Lesson 28
PRINCIPLE AND METHODS OF PASTEURIZATION

28.1 Introduction

The word pasteurization is derived from the name of an eminent French scientist Louis Pasteur (1860), who found that heating certain liquids specially wines to a high temperature improved their keeping quality. Pasteurization came into use on a commercial scale in the dairy industry shortly after 1880 in Germany and Denmark. This process is widely employed in all branches of dairy industry. Heat treatment destroys microorganisms present in milk. Further, a more or less complete inactivation of enzymes occurs, depending on temperature and treatment time. In order to retain as many sensory and nutritive properties of the raw materials as possible, different heating methods have been developed to destroy pathogenic organisms (pasteurization) or destroy all microorganisms and inactivate enzymes (sterilization).

28.2 Definition

According to International Dairy Federation (IDF), pasteurization can be defined as 'a process applied to a product with the object of minimizing possible health hazards arising from pathogenic microorganisms associated with milk by heat treatment, which is consistent with minimal chemical, physical and sensory changes in the product'.

In general, the term pasteurization as applied to market milk refers to the process of heating every particle of milk to at least 63°C for 30 min or 72°C for 15s or to any temperature-time combination which is equally efficient, in a properly operated equipment. After pasteurization, the milk is immediately cooled to 5°C or below.

28.3 Importance of Pasteurization

- To render milk safe for human consumption by destroying all the pathogenic microorganisms.
- To improve the keeping quality of milk by killing almost all spoilage organisms (88-99%).

28.4 Drawbacks of Pasteurization

- It may encourage slackening of efforts for hygienic milk production and may mask low quality milk.
- It diminishes the cream line or cream volume.
- Pasteurized milk may increase the renneting time.
- It fails to destroy bacterial toxins
- In India, pasteurization is not necessary as milk is invariably boiled on receipt by the consumer

28.5 Time-Temperature Combination for Specific Requirements

All pathogenic organisms are destroyed by pasteurization, except spore forming organisms. The thermal death point of tuberculosis germs (Mycobacterium tuberculosis) is slightly higher than that for inactivation of phosphatase enzyme. Pasteurization is carried out at a heat treatment temperature above that for phosphatase inactivation and yet below that for cream line reduction. The pasteurization ensures complete destruction of pathogens, a negative alkaline phosphatase test and least damage to the cream line which is shown in the table below:

Table 28.1 Time and temperature for specific purposes

Purpose	Temp. to be kept for 30 minutes	Temp. to be kept for 15 seconds
To kill tubercle bacilli	58.9°C	70.0°C
To destroy phosphatase	61.1°C	71.1°C
Pasteurization requirements	61.7°C	71.7°C
Cream line reduced	62.2°C	72.2°C

28.6 Methods of Pasteurization

28.6.1 Low-temperature long-time (LTLT)/Batch pasteurization

Milk is heated, held and cooled in the inner vessel. The space between vessel and the outer casing forms a jacket, through which the heating or cooling medium is circulated. To heat the milk, hot water or low-pressure steam is circulated through the jacket and milk is continuously agitated for rapid and uniform heating. The heating process could be manually or automatically controlled. The milk is heated to a minimum of 62.7°C and held at this temperature for minimum 30 min. It is then cooled as rapidly as possible to 4°C. A cooling medium is circulated in the jacket for chilling the milk, but more often the heated milk is discharged to a surface cooler where a film of milk flows down the corrugated metal plates or series of interlocked tubes. A cooling medium such as brine or chilled water is circulated on the other side of the plates or through the tubes (Fig.28.1).

