WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

To Increase the Efficiency of Evaporator using Various Techniques

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A B S T R A C T

Evaporator is used to increase the overall efficiency of system by using the refrigerant ,but sometimes material of evaporator design and its material affect more on the overall performance of the system. So selection of material as well as path of flow and time for the fluid that passing inside evaporator are considered for better performance .When air is used as the only heat source, the performance of the heat pump is about the same as that of a conventional air-source heat pump, and this paper does not research on it. Evaporators find their use in many of chemical industries like paper industries, sugar industries, black liquor industries and food industries. Different types of evaporator are required depending upon the feed and product conditions. Various software are available to make calculations easy.

Keywords: Evaporator , Efficiency of system, Refrigerant used, COP of system. Performance of Evaporator.

Nomenclature

Γ spray density of the evaporator
mw water flow rate of the condenser
m the number of columns of the tubes
l the length of the tubes
Qc heat output of the condenser
c specific heat of water
tci inlet water temperature of the condenser
tco outlet water temperature of the condenser
W power consumption of the compressor
Qe heat output of the evaporator
K heat transfer coefficient of the evaporator

1. Introduction.

Evaporation, a widely used method for the concentration of aqueous solutions, involves the removal of water from a solution by boiling the liquor in a suitable vessel, an evaporator, and withdrawing the vapour. If the solution contains dissolved solids, the resulting strong liquor may become saturated to that crystals are deposited. Liquors which are to be evaporated may be classified as follows:

a) Those which can be heated to high temperatures without decomposition, and those that can be heated only to a temperature of about 330 K.
b) Those which yield solids on concentration, in which case crystal size and shape may be important, and those which do not.
c) Those which, at a given pressure, boil at about the same temperature as water, and those which have a much higher boiling point.

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1.1. Working of Evaporator

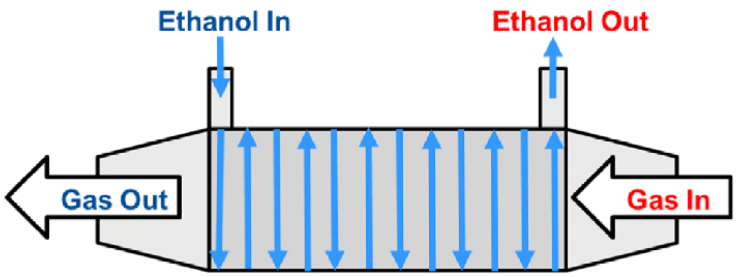

Fig 1 Flow of fluid through Evaporator [1]

Normally, in evaporation the thick liquor is the valuable product and the vapor is condensed and discarded. Example, mineral-bearing water often is evaporated to give a solid-free product for boiler feed, for special process requirements, or for human consumption. This technique is often known as water distillation, but technically it is evaporation. Large scale evaporation processes have been developed and used for recovering potable water from seawater. Here the condensed water is the desired product. Only a fraction of the total water in the feed is recovered, and the remainder is returned to the sea.

Single-effect evaporators are used when the throughput is low, when a cheap supply of steam is available, when expensive materials of construction must be used as is the case with corrosive feedstock and when the vapor is so contaminated so that it cannot be reused. Single effect units may be operated in batch, semi-batch or continuous batch modes or continuously. The single effect evaporator uses rather more than 1 kg of steam to evaporate 1 kg of water.

1.2 Effect of Multi Evaporator

In multi-effect evaporator, the vapor formed in first evaporator is used as a heating medium for second evaporator, Less heat is loss compared to single effect evaporator. In this effect steam consumption is less, generally 1kg of steam is used t o evaporate 1kg of water.

The condenser and air ejector are used to create vacuum and withdraw non condensable gases from the system.

There are various types of multiple effect evaporators depending upon feed input:

1. Forward feed
2. Backward feed
3. Mixed feed
4. Parallel feed

2. Different Parameter and Condition effect on Evaporator

1. M. Sathiyamoorthy et al. [1] conducted the study and It shows that multi effect evaporation has considerably less energy consumption pr unit production and energy is the most important term used in evaporation. He obtained from the study that the double effect evaporator gave minimum annual total cost. He explained total cost reduction of evaporator by using multi effect evaporator by application of mass and heat balance analysis for tomato juice. Due to an economic balance between added investment and saved energy he determined the optimization of the total cost.

2. Aijaz Husain et al. [3] performed study on thermal integration in multi effect evaporator. They considered a triple effect evaporator with additional effect as a secondary circuit to produce a low pressure steam. This experiment was conducted to concentrate waste water from 5% solid to 40% solid. They used forward type of feed with flow rate of 4700Kg/Hr and pressure of 2.0 to 2.5 Kg/cm (LPS steam). Concentrated output of 565Kg/Hr was obtained and solid concentration output was 41%. Steam economy and actual steam consumption was found out to be 0.8Kg steam/Kg water evaporated and 334Kg/Hr respectively.

