A REVIEW ON STUDY OF DIFFERENT TYPES OF EVAPORATORS AND THEIR SOFTWARE

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ABSTRACT:- *In this paper a detailed summary of different evaporators which are commonly used is discussed. 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. Various parameters like steam requirement, water evaporated, product concentration etc. can be easily obtained using software like C++, visual basic, matlab, scilab etc.*

***Key Words*: Evaporator, Steam Consumption, Software, Vapors, Concentration.**

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 vapor. 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.

Evaporation is achieved by adding heat to the solution to vaporize the solvent. The heat is supplied principally to provide the latent heat of vaporization, and, by adopting methods for recovery of heat from the vapor, it has been possible to achieve great economy in heat utilization. Whilst the normal heating medium is generally low pressure exhaust steam from turbines, special heat transfer fluids or flue gases are also used.

The design of an evaporation unit requires the particle application of data on heat transfer to boiling liquid, together with a realization of what happens to the liquid during concentration. In addition to the three main features outlined above, liquors which have an inverse solubility curve and which are therefore likely to deposit scale on the heating surface merit special attention.

The evaporation is conducted by vaporizing a portion of the solvent to produce a concentrated solution of thick liquor. Evaporation differs from drying in that the residue is a liquid—sometimes a highly viscous one—rather than a solid; it differs from distillation in that the vapor is a mixture, no attempt is made in the evaporation step to separate the vapor into fractions; it differs from crystallization in that emphasis is placed on concentrating a solution rather than forming and building crystals. Evaporation sometimes produces slurry of crystals in saturated mother liquor.

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 Evaporator:-

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.
The heat requirements of single-effect continuous evaporators may be obtained from mass and energy balances:

Mass Balance,

$$\dot{m}_F + \dot{m}_S = \dot{m}_V + \dot{m}_P + \dot{m}_C$$

Energy Balance,

$$\dot{m}_F 3H_F + \dot{m}_S 3H_S = \dot{m}_C 3H_C + \dot{m}_P 3H_P + \dot{m}_V 3H_V$$

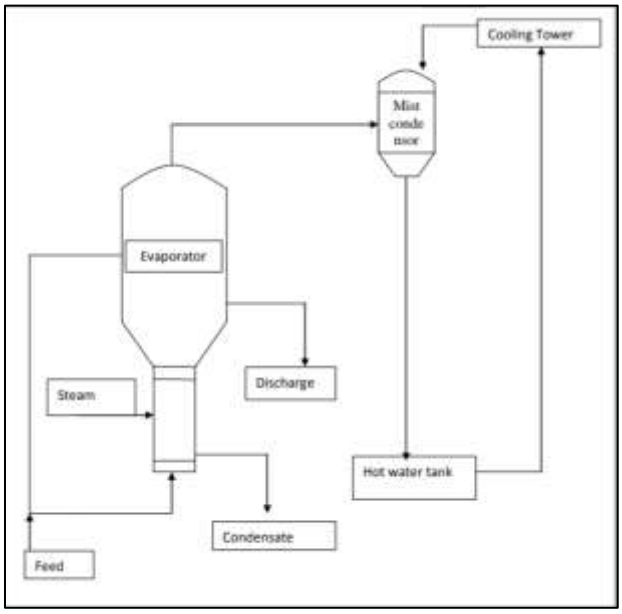

Figure 1: Single effect evaporator

Multi effect 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 to 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

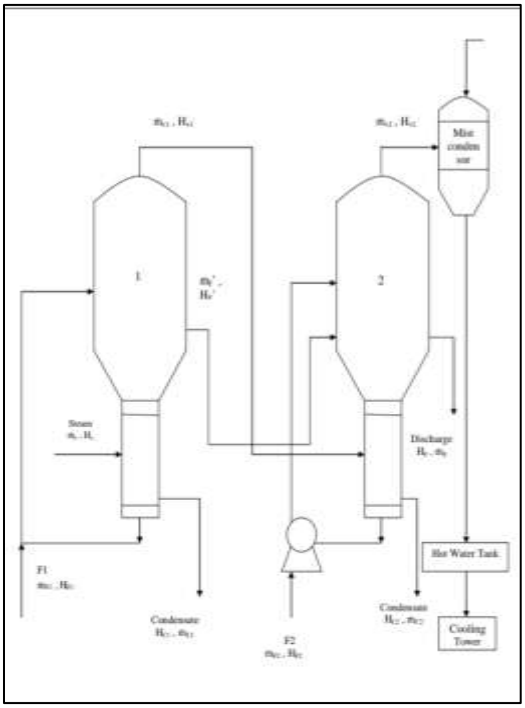

Figure 2: Double effect evaporator

LITERATURE SURVEY:

1. Manal stated 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. A study was carried out by Prashant Balpande, G. S. Zambre and A. P. Gawande 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 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. Frengzhen et. Al. studied the 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. Marcus studied that saving 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.