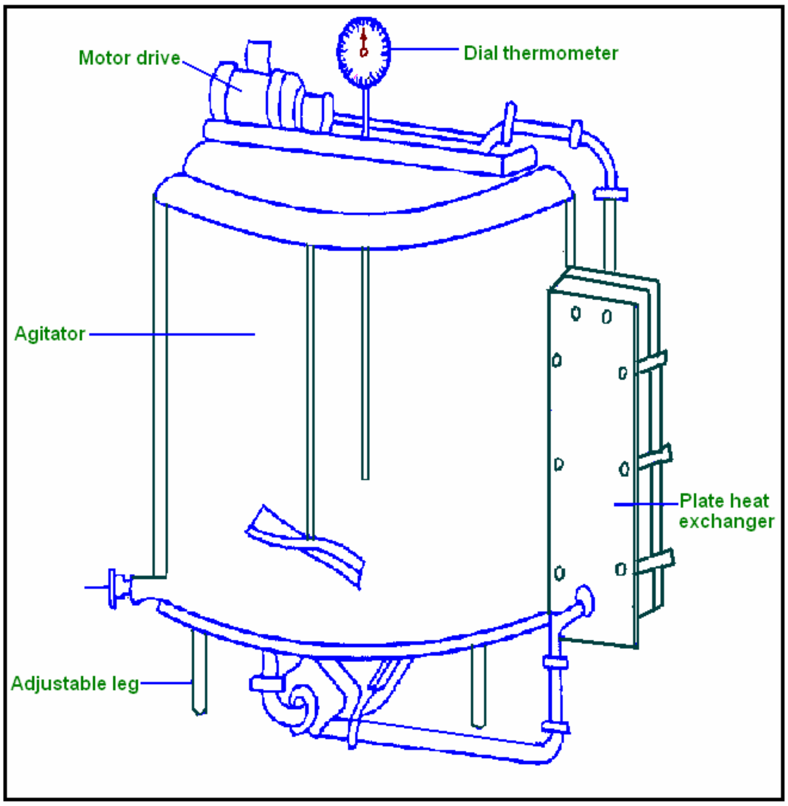


Fig. 28.1 Multipurpose vat with inner view

The LTLT pasteurizer may be of three types:

28.6.1.1 Water – jacketed vat

This is double-walled around the sides and bottom of the vat in which hot water or steam under partial vacuum circulates for heating, and cold water for cooling. The outer wall (lining) is usually insulated to reduce heat loss. The heat-exchange takes place through the wall of the inner lining. The difference between temperature of the hot water and the milk is kept to a minimum. The milk is agitated by slowly revolving paddles/propellers. When heating, the vat cover is left open for escape of off-flavors; and when holding, the cover is closed. During the holding period, an air space/foam heater (steam or electrically heated) prevents surface cooling of milk.

Advantage: Flexibility in usage - multipurpose vat.

28.6.1.2 Water–spray type

A film of water is sprayed from a perforated pipe over the surface of the tank holding the product which is continuously agitated. A rapidly moving continuous film of water provides rapid heat transfer.

28.6.1.3 Coil-vat type

The heating/cooling medium is pumped through a coil placed in either a horizontal or vertical position, while the coil is turned through the product. The turning coil agitates the product (but additional agitation may be necessary).
Disadvantage: Coils are difficult to clean.

28.7 High-temperature short-time (HTST) pasteurization
This was first developed by A.P.V. Co. in the United Kingdom in 1922. It is the modern method of pasteurizing milk and is invariably used where large volumes of milk are handled. The HTST pasteurizer gives a continuous flow of milk which is heated to 72°C for 15s and then promptly cooled to 5°C or below.

28.7.1 Advantages

1. Capacity to heat treat milk quickly and adequately, while maintaining rigid quality control over both the raw and finished product
2. Less floor space required
3. Lower initial cost
4. Milk packaging can start as soon as milk is pasteurized
5. Easily cleaned and sanitized (system adapts itself to CIP)
6. Lower operating cost (due to regeneration system)
7. Reduced milk losses
8. Development of thermophiles is not a problem
9. Automatic precision controls ensure proper pasteurization.

28.7.2 Disadvantages

1. The system is not well-adapted to handling small quantities of liquid milk products
2. Gaskets require constant attention for possible damage and lack of sanitation
3. Complete drainage is not possible (without losses exceeding those from the holder system)

4. Margin of safety in product sanitary control are so narrow that automatic control precision instruments are required in its operation
5. Lethal effect on high-thermoduric bacteria in raw milk is not as great as compared to LTLT system
6. Accumulation of milk-stone in the heating section.

