

*Review Article*

A Review on Studies and Research on Various Aspects of Evaporators

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ABSTRACT

One of the important process activities in chemical engineering is the concentration of the liquor. This is required in crystallization and many other processes to obtain solutions of required concentrations. Also in refrigeration and cooling plants, evaporator is one of the important components. Use of multiple effect evaporator can improve efficiency and energy consumption. Optimum number of evaporators can be determined by incremental cost analysis of added effects and corresponding savings. The current review aims at summarizing the studies and research on evaporators.

Key words: heat transfer area, temperature, efficiency, energy consumption.

INTRODUCTION

Chemical engineering is a diverse field which needs knowledge of many other disciplines. Energy and environment are two most important aspects of the modern engineering investigations. Various nonconventional energy sources can save our natural resources. [1-5] The applications of various methods for energy conservation and heat savings are being explored in the fields of boilers, drying, heating and cooling applications. [6-10]

The heat transfer is one such field. Almost all the chemical processes need some or other kind of heat exchanger for heating cooling, evaporation, condensation etc. The heat integration is also very important from the economical point of view. The evaporators are used for concentrating the solution. Also they find major application in refrigeration and cooling cycles. It is always desired to reduce

the size of evaporator and increase heat transfer. Pinch technology can be used to obtain optimum temperature. Maximum area for heat transfer can be obtained and plate type heat exchangers and its other modified forms are effective for this purpose. Also proper cleaning and handling can bring about significant cost savings. The current review aims at summarizing studies and research on evaporators.

RESEARCH ON EVAPORATORS

Mishra has carried out studies on methods for improving second law efficiency by using liquid vapour heat exchanger. [11] He carried out detailed energy and energy analysis of multi-evaporators at different temperatures with single compressor and single expansion valve using liquid vapour heat exchanger in vapour compression refrigeration systems. He observed that first law and second law

efficiency improved by 20% using liquid vapour heat exchanger in the vapour compression refrigeration systems. The most efficient component from irreversibility point of view was subcooler.

Salakki et.al. carried out studies aimed at improving the efficiency of multiple effect evaporator used for treating pharmaceutical waste. [12] According to them, evaporation and cooling are the common techniques used to extract available salts and reusable water. Multiple effect falling and forced circulation evaporators are normally used in pharmaceutical industries. Their studies focused on diagnosing the ills of the multiple effect evaporator to improve the efficiency and energy consumption. They carried out measures like pressure cleaning and arresting the leakages. These steps reduced the energy consumption of the evaporators by 40 percent. Munir et.al. carried out studies on modeling of falling film evaporators. [13] According to them, the modeling of dairy processing using commercial process simulator lags behind chemical and petrochemical process simulation due to the fact that most commercial process simulators do not contain food (e.g. milk) components in their component libraries, required for dairy process simulation. According to these model studies, around 0.1 - 9.4% differences between simulated and actual results were obtained.

Walford and Walthew studied preliminary model for oxalate formation in evaporator scale. [14] In their studies, they were not able to explain the presence of calcium oxalate in evaporator scale samples by the presence of oxalic acid in mixed juice samples. The model indicated that all the oxalate was removed during normal clarification and there should thus be little oxalate precipitation in the evaporators. Patel and Mavani carried out studies for

design of wiped film evaporator (WFE) system with recovery of working fluid for herbal products. [15] They described different types of reactors used for recovery. According to him, use of WFE (Wiped Film Evaporator) was simple & effective. In air conditioning system, evaporator is used to evaporate liquid and convert it to vapour while absorbing heat in the processes. They developed an experimental data for fin tube evaporator by carrying out experiments to improve the performance characteristics of evaporator. Parikh and Patel investigated parametric optimization of fin-tube type evaporator using FEA-DOE hybrid modeling. [16] They observed that the outlet temperature increase with the increase in tube pitch up to 25 mm, and then starts to decrease under given working conditions. They also found that when tube diameter value increases from 8.525 to 9.525 and 9.525 to 10.525 proportionally outlet temp graph also increases from 265 to 268 and 268 to 272.