3. A simulation was done [6] on quadruple effect evaporator with vapor bleeding used for juice heating by Somchart Chantasiriwn of Thammasat University Thailand. His model was a combination of quadruple effect evaporator and juice heater. Juice extracted from sugar cane was considered as feed in this model. In this model vapor bleed from first three evaporators was used to increase temperature in juice heater to a saturation temperature. Two performance parameters were considered which was amount of sugar juice processed and steam economy of evaporator. It was found that both parameters were more sensitive to surface area of first evaporator compared to other surface.

4. Song B. and Lin Z [9] conducted the study and Result of the study shows that distributor effect of refrigerator and used Mixed Model and K-epsilon Turbulence model to show or study the results they obtained by the optimum design of falling film evaporator. By use of numerical simulation they got the velocity vector distribution improved near the inlet of the distributor as the height of inlet increases due to the vortex formed at the top surface of the

distributor. In a non-uniform flow field where the side speed is so small with high speed at the middle. Here perforated baffle plates are used to avoid such incident from happening. In the uniform plate the three rows of holes are 0.11, 0.09 and 0.15 respectively.

5. Experiment shows [10] that energy is the major solution for handling the world's energy demand in the future. He studied that maximum energy demand was in evaporation plant in Kraft Pulp Mills. From the previous research he studied that energy savings can be obtained by reusing excess heat and that plants which use excess heat are known as process-integrated (PI) plants. He studied that electricity and lignin prices play the main role in changing the total cost. A 7-effect PI plant instead of &-effect conventional plant can be employed to save 26% of the live steam in the evaporation plant. Evaporation plant with lignin extraction (LE) requires more live steam and larger heat transfer surfaces than plants without LE. For differently designed plants, the heat transfer area can vary significantly. Due to this reason most simulation cases the objective function that is used to minimize heat transfer area should be used. As studied the heat transfer area automatically distributed evenly within the evaporation plant.

7. A comparative study [4] was done on enhancement of evaporator steam economy of large scale sugar industry in Ethiopia. The main objective of study was to reduce steam consumption for 4000TCD (tons of cane per day). Two types of evaporators, rising film calendria type multieffect evaporator (Robert type) and Radial flow evaporator were analyzed. It was observed that the total steam consumption of Robert type evaporator was 36.34% whereas for Radial type evaporator was 33.77%. These results were calculated for percentage evaporation of 77.5% of cane. Design suggested that the Robert type evaporator can be replaced by Radial flow evaporator due to its ease of handling and lower steam consumption.

8. A study [6] was done on design and operations of black liquor evaporators. His study focused on concentrating weak black liquor with 13-18% TS to 65-80% TS. He stated two basic types of evaporators for black liquor evaporation which were rising film evaporator and falling film evaporator. The design also included concentrators whose main purpose was to separate sulphur compounds, methanol and other solids from condensate. He mentioned two types of concentrators, falling film concentrators and forced circulation concentrators. Forced circulation concentrators reduced the risk of thermal decomposition of liquor and calcium carbonate scaling.

9. Experiment study [7] shows that such as steam economy, steam and power consumption, overall heat transfer coefficient and heat transfer area plays important role in study of evaporators. They conclude that the power consumption increases with increase in load on any evaporator. They also conclude that leakages can be harmful and high pressure cleaning will be performed to remove the scaling in evaporator.

3. Working of System

The structure of the dual-source evaporator is shown in Figure 1. The heat exchange coil, as an essential part for the evaporator, is composed of two sets of parallel serpentine tubes. The internal diameter of the steel tube is 22 mm. The two ends of adjacent tubes are connected with steel elbow. The inner surface of the tube is smooth and the outside is high ring-stiffened fins. The thickness and pitch of the fins are 0.2 mm and 5 mm, respectively. When the WASHP is running, the refrigerant (R22) flowing into evaporation tube absorbs the heat from wastewater and transfers it to the condenser to heat bath water. The wastewater with higher temperature is sprayed on the surface of the heat exchange coil and falls into the bottom of the tank. Then it is sprayed cyclically until temperature of the wastewater is decreased to 8℃. Then the fan starts working. The ambient air is blown into the evaporator from the bottom of the linear bar grille and discharged from the top of the fan. The finned tubes improve high heat-change efficiency even if the air was serve as the only source. Moreover, the utilization rate of the space is also increased since it replaces the parallel installation mode of evaporators.