28.7.3 Milk flow

The following steps or stages are involved as milk passes through the HTST pasteurizer:
1. Balance tank
2. Pump
3. Regenerative heating
4. Heating
5. Holding
6. Flow diversion valve (FDV)
7. Regenerative cooling
8. Cooling by chilled water or brine.

An arrangement for incorporation of the filter/clarifier, homogenizer, etc., in the circuit is also made possible. There is some variation in the use or order of these steps in different milk processing plants.

28.7.4 Functions of specific parts

28.7.4.1 Float-controlled balance tank (FCBT)

Maintains a constant head of the milk for feeding the raw milk pump; also receives milk diverted by FDV (if at all diverted).

28.7.4.2 Pump

Either a rotary positive pump between the regeneration and heating sections (USA), or a centrifugal pump with a flow control device to ensure constant output, after FCBT (UK and Europe) is used.

28.7.4.3 Plates

The Plate Heat Exchanger (PHE) (also called Paraflow) is commonly used in the HTST system. The PHE is a compact, easily cleaned unit. Its plates may be used for heating, cooling and regeneration. These plates are supported in a press between a terminal block in each heating and cooling sections. The heat moves from a hot to a cold medium through stainless steel plates. A space of approximately 3 mm is maintained between the plates by a non-absorbent rubber gasket or seal which can be vulcanized to them. The plates are numbered and must be properly assembled. They are tightened into place, and designed to provide a uniform, but somewhat turbulent flow for rapid heat transfer. Raised sections (corrugations) on the plates in the form of knobs, diamonds and channels, help provide the turbulent action. Greater capacity is secured by adding more plates. Ports are provided in appropriate places, both at the top and bottom of the plates, to permit both the product and the heating/cooling medium to flow without mixing.

28.7.4.4 Filter

Filter units are connected directly to the HTST system, placed after the pre-heater or regenerative (heating) section. These units, using 40-90 nylon mesh cloth are usually cylindrical in shape. Usually two filters are attached; when one is being used, other can be subjected to cleaning. This permits continuous operation.

28.7.4.5 Regeneration

The raw chilled incoming milk is partially and indirectly heated by the heated outgoing milk (milk-to-milk regeneration). This adds to the economy of the HTST process, as the incoming milk requires less heating by hot water to raise its temperature to pasteurization temperature in the heating section.

28.7.4.6 Heating

The preheated milk from regeneration section passes through heating section of HTST, where it is heated to 72°C or more with the help of hot water from hot well. Thereafter, the heated milk enters into the holding section (plates/tube).

28.7.4.7 Holding

The holding tube ensures that the milk is held for a specified time, not less than 15s., at the pasteurization temperature of 72°C or more.

28.7.4.8 Flow diversion valve (FDV)

This routes the milk after holding section. If the milk is properly pasteurized, it flows forward through the unit. In case the milk is not heated to the set heating temperature, it is automatically diverted by the FDV back to the Float Controlled Balance Tank (FCBT) for reprocessing. It is usually operated by air pressure working against a strong spring. If the temperature of heated milk falls below set temperature, air pressure is released and the valve snaps shut immediately. When the temperature is regained, air pressure builds up and the valve opens up for the forward flow to occur. The system is so arranged that any failure of electricity moves the valve in the diverted position.

28.7.4.9 Regeneration (cooling)

The pasteurized hot outgoing milk is partially and indirectly cooled by the incoming cold milk (milk-to-milk regeneration). This again adds to the economy of the HTST process. In fact, when pre-cooled (raw) milk is received, regeneration efficiency is 90% and above which obviates cooling using well water altogether.

28.7.4.10 Control panel

Contains instruments, controls, FDV-mechanism and holding system, all centralized in one moisture-proof panel. The lower half of the panel forms an air-insulated chamber which carries the holding tube.

