Dairy Process Engineering

Module- 1	**Evaporation**
Lesson- 6	**Operations and various feeding systems**

6.1 Introduction:

The most commonly used evaporation plant in the dairy is falling film evaporating plant consists of the following components which are assembled together in the required manner.

a) Heat transfer surface or calandria
b) Liquid/vapour separation system
c) Vapour removal system and vacuum control system
d) Ancillary equipment such as pumps for extracting and conveying milk, cooling water pumps, valves, gauges, thermometers etc.

a) Heat transfer Surface:

Efficient heat transfer from steam to liquid product is vital; both to the process and to the quality of the final product. Chemical, physical and biological changes in the product depend partly on time as well as temperatures. In general, high temperature and short time heat treatment produce less chemical and more biological effect than lower temperature sustained for long times. For economy it is important to keep the temperature as high, heating time as short as possible. Heat transfer rates and flow of product through the plant creates specific conditions within each type of equipment.

During heat transfer to milk, protein denaturation may take place on milk side if temperature of milk is high and when steam is condensing at high temperature. The build up of scale, which is hard and difficult to remove, reduces the rate of heat transfer at a much faster rate. Thus there is a need to wash the calandria after a period of operation to remove scale and restore the evaporation rate.

The use of two or more evaporators in series with gradually decreasing temperatures may be used to reduce the heat shock, especially when the more viscous product approaches final density. Thus, a triple effect plant operating at 70 ^{0}C, 57 ^{0}C and 44 ^{0}C in the final stage will give desirable product quality, concentration level and plant economy. This arrangement permits use of vapour from one effect to be reused for the next effect and so on, thus achieving greater economy as well as more gentle heat treatment.

The liquid product moves along the heating surface by convection assisted by vapour propulsion. The liquid is fed from the top of the tubes by means of weir or other device so as to form a thin film on the tube surface. Vapour from the evaporating liquid occupies the center of the tubes. Thus, only a thin quickly moving film is in contact with the heating surface. The falling film evaporator tends to provide a gentle heat treatment if properly operated.

b) Liquid/Vapour Separation System:

The separation of vapour from boiling liquid is possible by giving centrifugal or rotary motion at the entry to vapour separator. The adaptation of cyclone principle has removed the need for deflecting plants, baskets and entrainment separators in the vapour space. The tendency is to reduce the vapour system in size, because of the higher efficiency of separation.

c) Vapour Removal and Vacuum Control System:

The heart of the evaporator is the vacuum system, on which depends the successful operation, ease of operation and final product quality. It is important to remove vapour evaporated from the product as well as the noncondensable gases, which enter through leaks or are entrained in the product

d) Ancillary Equipment:

The main economy in evaporation is obtained by the continuous re-use of vapour. This vapour may be recompressed by live steam (TVR). The use of preheaters, interstage heaters and raw product heaters in the final condensate stage, all provide for economical operation. The use of heaters in this way also requires pumps to transfer the liquid product. These pumps are often operating against vacuum, and require water seals to maintain the vacuum.

6.2 Different feed flow arrangements in Multiple-effect evaporators .

In a forward feed system, the flow of process fluids and of steam are parallel. Forward feed has the advantage that no pumps are needed to move the solution from effect to effect (not applicable to modern calandria type evaporator). It has the disadvantage that all the heating of cool feed is done in the first effect, so that less vapour is generated here for each kg of steam resulting in lower economy. It has the further disadvantage that the most concentrated solution is subjected to the coolest temperatures. Low temperatures may be helpful in preventing decomposition of organics, but the high viscosity that may be found sharply reduces the heat transfer coefficient in this last effect.

Fig. 6.1 Forward and Backward Feed systems in Multiple-Effect Evaporation

In a backward feed system, the feed flows counter to the steam flow. Pumps are required between the effects. The feed solution is heated as it enters each effect, which usually results in better economy than that obtained with forward feed. The viscosity spread is reduced since the concentrated product evaporates at the highest temperature but heat sensitive materials may be affected. Forward feed system is generally used for heat sensitive product , while the backward feed is used for highly viscous product.

For best overall performance, evaporators may be operated with flow sequences that combine these two (i.e. mixed feed), or they may be fed in parallel with fresh feed evaporating to final concentration in each effect.

Fig. 6.2 Mixed Feed and Parallel Feed Multiple-Effect Evaporation

6.3 Capacity of Multiple – effect evaporators:

Although the use of the multiple-effect principle increases the steam economy, it must not be thought that there are no compensating disadvantages coordinate in importance with the economy of an evaporator system is the question of its capacity. By capacity is meant the total evaporation per hour obtained since latent heats are nearly constant over the ranges of pressure ordinarily involved, capacity is also measured by the total heat transferred in all effects. The heat transferred in these effects can be represented by the following equations

$q = q_1 + q_2 + q_3 = U_1A_1 \Delta t_1 + U_2A_2 \Delta t_2 + U_3A_3 \Delta t_3$

Assume, now that all effects have equal areas & that an average coefficient U_{av} can be applied to the system. Then equation can be written as

$q = U_{av} A (\Delta t_1 + \Delta t_2 + \Delta t_3)$

However, the sum of the individual temperature drops equals the total over-all temperature drop between the temperature of the steam and the temperature in the condenser & therefore $q = U_{av} A \Delta t$.

Suppose now that a single-effect evaporator of area A be operated with the same over-all temperature difference viz. with steam at 110^o C and a vapour temp of 52^{o}C Assume also that the over-all coefficient of the single-effect is equal to the U_{av} of the triple effect. The capacity of the single effect will be $q = U_{av} A \Delta t$.

This is exactly the same equation as that for the triple effect. No matter how many effects one use, provided the average over-all coefficients are the same exactly the same equation will be obtained for calculating the capacity of any evaporator. It follows from this that if the number of effects of an evaporation system is varied and if the total temperature difference is kept constant, the total capacity of the system remains substantially unchanged.