Chapter 6

STERILIZATION

(Objectives of sterilization, Methods of sterilization, In-bottle sterilization, UHT sterilization, Means to reduce fouling in heat exchangers)

Objective of sterilization

The sterilization is the process of heating to a high enough temperature (usually more than 100°C) for specific time to kill almost all bacteria. The sterilized milk can be stored at room temperature for a long period of time.

The sterilization of milk has the following characteristics.

- Temperature more than 100°C is used in the process.
- No chilling is required for storage. Excellent storage life at room temperature.
- High operating pressure is employed to prevent milk from boiling at the processing temperature.

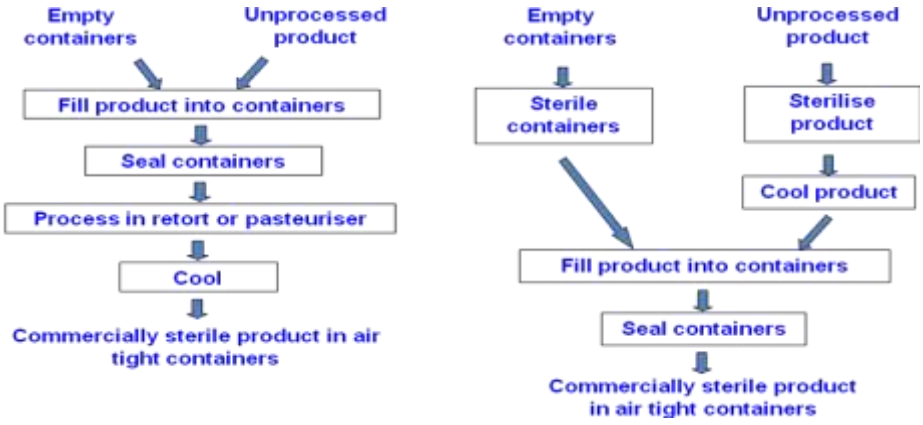
Methods of sterilization

In general there are two methods of sterilization.

Conventional method: Packaging is done before heat treatment. The processing is usually carried out at 105-110°C for 30-45 min. It is also known as *In-bottle sterilization*.

UHT or aseptic method: Packaging is done after heat treatment. The ultra high temperature short time (UHTST) and very high temperature short time (VHTST) processes come under this category. The processing is at 135-150°C for 1-20 seconds. Then the commodity is packed aseptically.

The difference between the conventional method and aseptic processing method can be better understood with the help of Fig. 6.1.



Conventional method Aseptic method

Fig. 6.1 Difference between conventional and aseptic processing methods

Conventional canning/ in-bottle sterilization

The in-bottle sterilization method can be further categorized as batch or continuous types. The basic flow chart to explain the in-bottle sterilization is given in Fig. 6.2.

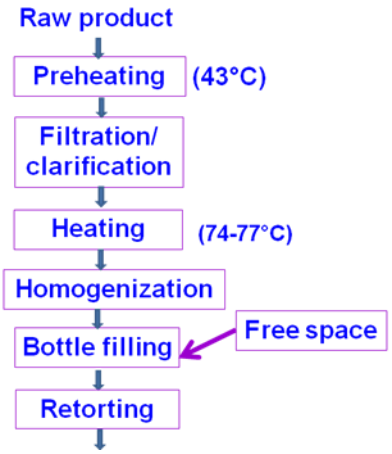


Fig. 6.2 In-bottle sterilization process

Batch sterilization

The equipment which is used for the sterilization process is called a retort and the processing is often called retorting. The batch retorts can be either horizontal type or vertical type. The retort has a lid or door with good fastening. It has necessary controls for temperature, pressure and safety devices. They can also be of circular or rectangular cross section.