28.7.4.11 Automatic control devices

These include (a) steam pressure controller, (b) water temperature controller and (c) milk temperature recorder.

28.7.4.12 Steam pressure controller

Maintains a constant hot water temperature for heating milk accurately to the required pasteurization temperature. It acts as a reducing valve in the steam supply line to give a constant steam pressure.

28.7.4.13 Water temperature controller

Regulates the amount of steam entering the hot water circulating system.

28.7.4.14 Milk temperature recorder

Records the temperature of milk leaving the holding tube/plate. This is an electric contact instrument that operates either a FDV or a milk pump, automatically preventing milk from leaving the holding section at temperatures below the one set in the control panel. Both the frequency and duration of the flow diversion (if at all) and the temperature of milk leaving the heating section are recorded in the thermograph (recording chart) by means of two different colored pens.

28.7.4.15 Hot water

Circulates hot water through the heating section of the machine to maintain the correct milk heating temperature within very fine limits.

28.7.4.16 Pressure in the system

The normal pressures maintained in the HTST system are:

Table 28.2 Normal Pressure maintained in the HTST System

Pasteurized milk	15 psi
Raw milk	14 psi
Heating/cooling medium	12 to 13 psi

28.8 Testing of Holding Time

The holding time is calculated between the points at which the heated milk leaves the heating section and reaches the FDV. The efficiency of pasteurization in the HTST system depends on attaining the requisite temperature along with the desired holding time. Hence, the latter should be checked periodically. Several methods are used for determining the holding time, viz. the electrical conductivity method (of a salt solution); the dye injection method; the electronic timer method; etc. The requirements for heat treatment and modifications which can occur in milk, time-temperature profiles have been established for heat treatment processes.

28.9 Devices for Controlling the Heat Treatment Process

1. Automatic temperature control and recording devices.
2. Automatic safety device to avoid insufficient heating of the milk (bypass installation) with recording device for time/temperature and valve position for the flow, as well as passage and recirculation of the milk or cleaning.
3. Safety device with automatic recording against unplanned blending of pasteurized or sterilized milk with non-heated milk based on pressure increase after the heating or holding section of the heat exchanger.

The most widely used installation for the heat treatment of milk is plate heat exchanger. For reason related to the flow conditions, tubular heat exchangers are used when operating at temperature level >100°C.

Lesson 29
HEAT EXCHANGERS - PLATE AND TUBULAR TYPE

29.1 Introduction

The plate heat exchanger has found wide application in pasteurization and sterilization. It consists of a series of plates, terminals between the plates and a head terminal on to which the plates are pressed with the end terminal. For installation, cleaning and changing of plate rubbers, the plates and intermediate terminals can easily be moved backwards and forwards on carrying bars in a frame. Liquids can be passed in and out of the plant via the intermediate, head and end terminals. The liquid can flow alternately with a colder or warmer medium through the plates in such a manner that one plate occurs in zones close to walls because of low rates of flow.

