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Evaluation of Performance of a Novel Forced Type Evaporation

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Abstract

Evaporation process is conducted by vaporizing a portion of the solvent to produce a concentrated solution or thick liquor. Evaporation is different from distillation in that there is no attempt to separate the vapours into individual components. This work represents the sensitivity of one stirred spiral evaporator on the common changes which is obtained on feed temperature. Usual values of feed temperatures obtained from one salt Stirred Spiral Evaporator are divided into three groups of Run1, 26.8 C-28 C, Run 2, 25.2 C-26.4 C, and Run 3, 24.2 C-25 C.

Keywords

Liquor, Temperature, Crystal, Energy Consumption

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1. Introduction

Evaporation is conducted by vaporizing a portion of the solvent to produce a concentrated solution or thick liquor. Evaporation is different from distillation in that there is no attempt to separate the vapours into individual components. Evaporators are used to separate materials based on differences in their boiling temperatures. Either the vapour or the concentrate stream, or both, may be the desired product. Its purpose is to concentrate non-volatile solutes such as organic compounds, inorganic salts, acids or bases [1]. Typical solutes include phosphoric acid, caustic soda, sodium chloride, sodium sulphate, gelatine, syrups and urea [2]. Evaporation is conducted by vaporizing a portion of the solvent to produce a concentrated solution or thick liquor. Evaporation is different from distillation in that there is no attempt to separate the vapours into individual components. Evaporation differs from drying in the sense that the residue is a liquid - sometimes a highly viscous one - rather than a solid [3 and 4]. Another difference is that, in evaporation the vapour is usually a single component, and even when the vapour is a mixture, no attempt is made in the evaporation step to separate vapours into individual components [5]. Evaporation differs from crystallization in that emphasis is placed on concentrating a solution rather than forming and building crystals. Evaporators are categorized in three sections; a). Short tube vertical evaporator (Calandria evaporator), b). Rising film (Climbing film) evaporator or vertical tube evaporator, c). Falling film evaporator and d). Forced circulation tubular evaporator. The liquid in a forced circulation evaporator is pumped using a motor through the tubes to minimize tube scaling or salting when precipitates are formed during evaporation. Forced circulation evaporators are used in mining industry, and used to evaporate corrosive or highly viscous solutions [6]. Forced circulation evaporators are efficient in transferring heat from steam to liquid, maintaining continuous liquid flow, low amount of salting, scaling and fouling. These types of evaporators are used for the separation of sodium chloride,

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sodium sulphate, urea, ammonium sulphate, magnesium chloride, citric acid and caustic potash.

Published papers from 1986 to 1995 focused on the technical feasibility of forced crystallizers [6 and 7]. During 1995 to 2000 the researches have been focused on development of forced crystallizers. Since 2000, the published papers have been investigated the operating conditions which improved the thermodynamic efficiency and economics in order to make it more cost effective and competitive with other concentrating techniques such as heating desalination ponds, concentrating channels [7, 8 and 9].

Totally, the crystallization is occurred when the saturated solution is changed to its supersaturated and this process can be achieved by solution evaporating [10, 11 and 12].

This technique is an environmental friendly and cost saving process competitive with other concentrating techniques [13 and 14]. Therefore, the most industrial crystallizers are of the evaporative type and these types are used for more than 50% of the sodium chloride crystals production in the world [15]. Since the most common evaporative type is the forced evaporator (FE) model is selected for this study [16]. Today's the studies regarding the performance of FCC are essential to evaluate the operating parameters of the Stirred Spiral Evaporator.

2. Materials and Methods

2.1. Experimental Set up

The Stirred Spiral Evaporator is made of stainless steel and it's insulated to conserve the energy and thermometers record temperatures of suction and discharge lines of centrifugal pump, liquor of evaporator and exit line of heat exchanger. A glass gauge demonstrates the level of liquor in evaporator and a pressure gauge monitored the operating pressure and provides safety. Two electrical coils are used in heat exchanger as energy supplier and temperature can be set in different values. A condenser is situated on top of crystallizer to condense effluent vapours.

2.2. Methods

The process of evaporation is used basically to separate minerals from their water solution, as the solution reaches saturation state. Evaporation is one of the pristine unit processes. When the salinity percentage of brackish water in blender reaches to 20%, the brine is drained and blender is refilled with salt and water.