Fig. 6.3 A horizontal retort

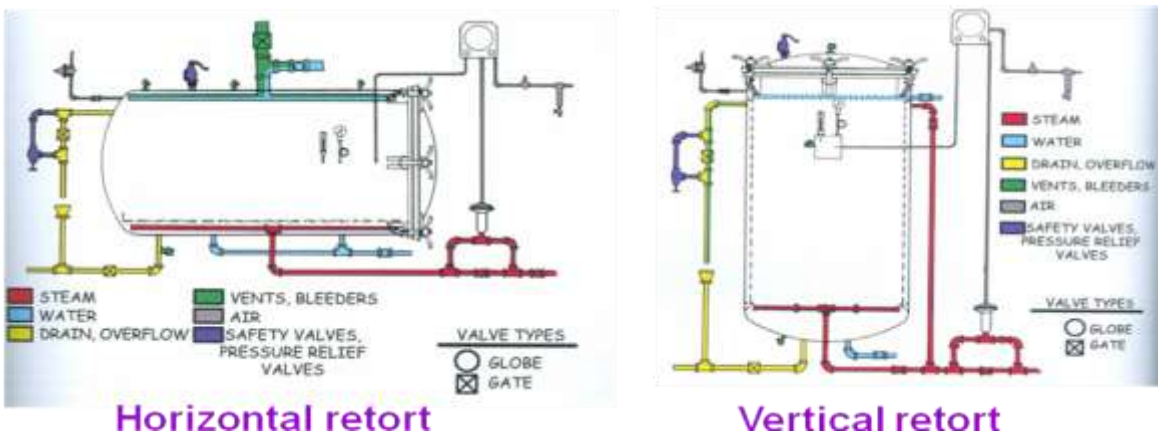


Fig. 6.4 Basic parts of retort

The batch retorting process can be explained as follows.

- The bottles are loaded onto crates and then the crates are travelled into sterilizer with the help of a trolley/truck.
- After the commodity is packed, the door is closed, the vessel is supplied with steam at required pressure.
- The processing time and pressure are properly maintained by controls.
- After desired processing time, steam is vented to atmosphere.
- After this the crates (bottles/cans) are immediately cooled by air (fans) to avoid further cooking of the product.

Water spray or cascading water retort

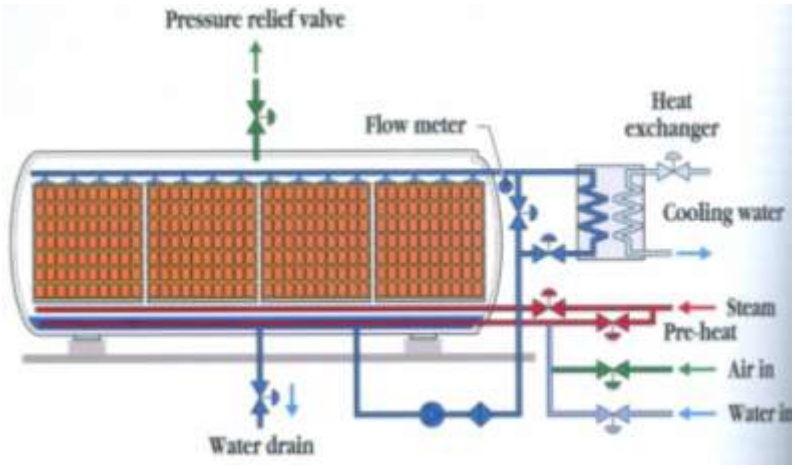


Fig. 6.5 Water spray or cascading water retort

The characteristics of water spray or cascading water retort are as follows.

- It uses a low volume of water.
- Water does not completely cover the containers during processing, but instead sprays or cascades (showers) on the containers.

- The system collects (draws) water from the bottom and reintroduces through sprays from the top and mid-section of the vessel to heat or cool.
- Heating of water is done internally by steam spreaders.
- Air is the source of overpressure.

Rotary batch sterilizer

This sterilizer agitates milk during heating by rotating the load of bottles about a horizontal axis.