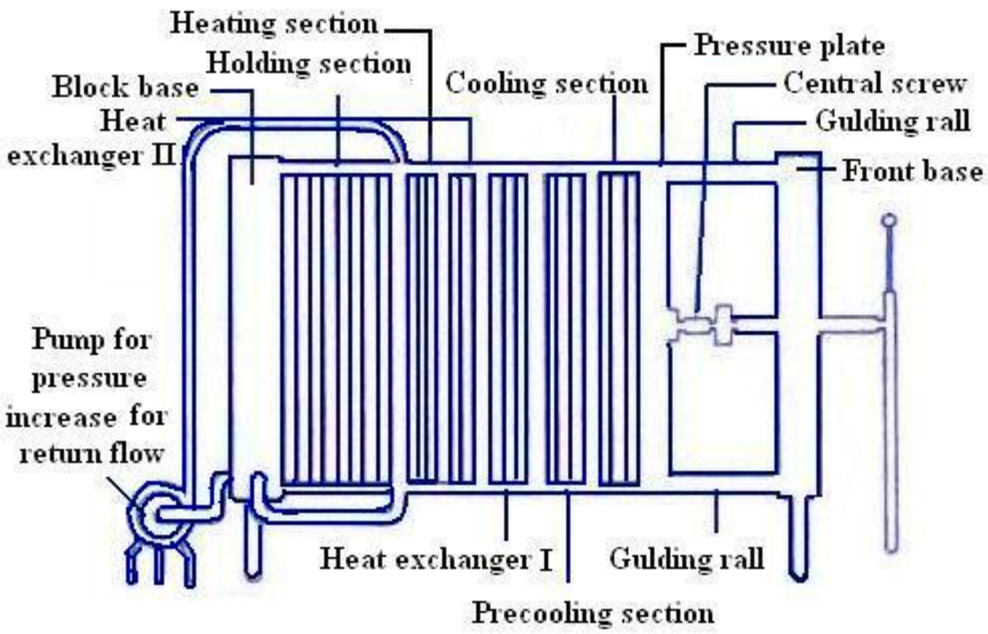


Fig. 29.1 Plate Heat exchanger for short time heating of milk

29.2 Design and Operating Principle of a Plate Heat Exchanger

The configuration of the individual sections of a plate heat exchanger is shown in the figure (Fig.29.1). Several heat exchange plates are assembled and are installed section wise in a frame. In many cases, plate heat exchangers for short-time heating have no holding section, but they have a tubular holding pipe besides the plate heat exchanger. This makes it possible to keep plate heat exchanger very small and space efficient. Ultra-high heat treatment plate heat exchangers are designed in a modular form.

29.3 Heat Exchanger Plates

Heat exchanger plates (Fig. 29.2) are made from stainless steel and have a heating surface of 0.2-0.4 m^2. A relatively large surface, considering the overall dimensions, is achieved by the fishbone-like pressed surface pattern. At the same time, very good turbulence is achieved between the plates (Fig. 29.3), thus creating nearly identical heat transfer conditions for all product particles, and a different thermal load is excluded. Close to the passage openings and between the distances, holders are shaped into the plates, which maintain a uniform distance between the plates. Additional longitudinal-shaped cams in the area of the inlet serve for good product distribution over the entire surface of the plate.

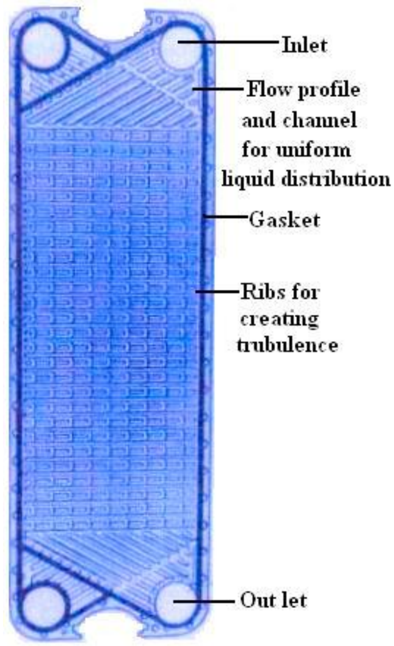


Fig. 29.2 Heat exchanger plate

Fig. 29.3 Turbulence between plates

Sealing the flows from each other and from the outside is done on the periphery of the plates and around the inlet/outlet openings with profiled gaskets, which are glued into the correspondingly shaped grooves. Further the plates are set up for hydrodynamic reasons in such a way that the inlet and outlet for the media are on the same side of the plate. This means that the inflow of the medium is on one side and the outflow is on the other side, resulting in simplified piping connections and reduced assembly costs. In each section, wherever there is heat transfer, one medium enters through the inflow and a second exits into the return flow.

In order to have a uniform fluid velocity between the plates and fluid distribution over the entire plate surface, the fluid velocity of the media must be 20 – 25 m/s. This fluid velocity depends among other things, on the flow rate and pressure drop. As the pressure drop decreases with longer distance, considerable pressure differences can be observed between the inflow and the outflow.

