brine solution in the high temperature unit. In the multi stage flashing process maintaining the pressure at each process is difficult due to integrated connection of the pipe lines and also the brine circulation in maintenances of desalination industry[2-5]. The pressure in flashing system can be separately maintained in the proposed desalination system and suitable for both small scale and large scale productions. By using humidification technology the production rate of distilled water and thermal performance of the system is increased[6]. In the multi stage flashing system the tubes are arranged in bundle like structure that makes leakages in water vapour when transformation of vapour from one stage to another, hence regular maintenances is required[7-8]. Lourdes[9] made comparisons of seawater desalination with solar technology and results direct steam generation increase the fresh water production from 18-32% and the proposed plant also well suitable for the solar direct steam generation plant. The temperature of the thermic fluid can be produced in the flat plate solar collector by using fins[10]. The thermodynamic property equations for pure water and sea water are solving from the literature[11].

The drinking water is essentials for all the living things especially for humans. But most of the water in world having more salt content and it can be converted for drinking water by using various methods. The flashing distillation method is one of the suitable methods for distillation at low temperature. Similarly the cooling is mandatory for the nuclear power plant and the sea water is used for cooling the nuclear reactor. The large quantity of hot water is coming out at the exit of the nuclear power plant. This hot water is again heated to 80-120 ⁰C and distilled water is produced by the flashing method. The hot water from the exit of the nuclear power plant is split into no of lines, and one part of sea water is going for the high pressure flashing system. The remaining mass for other low pressure flashing system depends on the heat load of the high temperature exit brine solutions. Nuclear exit hot water is moving to the high temperature unit and low temperature unit but low temperature unit mass flow rate is decided by the heat load produced by the high temperature unit brine solution. The high temperature unit consists of flashing system and having upper port for exit of distilled water and lower port for removing brine water.

The brine having more heat energy and it can utilize for the low temperature unit flashing system. The flat plate solar collector is used to reheat the exit cooling water of the nuclear plant and this cooling its own water vapor while entering. After discharge the energy it is heated by the solar flat plate collector and connected to the high temperature unit. In the high temperature unit, the hot water is flashed and steam is produced which is collected in the upper port. The reaming brine solution from the high temperature unit is directly connected to the low temperature unit to provide the energy for the flashing at the low pressure. The remaining the exit cooling water of the power plant is again heated by the high temperature unit brine solution. As like the high temperature unit, the same process happening in the low temperature unit but in low pressure hence more distilled water can be produced.

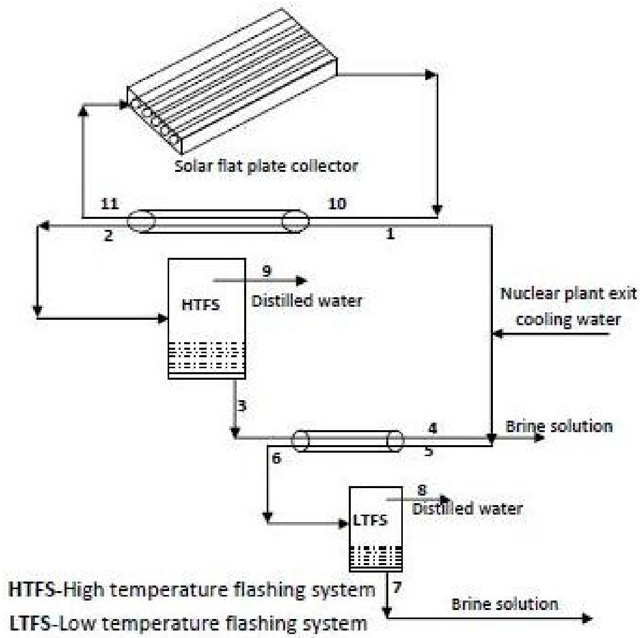

Figure-1
High and low temperature solar desalination system with 80 °C as thermic fluid temperature