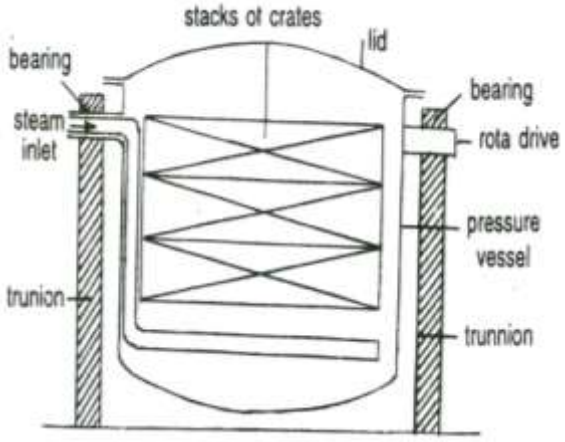


Fig. 6.6 Rotary batch sterilizer

Hydrostatic retort

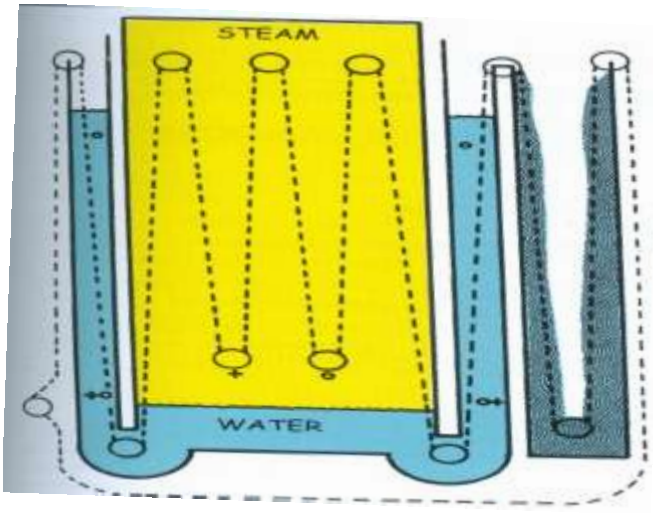


Fig. 6.7 Hydrostatic retort

The characteristics of hydrostatic retort are as follows.

- It operates with steam as the processing medium.
- The processing chamber (also known as steam dome) is maintained at constant temperature.

- It has a continuous conveyor chain that transports containers at a constant rate.
- There is minimal container agitation during processing.

(*However, some use cascading water with over pressure as the processing medium and some provide container rotation or rocking during processing*.)

- Two, four, six or eight pass hydrostatic retorts are common.
- Pressure within the chamber is maintained and counterbalanced by the weight of water in the feed and discharge gates.
- To increase the temperature, the pressure must increase and thus height of water column must increase.
- For the processing chamber temperature as 121°C, we require 103.4 kPa pressure in the chamber, i.e. the height of water column in the feed and discharge legs must be 11.3m above the steam-water interface.

Continuous sterilizer

In the continuous sterilizers, the cans enter and exit the sterilizer in a continuous manner.

Continuous rotary retort

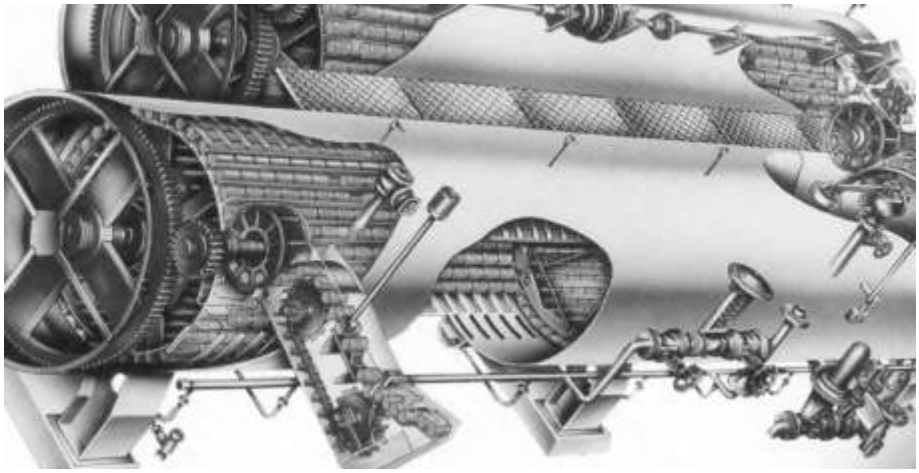


Fig. 6.8 Continuous rotary retort

The characteristics of continuous rotary retort are as follows.