29.4 Connecting Plates

They are installed between the plate assemblies of the individual sections and separate them from each other. Connecting points, which can be replaced in most cases, permit the connection to other installations (Fig. 29.4 and 29.5).

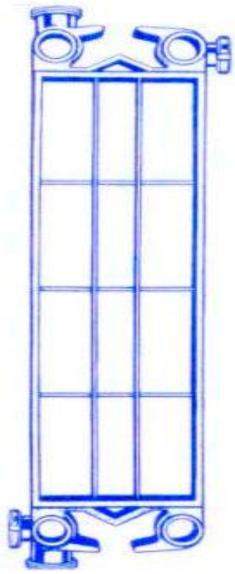


Fig. 29.4 Connecting plate

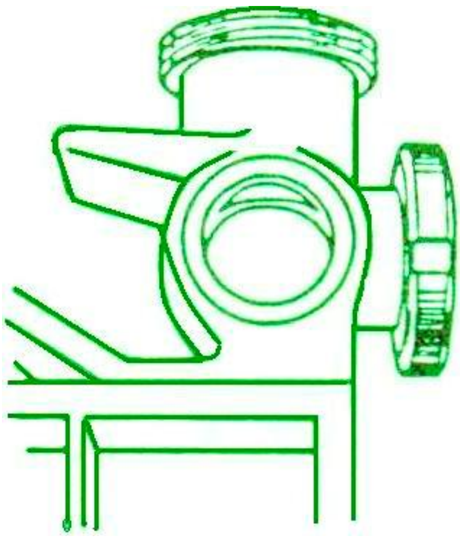


Fig. 29.5 Connecting corner

29.4.1 Flow patterns and circuits

A flow is formed between two plates of a plate assembly. By sequencing the various plates, flow patterns and stages are established in a section. Parallel flow patterns form one stage. The stages are installed in series in a section. The number of parallel flows per stage and the serial stages are chosen according to circumstances; the heating and holding section should not be modified by the operator. A simple flow pattern is shown in figure (Fig. 29.6).

29.5 Heating in a Plate Heat Exchanger

Heating is done with either steam or hot water, which is made by using steam. Constant pressure and temperature conditions in the steam supply pipes are the basis for a non interrupted process. The choice of a correctly calculated pipe diameter of the steam pipe lines and effective pressure control are the basis for constant conditions. For heating purposes, saturated steam (no superheated steam) is used, which should have the quality of a wet steam (2-8% water content). Pressure should be 0.96¬ to 1.96 bar.