Yu et.al. carried out studies on water boiling heat transfer on horizontal copper rod surface at sub-atmospheric pressure. [17] According to them, the research on water boiling heat transfer at sub-atmospheric pressure has been an important issue and there is a lack of data on the characteristics at sub-atmospheric pressures, especially lower than 3 kPa (the saturation temperature is 24 °C). They observed that when the heat flux was constant, the heat transfer coefficient increased with increasing pressure. Also at low pressure, the increase of boiling heat transfer coefficient with increasing pressure was slow. According to the studies carried out by Mishra for detailed energy and energy analysis of multi-evaporators at different temperatures with single compressor and single expansion valve using liquid vapour heat exchanger-vapour compression refrigeration systems, first law and second law efficiency

improved by 20% using liquid vapour heat exchanger in the vapour compression refrigeration systems. [18] Zhao et.al. carried out an investigation on heat transfer coefficient of horizontal tube falling film evaporator. [19] They carried out analysis of the flow of the liquid film on the inside and outside of the evaporator tube under steady working conditions and the effects of evaporation temperature, heat transfer temperature difference, and tube diameter on the local heat transfer coefficient and the total heat transfer coefficient. They derived an empirical formula relating the condensation heat transfer film coefficient and the evaporation heat transfer film coefficient. Shen et.al. carried out an investigation on characteristics of double-evaporators in VRV air conditioner. [20] According to their research, in a double-systems air conditioner, when the boundary conditions of one evaporator are changed, there will be influences on the other evaporator definitely. According to them, paralleled evaporators have influences on each other via the suction pressure.

Ahmad and Khan carried out studies aimed at developing a program in C++ software for the design of triple effect evaporator in forward feed mode with mechanical design. [21] In their design, they used a short tube vertical evaporator (STV) and calandria type evaporator. Kumar et.al. carried out studies on parametric effect on optimality of various feeding sequences of a multieffect evaporators in paper industry using mathematical modeling and simulation with MATLAB. [22] They described a steady state model of a multiple effect evaporator system for simulation and control purposes. The model consisted of overall as well as component mass balance equations. Also energy balance equations and heat transfer rate equations for area calculations for all the effects were included. They studied the optimality of three sequences i.e. backward,

mixed and splitting feed by varying input parameters. They concluded that mixed feed is always optimal for entire range of each of the parameters.

According to studies carried out by Arya and Chavda, configuration scroll compressor and plate heat evaporator can give better results as compared to the configuration scroll compressor and shell and tube evaporator for a chilling plant. [23] They found that the boiling process of liquid at its saturation temperature has the following three distinct regimes namely Interface evaporation, nucleate boiling and Film Boiling.

Maheshwari et.al. investigated refrigeration system designed for low temperature which has Zero-Ozone depleting point. Better heat transfer characteristic gives greater refrigerant effect. [24] They observed that the temperature of the evaporator coil is low due to the low temperature of the refrigerant inside the coil and the low temperature of the refrigerant remains unchanged. This is due to fact that, any heat it absorbs is converted into latent heat as boiling proceeds. Krasnoshlykov and Maksimov discussed natural convection in a freezer at different modes of operation of the refrigeration unit. [25] Their study revealed that convective flows in a study area produce influence on the temperature field.

CONCLUSION

Evaporation and cooling are the common techniques used to extract available salts and reusable water. Multiple effect falling and forced circulation evaporators are normally used in pharmaceutical industries. First law and second law efficiency can be improved by 20% using liquid vapour heat exchanger in the vapour compression refrigeration systems. Use of WFE (Wiped Film Evaporator) was simple & effective for herbal products. Water boiling heat transfer at sub-atmospheric

pressure is important but there is a lack of data on the characteristics at sub-atmospheric pressures, especially lower than 3 kPa. Plate heat evaporator with scroll compressor can give better results as compared to the configuration of scroll compressor and shell and tube evaporator for a chilling plant. It can be concluded that proper maintenance, energy conservation methods, optimum number of effects, simulation and control of process parameters are important factors for evaporator operation.

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