• The refrigerant circulation system. It is made up of dual-source evaporator, gas-liquid separator, compressor, oil separator, condenser, high pressure liquid receiver, dry-filter, expanding valve, etc. The heating capacity of the heat pump is 35 kW and the compressor power is 7HP. • Water circulation system. It is made up of wastewater storage tank, spraying circulation pump, two plate heat exchangers, hot water storage tank and hot water circulation pump. In the process of experiment, the clean tap-water is used to simulate waste water. In order to realize the stable working condition of the experimental system, the heat of the domestic hot water heated by the heat pump is transferred to the wastewater by plate heat exchanger .

Then the wastewater is heated by electric heaters to the needed temperature. On the other hand, in order to satisfy the requirement of inlet temperature, the tap-water is used to decrease further the temperature of the hot water. • The data acquisition system. The thermocouples, pressure sensors and flow meters are installed at the required locations, which was shown in Figure 2. And the power needed of the system is monitored by electric energy meter. Based on the principle of error transmission, the relative error of parameters such as heating capacity, COP, heat transfer coefficient and so on are obtained. The test instruments meet the precision requirements.

4. COP of System

By calculation and analysis of heating capacity and power consumption, the variation of the COP with different working conditions are given in figure 4. The COP of the WASHP changes from 4.12 to 5.02 under the control conditions. And the performance is significantly improved by increase of spray density and temperature of wastewater. When spray density higher than 0.40 kg/(m·s), the COP nearly reaches to the maximum value, following the same conclusions as heating capacity variation. So the spray density at 0.40 kg/(m·s) is considered as the optimum spray density of the system. Figure 5 shows the relation between COP and spray temperature at the optimum spray density of 0.40 kg/(m·s) and the condensation temperature of 45℃. The COP increases from 2.94 to 4.75 with an average of 3.97 when the spray temperature varies from 8℃ to 30℃, almost linear increase. It is clear that the performance of the heat pump system is greatly influenced by spray temperature. In addition, when the temperature of the wastewater has become close to 8℃, ice will have occurred on the surface of the heat transfer and the performance is affected seriously. Thus wastewater must be discharged at this temperature, and fan starts to work if the needed heat is still not enough at this time.

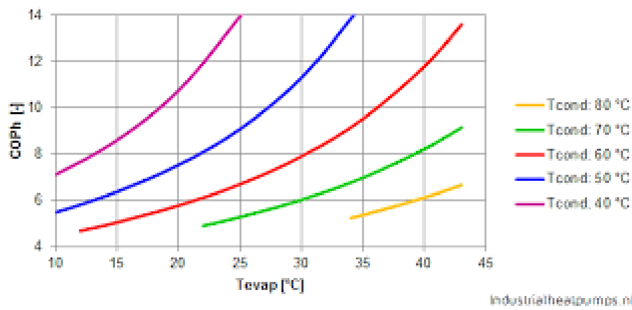

Fig 2. COP of Evaporator at various conditions.[3]

5. Heat Transfer Coefficient of The Evaporator

The variation of heat transfer coefficient of the evaporator with spray density and temperature of wastewater. The loss heat of evaporator cannot be ignored in the evaporator. Considering it, the heat transfer coefficient of the evaporator varies from 612.01 W/m2·K to 1003.56 W/m2·K, enhanced with increase of spray density and temperature of wastewater.

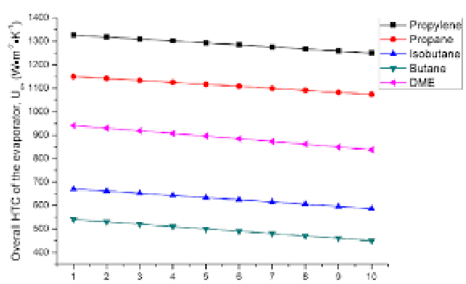

Fig 3. Heat Transfer rate of Evaporator [5]

6. Conclusion

According to the performance test results, it is found out that heating capacity and COP of the WASHP increases gradually with increase of spray temperature and density, which the maximum approximately 26.45kW and 5.02, respectively. The effects of spray temperature on heating capacity and COP are remarkable, but effects on spray density are limited. And when spray density higher than 0.40 kg/(m·s), the heating capacity and COP had nearly reach to the maximum. It is concluded that the optimum spray density of the system is 0.40 kg/(m·s).

In the optimum spray density, ice occurred on the surface of the heat transfer when the temperature of wastewater is cycled to 8℃. Thereafter, air source plays a supplementary role to provide insufficient heat under the action of the fan.

The flow patterns in the process of evaporation contain stratified-wavy, intermittent and annular flows in the velocity range covered by the tests. In most cases, when the mass velocity of refrigerant is not very small and the evaporation pressure is not very high, the flow inside the tubes could be considered as annular because it is the predominant flow pattern occupying more than 96% of the tube length,

Acknowledgements

We are thankful to of Team members and staff of our Institute for helping us in this article.

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