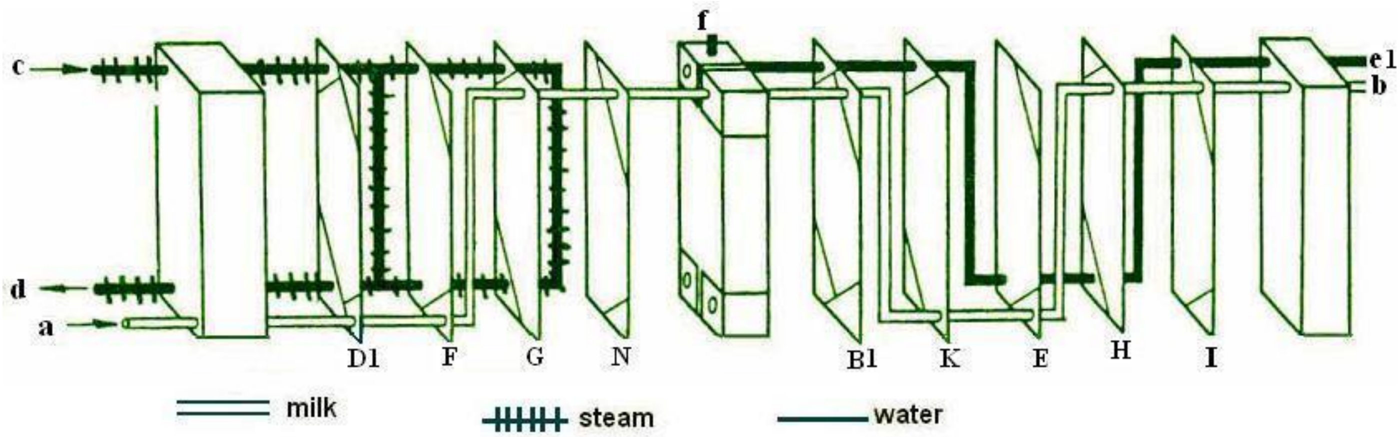


Fig. 29.6 Heat exchange and flow directions in heat exchanger

a) Milk inlet, right side b) Milk outlet, right side c) Steam inlet, left side d) Condensate outlet, left side e) Water inlet, left side f) Water outlet left top 01, F, G and so on indicate the plates, 1...4 and 5 ... 9 the number of plates.

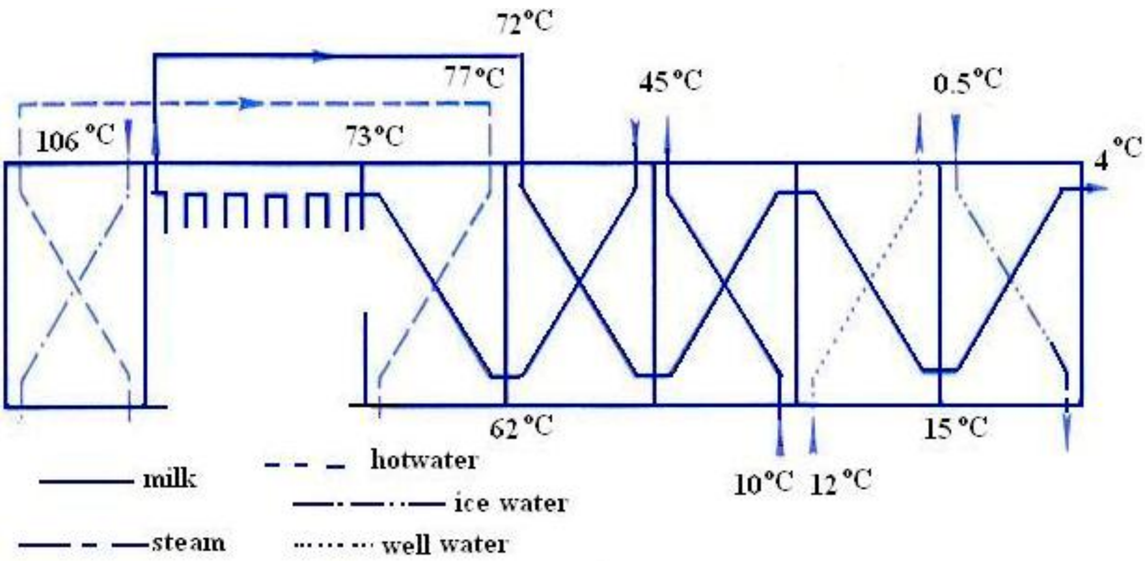
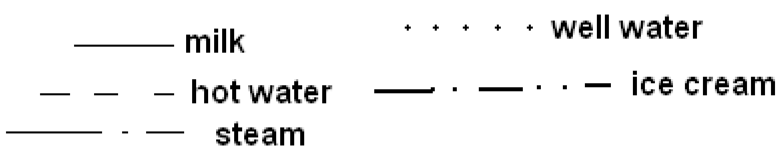