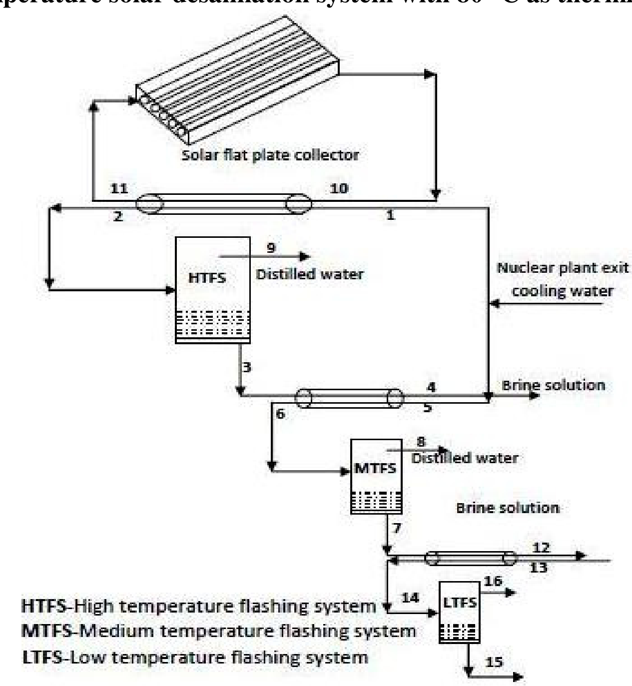

Figure-2
High, medium and low temperature solar desalination system with 120°C as thermic fluid temperature

The figure 1 and figure 2 is designed for the 80 and 120ºC of the thermic fluid inlet temperature ‘point 10’ respectively. The 120ºC thermic fluid temperature induces the brine solution to produce more heat load, hence third stage of flashing system takes place. This step by step reduction heat load helps to utilize more thermal energy and also distilled water. The no of low temperature flashing system stages is limited by the brine solution concentration and high temperature heat load.

Thermodynamic formulations: The heat supplied by the solar flat plate collector is equal to the heat required by the flashing system.

$$m_{10}CP(T_{10}-T_{11}) = m_9h_9 + m_3h_3 - m_2h_2 \quad (1)$$

By using the equation 1 the required mass flow rate of thermic fluid is calculated for the flashing system.

$$m_{10} = \frac{(m_9h_9 + m_3h_3 - m_2h_2)}{CP(T_{10}-T_{11})} \quad (2)$$

The amount of mass rate to the low temperature flashing syatem can be calculated by the same energy balance equation, hence equation 4 is used

$$m_3CP(T_3-T_4) = m_8h_8 + m_7h_7 - m_6h_6 \quad (3)$$

$$m_6 = \frac{(m_8h_8 + m_7h_7) - m_3CP(T_3-T_4)}{h_6} \quad (4)$$

The inlet sea water mass flow rate is equal is to the sum of the distilled water and brine solution.

$$m_2 = m_9 + m_3 \quad (5)$$

$$m_2x_2 = m_9x_9 + m_3x_3 \quad (6)$$

$$m_6 = m_8 + m_7 \quad (7)$$

$$m_6x_6 = m_8x_8 + m_7x_7 \quad (8)$$

$$\frac{m_3}{m_2} = \frac{x_9 - x_2}{x_9 - x_3} \quad (9)$$

The concentration of the distilled water is zero and sub in equation 9 and equation 11.

$$x_9 = 0$$

$$m_3 = \frac{x_2}{x_3}m_2 \quad (10)$$

$$\frac{m_9}{m_2} = \frac{x_3 - x_2}{x_3 - x_9} \quad (11)$$

$$m_9 = \frac{x_3 - x_2}{x_3}m_2 \quad (12)$$

The mass flow rate of the low temperature flashing unit can be found by using the same mass and energy balance equation.

$$\frac{m_7}{m_6} = \frac{x_8 - x_6}{x_8 - x_7} \quad (13)$$

$$m_7 = \frac{x_6}{x_7}m_6 \quad (14)$$

$$\frac{m_8}{m_6} = \frac{x_7 - x_6}{x_7 - x_8} \quad (15)$$

$$m_8 = \frac{x_7 - x_6}{x_7}m_6 \quad (16)$$

$$m_{15} = \frac{x_{14}}{x_{15}}m_{14} \quad (17)$$

$$m_{16} = \frac{x_{15} - x_{14}}{x_{15}}m_{14} \quad (18)$$

Results and Discussion

The pressure of the flashing system depends on the thermic fluid temperature which is having pinch point variation of 10ºC and the concentration of the brine solution. Figure-3 is plotted between the flashing pressure and thermic fluid temperature at constant brine solution concentration of 70g/kg. And it shows, at constant brine solution concentration the flashing pressure increases when the thermic fluid temperature increase. For the thermic fluid temperature of 120ºC and nuclear exit hot water of 35ºC shows high temperature flashing pressure of 139.49 kPa and 97.25 kPa for low temperature flashing system. For the low thermic fluid temperature very low vacuum needs to maintain in the low temperature unit, hence maintaining the high temperature helps to decrease the difficulty in the low temperature unit maintenance.