3. Results and Discussion

Three different temperatures are considered in the study. Feed temperature is changed due to the environmental condition. Figure 1 shows the effect of heat exchanger temperature on the operating pressure at three different ranges of temperatures of feed. The regular feed temperature variations divided in ranges of temperature as 24.2 C-25 C (Run 1), 25.2 C- 26.4 C (Run 2), 26.8 C-28 C (Run 3) to evaluate the process performance. Figure 1 shows the relation between the heat exchanger temperature and the pressure inside the crystallizer vessel. The higher temperatures of heat exchanger lead a little higher operation pressures. However, the changes of 5 C in the heat exchanger temperature change the amount of operation pressure about 5 kPa, averagely. Totally, the temperature variations between 84.7 C and 91.1 C lead the 10 kPa pressure difference in the required operation pressure. The higher temperature of heat exchanger produces hot water recycle stream with higher temperature and makes much more vapours inside the crystallizer. So, the increase in the amount of produced vapour inside the vessel makes higher operation pressure.

Surely, the optimum conditions and determination of the best operation pressure and heat exchanger temperature depends thoroughly on the analysing the quality of product.

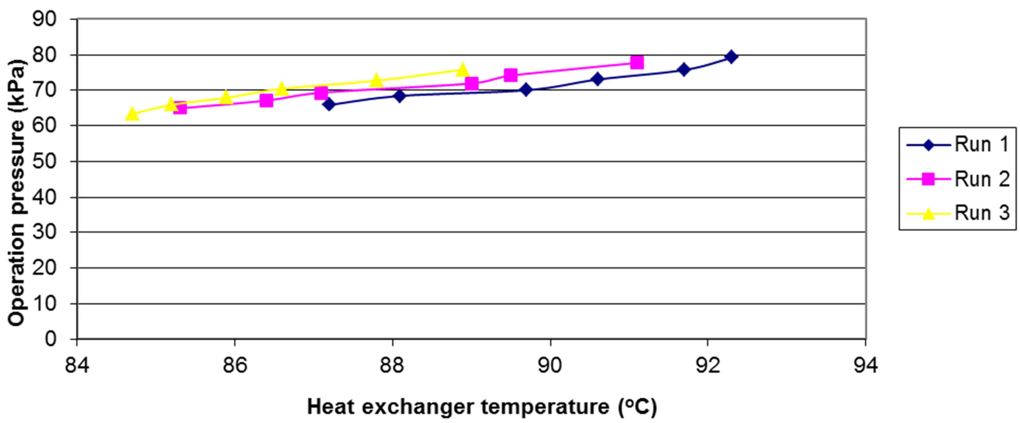

Figure 1. The operation pressure versus heat exchanger temperature.

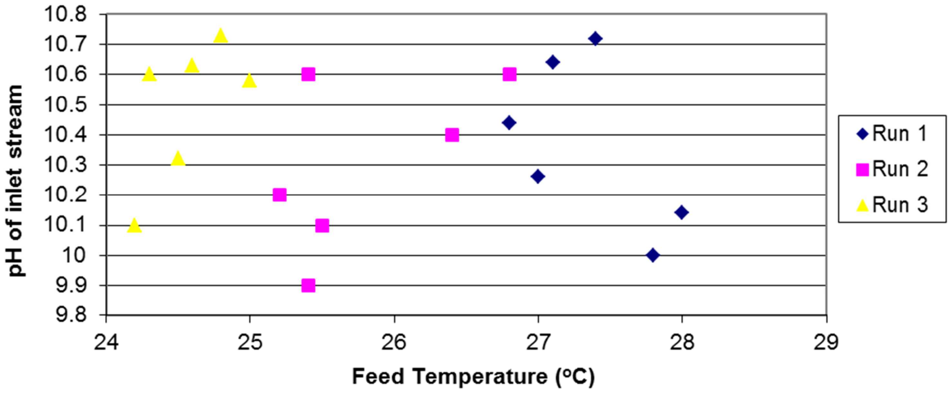

Figure 2. pH value of inlet stream versus the feed temperature on the.

The effect of feed temperature on the amount of pH is illustrated in Figure 2. The dependency of pH of salty feed on the temperature during the usual changes in the environment is about 0.8. This is important for evaluation of changes in the amount of main parameters in the operation of Stirred Spiral Evaporator and the quality of the product.