6. A study was done by Vanitha Dunna and P.S.Kishore on thermal analysis of triple effect falling film evaporator . Their study focused on production of distilled water. A triple effect evaporator with forward feed and parallel flow of liquid was considered. They studied the variation of physical properties such as mass flow rate, steam generation rate, enthalpies, heat of evaporation, and rate of evaporation for input pressure range of 24 bar to 16 bar. It was seen that at different input pressure (24,22,20,18,16) there was a very slight decrease in enthalpy by 2.08%,2.09%,2.12%,2.13% and 2.20% where as the mass flow rate increases by 11.9%,11.88%,11.73%,11.26% and 11.12%. Also the rate of evaporation increases by 7.25%, 6.95% ,6.67%, 6.59% and 6.41%. On comparison of multiple effect evaporators with single effect evaporator it was observed that the increase in mass flow rate was 199.91%.

7. A comparative study was done by M. Sathiyamoorthy, Amanuel Gebrekrstos and G. Balachandran 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 was done by Jean Claude Patel 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. Aijaz et.al. Studied that, terms 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.

10. Tayseir et.Al studied that, steam economy of the evaporator system increases with increase in the effect. Evaporators are integral part. They studied the quadruple effect on the falling film evaporator using simulation. They validated there results with industrial data and studied the overall mass balance equation, energy balance equations, component mass balance equations and heat transfer rate equations for calculation of area for each effect they studied. Any other saline water conc. System can get results by using this methodology.

11. A study was done by Deepak Kumar, Anjana Gupta and Somesh Kumar on dynamic simulation of multi effect evaporators in paper industry using Matlab. The main aim of this study was to develop dynamic mathematical model for evaporator for concentrating black liquor. The model consisted of sextuple backward feed which was used to simulate material, energy balance equations and parametric correlations. A transient study was made on liquor temperature, product flow rate and feed flow rate.

12. A research was done by Adriano. V. Ensinas, Silvia. A. Nebra, Mighuel. A. Lozano and Luis Serra on design of evaporation system and heater networks in sugar cane factories using a thermo economic optimization

procedure. The thermo economic optimization procedure for design of evaporation system and heater network with minimum operating cost and investment cost was done on EES software (EES 2006). The results obtained were based on 10000 tons sugar cane produced per year. It was noted that the vapor bleed from first evaporator effect when used for last evaporation affects reduced steam requirement utilizing 16% less energy. After optimization it was found that there was about 73.8% total cost reduction.

13. A program in C++ software was developed by Faizan Ahmed and Naseen Ahmed Khan for design of triple effect evaporator. In mechanical design a short tube evaporator with forward feed was considered. The software developed was used for solving non linear equations for the evaporation system. The conditions mentioned included steam pressure of first evaporator, final pressure of last evaporator, feed condition and flow to first effect and physical properties of a liquid and vapor. Surface area requirements, steam economy, total evaporation rate, number of tubes were calculated using developed software.

14. Leena. M. Borkar from Nagpur University developed visual basic software for a single effect evaporator. Visual basic is known for its powerful programming approach for developing sophisticated and graphical application for Microsoft environment. Software's main purpose was to calculate steam requirement, heat surface area and steam economy. She states that this software is user friendly as it provides information regarding basic theories and principles for calculations of parameters required for evaporator design. It also includes data base files of physical parameters like temperature, enthalpy and latent heat of different components. The user has to give input details and after execution of program output will be obtained.

15. Tejal. T. Wani, Amol. A. Gawali and Madhav. S. Joshi developed a bare tube typed finned three evaporators system to maintain different operating temperatures in evaporator. The design also included a single compressor, expansion device, air condenser, fan, receiver, filter-drier, backpressure valve and accumulator. They stated that evaporator temperature and condensing temperature determine cooling capacity of evaporator. They carried out an experiment in which they maintained the temperature of evaporator as -10^{o}C, 0^{o}C and 100^{o}C respectively. Power consumed by performance at various heat loads was studied. It was observed that compressor requires more power for suction of refrigerant and it was observed that coefficient of performance of system increases with increase in load.

16. Aminu Tijjani, H.K. Verma and Chhaya Sharma developed a PID controller for a single effect evaporator. They considered black liquor evaporator with forward feed for development of PID controller. They discussed four different control configurations which were simple PID controller, PID controller with forward feed control for single effect, PID controller using BPR and Modified PID controller. Modified controller is the combination of simple PID controller with feedback control, forward feed control for single effect evaporator and BPR(Boiling point rise) to determine concentration.

CONCLUSION:

Evaporators are mainly used to concentrate a weak solution by using certain heating medium. Most commonly used heating medium is steam. There are mainly two types of evaporators, single effect evaporator and multi-effect evaporator. Multi-effect evaporator is more economical compared to single effect as the vapor produced in the first effect are used as heating medium for latter effects. Various software are available with help of which calculation can be done easily. C++, visual basic, matlab and scilab are used to find various parameters of evaporators like steam economy, power consumption, water evaporated, product and feed concentrations, overall HTC and heat transfer area.

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