The low temperature unit inlet mass flow is predicted by fixing the specific mass flow rate of high temperature unit. High thermic fluid temperature of 120ºC with inlet mass flow rate of 1 kg/s helps to produce additional distilled water of 0.019kg/s in low temperature unit and the total distilled water increases from 0.486 to 0.505 kg/s . At the constant sea water concentration and brine solution the production of distilled water in low temperature unit increase by increasing the thermic fluid temperature as shown in the figure-4, and its shows 0.063 kg/s for 80 ºC and 0.067 kg/s for 120 ºC of thermic fluid temperature respectively for the sea water concentration of 48 g/kg. Total distilled water production is decreasing by increasing the seawater concentration at the constant thermic fluid temperature.

Figure-5 shows the analysis of heat load produced by the high temperature unit which is useful to the low temperature unit at various temperature and seawater concentration and total thermic mass flow rate required for the successful running of overall plant. Increase in seawater concentration increases the heat load at constant brine concentration of 70 g/kg and constant temperature. For the lower seawater concentration requires more thermic fluid mass flow rate at the same temperature as shown in the figure-4. Hence for thermic fluid temperature of 120 °C requires 3.81 kg/s of thermic fluid and it is able to produce 71.66 kW of heat and it is used to produce the distilled water of 0.032 kg/s.