There is not any fix pattern in definition of the relation between the pH value and the temperature value according to the data. This seems because of the implicit influence of pH value on the feed temperature.

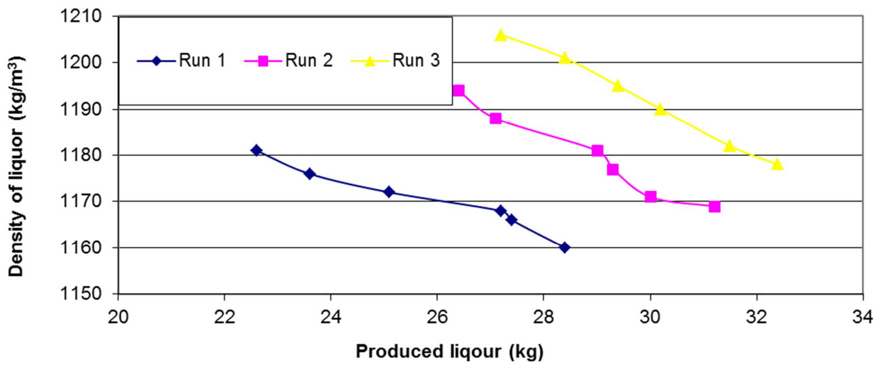

Figure 3. The density of liquor versus produced liquor.

Variations in the amounts of density of liquor and the produced amount of it are shown in Figure 3. Experiments with three different ranges of temperature show the decrease in the amount of density with the increase in the amount of produced liquor. The higher feed temperatures show the higher amount of density and also the amount of produced liquor. Using temperature ranges of Run 1, the amount of produced liquor varies from 22.6 kg to 28.4 kg and the values of density changes from 1181 kg/m^3 to 1160 kg/m^3, respectively. Changes in the amount of produced liquor from 26.4 kg to 31.2 kg are obtained with changes in the amounts of densities from 1188 kg/m^3 to 1169 kg/m^3, respectively using Run2 for the feed temperature. Also, the variations of density and the amount of produced liquor are 1206 kg/m^3 to 1178 kg/m^3 and 27.2 kg to 32.4 kg for Run 3, respectively.

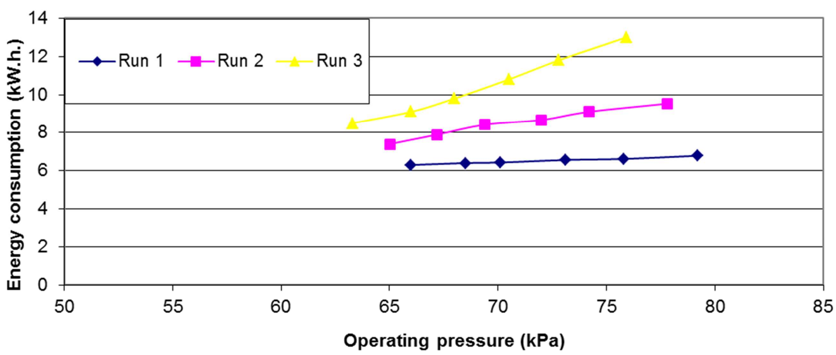

Figure 4. The energy consumption versus operating pressure.

The effect of feed temperature and feed pressure is shown in Figure 4. The higher values of energy consumption are obtained at the higher amounts of pressure. The higher feed temperature provides higher initial internal energy and the saturated condition is reached by consuming lower amount of energy in heat exchanger. The lower ranges of energy consumption are obtained at the lower ranges of feed temperature.

4. Conclusion

This work investigates the effect of common changes in the feed temperature of one stirred spiral evaporator which are emerged on the salt production process, usually. Three groups of temperature are defined and the changes of important production factors are studied. The amount of vaporization rate, cooling water flow rate, production rate, liquor flow rate and density, colour and size distribution of salt crystal and operation pressure are considered changing the feed temperature.

The tolerance of process according to feed temperature changes is considered experimentally. Analysing the results, the first group of feed temperature, Run 1, 26.8 C to 28 C leads the proper white salt crystal with size distribution of 0.165 to 0.34 and vaporization rate lower than 0.067 kg/ min. Also, Run2, feed temperature between 25.2 C and 26.4 C leads the white salt crystal when the vaporization rate is lower than 0.06 kg/min and size distribution of crystal changes from 0.165 to 0.31.

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