- There is continuous container handling and intermittent product agitation.
- The retort system is constructed of a series of cylindrical vessels called shells (typically 1.5 m diameter).
- Processing and cooling in separate shells connected by transfer valves.
- To maintain pressure in the shells, containers enter and exit through self-sealing inlet and discharge valves.
- Agitation occurs when the containers roll on the bottom of a shell.
- Product agitation increases rate of heat penetration, allows use of higher processing temperature (up to 138°C), and improves product uniformity and quality.

- Large initial investment and additional critical factors to monitor and control.
- Retorts will accommodate a limited range of both length and diameter of cylindrical container sizes due to the physical restrictions imposed by reel steps, spacing of the spiral and other factors.

General problems in in-bottle sterilization

There are two kinds of problems in heat treatment

1. Heat has to pass through the container first before it goes into the milk.
2. Use of glass as container material may cause some auxiliary problems.

While processing milk in bottles, a ring of white solids is found on wall of the bottle at edges of milk surface. It could be due to excessive foam formed during bottle filling operation. It can be avoided by rotation or violent shaking of the bottle during heating and cooling cycle.

Important accessories in retorts

The following are the important accessories in a retort.

- Air vent
- Temperature recorder/ thermometer
- Pressure gauge

They should perform accurately so that damage to the product and to the people and machines are avoided.

Steam requirement for retorting

Assuming that milk bottles are loaded at 70°C and sterilised at 113°C by steam with a heat capacity of 2320 kJ/kg, the steam requirement is about 0.1 kg steam for each litre of milk. However, in practice, the usually steam capacity ranges between 0.2-0.6 kg of steam per litre of milk according to the plant characteristics.

Bottle cooling by natural air

As it has been mentioned earlier, the bottles have to be immediately cooled after processing so that the product is not overcooked and the quality is not impaired. However, it is essential that any type of thermal shock is avoided during the cooling process. First the steam is vented outside to reduce the pressure and temperature inside the retort. Then cooling of the containers is done either by air or water.

Controlled water cooling within the sterilizer is practised in commercial canning for metal cans, but not for glass bottles, as they may break.

ULTRA HIGH TEMPERATURE STERILIZATION

The main features of Ultra High Temperature (UHT) or aseptic processing are as follows.

- Temperature of 135-150°C is maintained for a few seconds.
- So the product is treated in a continuous heat exchanger.
- Causes much less chemical change than the conventional sterilization process.

The classification of UHT sterilization processes as regards to different types of heating medium and methods are given in Fig. 6.9.