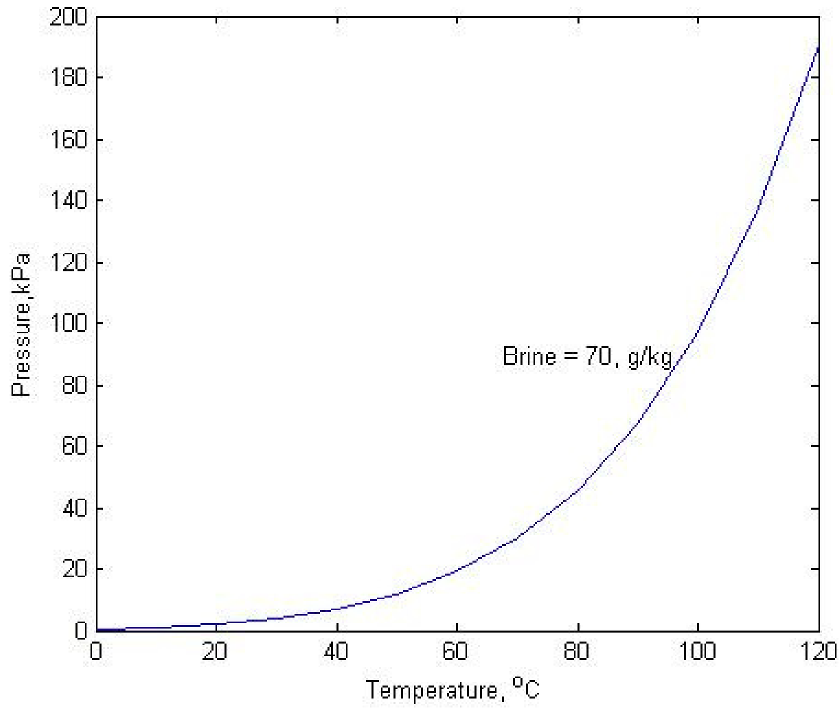

Figure-3
Pressure vs Temperature graph

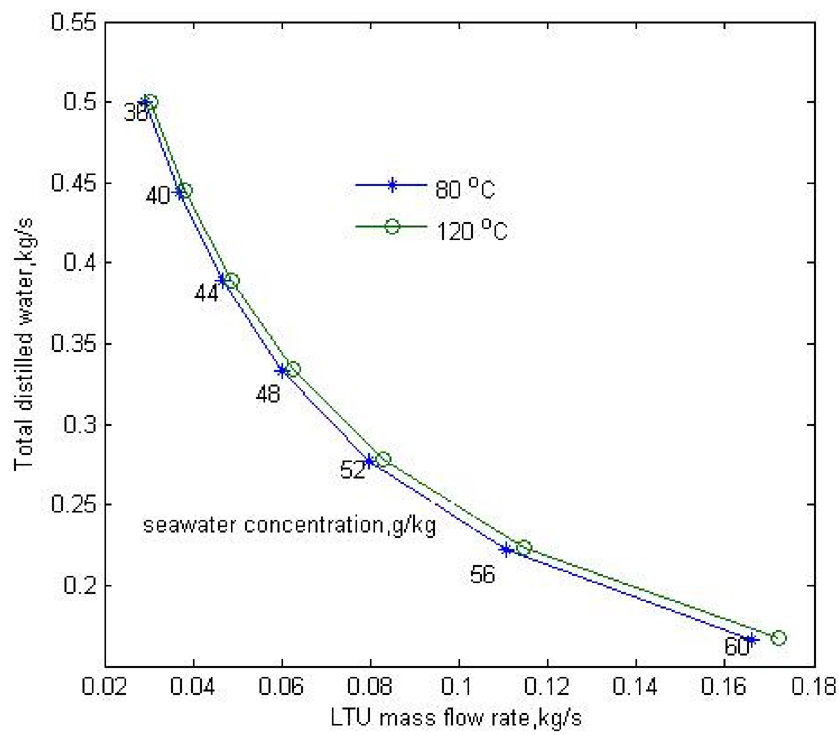

Figure-4
Variation of low/medium temperature unit mass flow rate and total distilled water production.

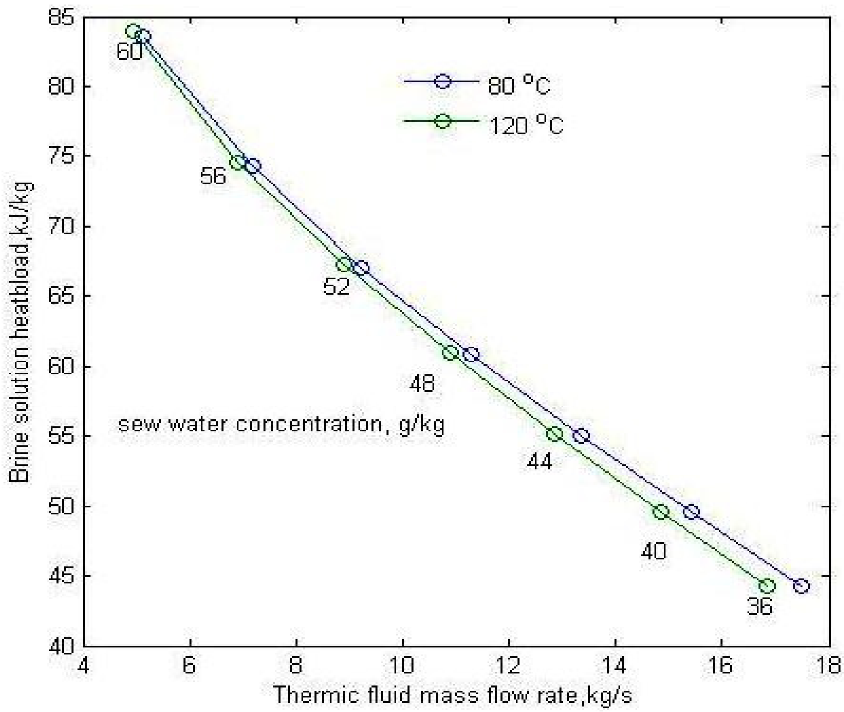

Figure-5

Analysis of thermic fluid mass flow rate and heat load for both 80 and 120 °C of thermic fluid temperature.

Conclusion

The low and high temperature flashing system helps to produce more distilled water by using the exit brine solution of high temperature unit. For specific inlet mass flow rate to high temperature unit produces 71.66 kW of heat with 10°C pinch point variation at 120°C thermic fluid temperature. The low temperature unit produces 0.032 kg/s of distilled water and total distilled water of 0.175 kg/s at the same temperature. The high thermic fluid temperature needs to maintain to avoid the low flashing pressure in the low temperature unit.

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