Study on Concentration of Sea Water with High Performance by Evaporation Method

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Summary

A simplified model is developed in order to analyze multiple-effect distillation process of sea water, and feasibility of concentration with the performance required for salt manufacture is investigated. Number of effects and construction of the system are examined for the distillation by the small energy to be equal to that of concentration by the electrodialysis.

From mass and energy balances for the distillation system, the performance ratio, which is defined as the ratio of the total distillate rate to the feed steam rate, required for the concentration to 20 wt%NaCl by the same amount of energy as that consumed by the electrodialysis is estimated to be approximately 45. Which is much larger than that of conventional desalination plant. Whereas, performance ratio for the concentration from sea water to 100 wt%NaCl with the same energy as that in a current electrodialysis system combined with multi-effect distillation is estimated to be approximately 14, and this value is shown to be feasible in principle, from the analysis based on the model. Thorough heat recovery from distillate and vapor generated due to flash evaporation in the effects is suggested to be indispensable for the attainment of the high performance ratio required.

The efficiency of evaporation in each effect may significantly affect the performance of the system, and therefore, appropriate improvement for the analytical model would be necessary. Examination based on the viewpoint of the total cost including capital costs as well as energy cost is also needed. Alternative methods such as vapor compression distillation and combined ones might be of higher performance and should be examined.

Numerical Simulation of Seawater Concentrating using Thermal Evaporation

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A numerical simulation is performed for seawater concentrating by thermal evaporation using a multiple effect evaporator in order to investigate its economical feasibility. Amounts of required energy is compared with that for the seawater concentrating by electrodialysis.

The system considered in the simulation is a series of falling film-long tube vertical evaporators, which do not require mechanisms of forced fluid circulation consuming electric power and whose overall heat transfer coefficient can easily be increased utilizing heat transfer enhanced tubes. The number of evaporators linked in series is 3 to 20 and the forward flow feed is employed. In the calculation, the temperature dependence is considered for the evaporation heat, and both the temperature and concentration dependence is considered for the heat capacity and the boiling point rise. Moreover, in estimating the overall heat transfer coefficient, changes in the viscosity and the heat capacity with temperature and concentration are considered.

Calculations were performed on the supposition that seawater of 3wt%-NaCl at 25°C is concentrated up to 25wt%-NaCl and the flow rate of seawater is 2033 ton/hr, which corresponds to a year production of 500 thousand tons-NaCl. In the calculations, the number of evaporators, the temperature of supplied vapor, and the overall heat transfer coefficient were varied. As the temperature of supplied vapor increases, its flow rate increases, while the heat transfer area and the evaporation ratio decrease. The evaporation ratio gradually decreases its increasing rate with the number of evaporator. The reason can be that most of the latent heat of supplied vapor is used for preheating of the seawater because of the large temperature difference between the supplied vapor and seawater. To obtain an economical effect by increasing the number of evaporator, it is necessary to increase the evaporation ratio. For this purpose, recovery of the sensible heat of drain flowing out of evaporators to preheat the seawater is examined. When recuperators with the temperature effectiveness of 90% are used, the evaporation ratio increases by about 2 when the number of evaporators is 20. Calculated results for the condition that the number of evaporators is 20, the temperature of supplied vapor is 120°C, the overall heat transfer coefficient is 2000 $kcal \cdot m^{-2} \cdot hr^{-1} \cdot °C^{-1}$, and the temperature effectiveness of recuperators is 90%, show that the theral evaporation requires 8 times energy of the electrodialysis. However, it is also suggested that the thermal evaporation is comparable to the electrodialysis in view of required energy when the seawater is concentrated up to 26% and the last two or three evaporators are used as crystallizers.