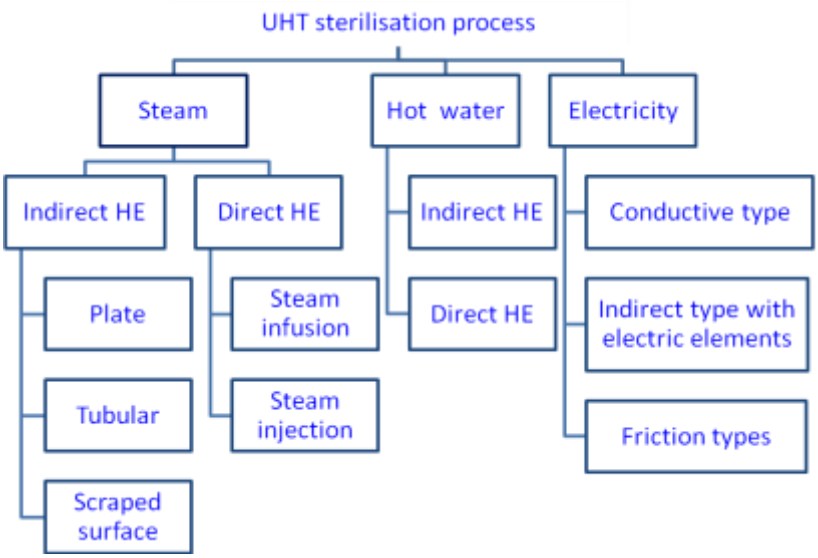


Fig. 6.9 Classification of UHT sterilization process

The flow chart of a UHT sterilization process is shown in Fig. 6.10. We have already discussed about the functions of different parts in the pasteurization section. In this case, the temperature is increased to 135-150°C and the holding time is less. Hence the length of holding tube is much smaller than the HTST pasteurization methods.

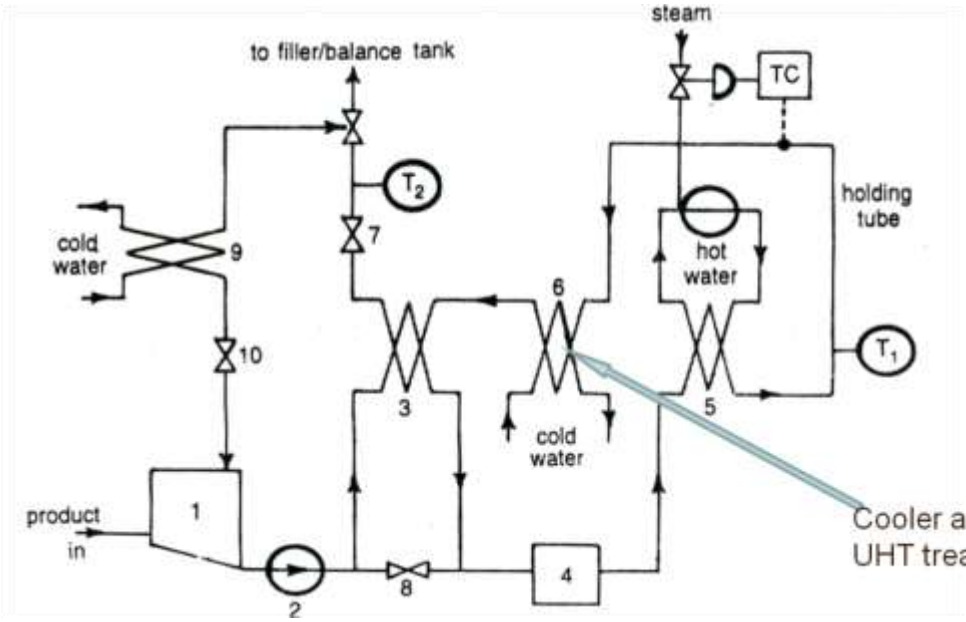


Fig. 6.10 UHT sterilization process (indirect heating type)

(1) level-controlled balance tank (2) centrifugal pump (3) plate heat exchanger (4) homogenizer (5) heat exchanger (6) cooling section (7) restriction (8) by-pass valve (9) cooler (10) back-pressure valve

In the heating chambers, a high pressure is maintained on the milk side. Fig. 6.11 gives a cause-effect diagram to explain why high pressure is required in the chambers.

