Study on Concentration Concentration of Sea Water

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Summary

It has been passed about 40 years since electro-dialysis(ED) method was applied to seawater (SW) concentration in the table salt production process. In these decades, technology for SW concentration has been highly developed. However, development of ED has been stagnated during this 15 years. Our research project aims to find out the way to break this stagnation by ②a very basic approach to fabricating ion exchange membrane. And taking account of the recently found fact that NF membrane has capability to remove scale-components: multi-valence ions, particularly sulfate ion, from SW, those might become feasible other methods once considered infeasible such as ① reverse osmosis (RO), ③thermal, etc.

① Proposal of a new evaluation method of RO performance using dialysis

To make RO reality, is indispensable high pressure(up to 20 MPa) resistive RO membrane (HPRO) ,in the development of which we need cooperation from polymer scientists from academic field. They have never paid any interest in the research in RO membrane and its materials because laborious work is needed to characterize the membrane by the conventional method. A two stage dialysis method which does not require laborious work, is proposed to evaluate RO membrane by 3 parameters Lp(water permeability), ω (solute permeability) and σ (reflection coefficient). The measured parameters for cellulose acetate membrane agree well with the reported values by conventional method.

② Phase separation mechanism and morphology development during formation of ion-exchange membrane

The morphology development during polymerization of styrene and divinyl-benzene with the addition of rubber was measured by an apparatus of light scattering measurement, and an optical microscope and a transmission electron. As the polymerization proceed, a peek in light scattering profile appears and then the intensity increases continuously with time. The peek stays at almost constant position. Regular phase-separated structure was observed in polymerized sample by optical microscope observation. From this result and differential scanning calorimeter analysis, it is clearly shown that the morphology in the ion-exchange membrane is formed by phase-separation in styrene phase and rubber via the spinodal decomposition. It is also suggested that the phase separation morphology can be controlled by proper choice of polymerization speed and miscibility between polystyrene and rubber.

③ Concentration of seawater by thermal methods

Using computer simulation, an attempt was made to reevaluate thermal SW concentration in view of easiness of scale-up and the possibility of increasing the heating temperature as the results of removal of scale components from the incoming SW by NF membrane. The higher the heating temperature, the higher the the thermal efficiency. Research was carried out on the following 2 sub-sub-themes

③ —① Study on concentration of seawater with high performance by evaporation method

A simplified method is developed in order to analyze multiple-effect distillation process of SW, and feasibility is investigated for concentration with the performance required for salt production. It is estimated as approximately 14, the performance ratio(defined as the ratio of the total distillate rate to the feed steam rate) to concentrate SW from the raw to 100% NaCl with the same energy as that in a conventional ED process combine with multi-effect crystallization. And also thorough heat recovery from the distillate and the vapor generated due to flash evaporation in the effects is suggested to be indispensable for the required high performance ratio

③ —② Numerical simulation of concentration of seawater

The calculation was carried out, using a simulation of multiple-effect of evaporation with boiling heat transfer. The possibility is shown to produce salt by the thermal process by the same energy as that in the conventional production process, provided if it is possible to combine the both processes of concentration and crystallization

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.