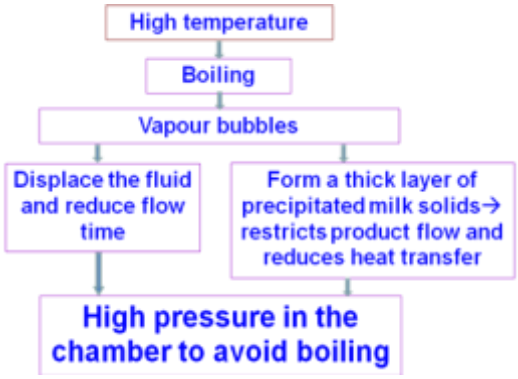


Fig. 6.11 Why high pressure is required in chambers

- As can be seen from Fig. 6.11, high temperature maintained in the chambers cause boiling of milk and it forms vapour bubbles. The vapour bubbles have two effects, i.e., they displace the fluid and reduce the flow time; and they also form a thick layer precipitation of milk solids which restricts product flow and reduces heat transfer. Therefore, high pressure is required in the chamber to avoid boiling.
- At a temperature of 135°C and 150°C, a back pressure of about 2 bar and 3.75 bar are needed respectively. However, to prevent the separation of air at high temperature and formation of bubbles by the dissolved air, a back pressure over and above this is required, i.e. internal pressures of about 4 bar is required, where the temperature may be above 140°C.
- Because of hydrodynamic pressure drop resulting from the product being pumped through the heat exchanger, higher pressure may be reached in other parts. This highest internal pressure may reach 6-8 bar.

UHT Sterilization in plate heat exchanger

The plate heat exchangers are most commonly used in indirect type UHT heat sterilization. The plate heat exchanger must be able to withstand the high pressure.

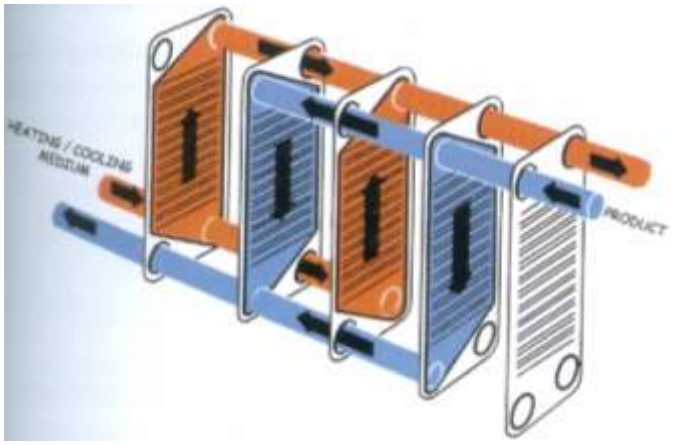


Fig. 6.12 Schematic diagram of a plate heat exchanger

To withstand these severe conditions of temperature and pressure, the gasket materials used with plates must be more sophisticated and expensive. Medium nitrile rubber is suitable for temperatures up to about 138°C. For higher temperatures (i.e. up to 155-160^{o}C) resin-cured butyl rubber is suitable.

UHT sterilization with direct type heat exchanger

Fig. 6.13 shows the flow sequence in UHT sterilization with direct steam injection type heat exchanger.

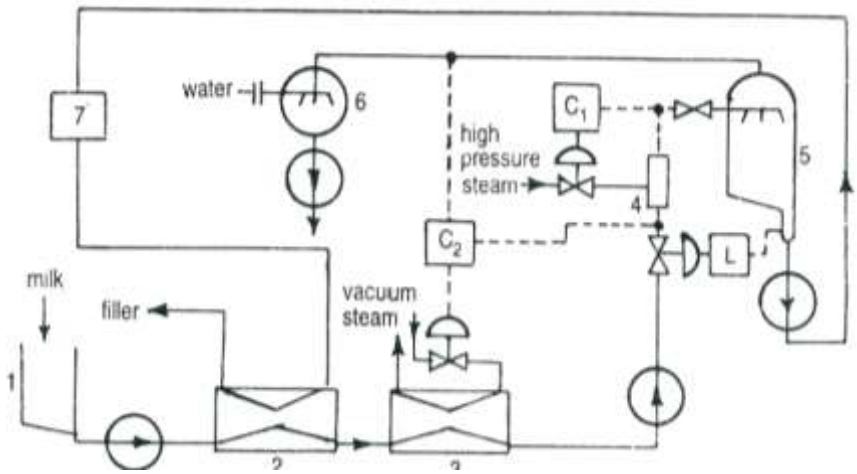
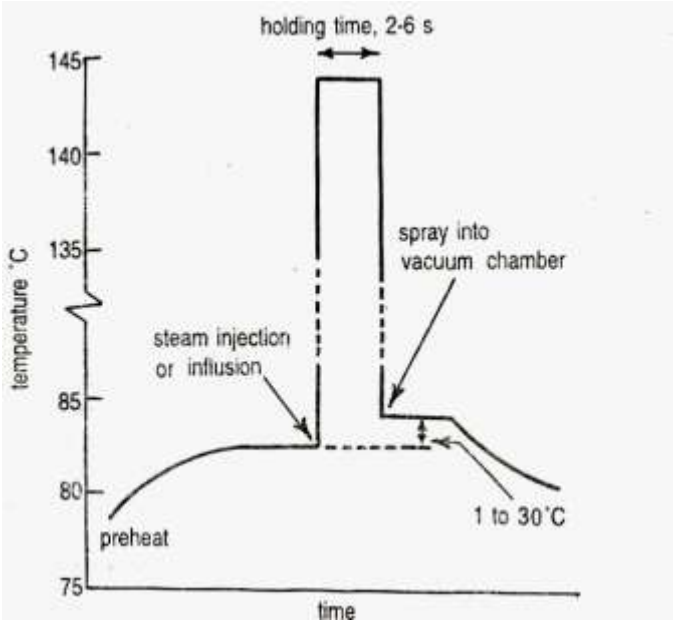


Fig. 6.13 UHT sterilization process (direct heating type)

(1) level-controlled balance tank (2) pre-heater (regenerator) (3) heat exchanger (4) steam injector (5) expansion cooling vessel (6) water jet/ surface condenser (7) homogeniser (L) controller (C) temperature controller



Direct heating injection type system

- The direct steam injection can increase the temperature of milk within fraction of a second and the holding time required is very less.
- The amount of steam to be condensed per kg product is about 0.11 kg or 11per cent of the product.
- If all this added volume is to be removed in cooling vessel, a small error in the balance will have a considerable practical and commercial effect on the total product volume leaving the plant.
- For accurate compensation, the temperature of vapour leaving the flash vessel should be slightly higher than that of the product before mixing with steam.

Ways to reduce fouling

- A high surface finish of the heat exchangers is required as rough surface provides more surface to which material can stick on.
- The higher the liquid flow velocity, the less is the amount of fouling.
- A lower temperature differential between the heating medium and the product leads to less fouling (a lower differential lowers the temperature at the heating surface-product interface).
- Preheating: The amount of deposit is less if the product is first heated to 75°C or above and held at that temperature for 10 min or more. (There will be reduced deposit due to denaturation of serum proteins and insolubilization of the milk salts by preholding at temperatures between 85°C and 110°C.)

Back-pressure to reduce fouling: It is necessary to maintain a sufficient back-pressure on the product not only to prevent boiling at the highest temperature within the heat exchangers but also to prevent the separation of dissolved gases which are normally present in the product. Thus ultimately it helps to minimize fouling. *The use of a high back pressure to reduce fouling is now standard practice in the UHT heat exchangers.*

- A back pressure of at least 1 bar above that corresponding to the highest temperature in the heat exchanger is required.
- The use of pressurized hot water tends to induce less fouling than steam heating and high product velocities also help to reduce deposits.
- This later approach is limited to holding time and pressure drop considerations.

CHECK YOUR PROGRESS

1. Explain the difference between the conventional canning and aseptic processing.
2. What are the specific time and temperature requirements for sterilization of milk?
3. Describe the process of batch sterilization.
4. Differentiate between a normal retort and rotary batch sterilizer.

5. Name the important accessories in a batch sterilizer and explain their functions.
6. What are the different types of sterilizers used in UHT sterilization?
7. Why is it required to maintain high pressure in the sterilization chamber in UHT sterilization? What is the normal range of pressure maintained?
8. What specific care should we take if we are sterilizing milk with plate heat exchangers?
9. Draw the flow chart of a continuous UHT sterilization process.
10. How do we remove the extra moisture added to milk during direct type heat exchangers?
11. What are the problems caused by fouling in heat exchangers during sterilization of milk?
12. Explain the different means to reduce fouling in heat exchangers.