Fig. 29.7 Heat supply to a plate heat exchanger for short time heat treatment



Heat supply to a plate heat exchanger for short-time heat treatment

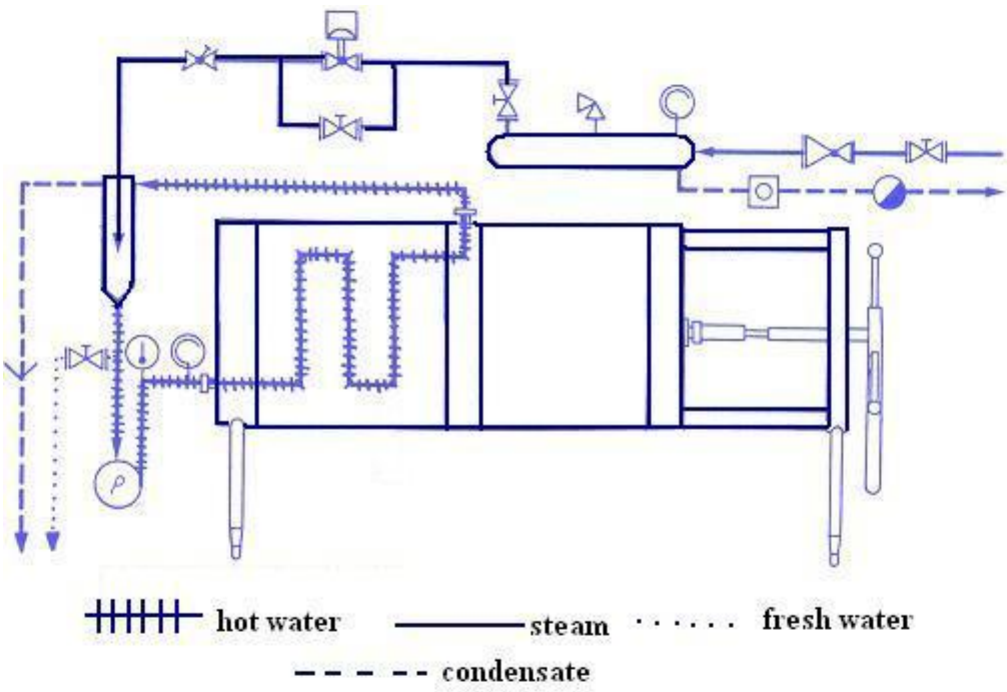


Fig. 29.8 Heat supply to a plate heat exchanger for short-time heat treatment

1. Steam distribution 2. Mixing battery 3. Plate heat exchanger

Steam injection is used in plate heat exchangers both for the high-heat process and for heating cream. Due to the relatively wide differences between the steam temperature and the product temperature as well as the high steam temperatures (> 100°C), the risk of burning milk is high and therefore enhanced depositions in the heating section must be considered (Fig 29.7). Short-time heating and thermization use hot water, which can be obtained in three different ways:

1. In a separate section of the plate heat exchanger
2. In a mixing nozzle
3. In a hot water battery

The flow in figure (Fig. 29.8) shows that the pressure-reduced steam passes through a membrane valve into the hot water mixing battery, where it is mixed with water. The membrane valve controls the steam quantity as a function of the set temperature and the valve is actuated pneumatically, adjusting the hot water temperature accordingly. The steam distributor can be eliminated if wet steam can be sup¬plied directly from the steam boiler, as wet steam cools down along its way in the steam pipes. Steam is dried by pressure reduction; it does not superheat.

29.6 Tubular Heat Exchangers

In tubular heat exchangers, milk products flow through tubes which are heated or cooled externally (Fig 29.9 and 29.10). The flow can be more easily controlled in the case of single tube than in a bundle of tubes. The advantage of a bundle of tubes is that larger heat exchange surface can be fitted economically into a smaller space. The spirally arranged single tube tubular heater, consisting of coaxial double tubes saves space and can be used for sterilizing milk. The milk can pass through the following stages in a continuous stream:

Preheating by means of the return flow of milk through the annular space. Heating with hot water or steam. Holding at pasteurizing or sterilizing temperature. Cooling by giving up heat to the incoming milk. Cooling with chilled water or brine.

A separator is often inserted between the preheater and the heater and a homogenizer before or after the heater.

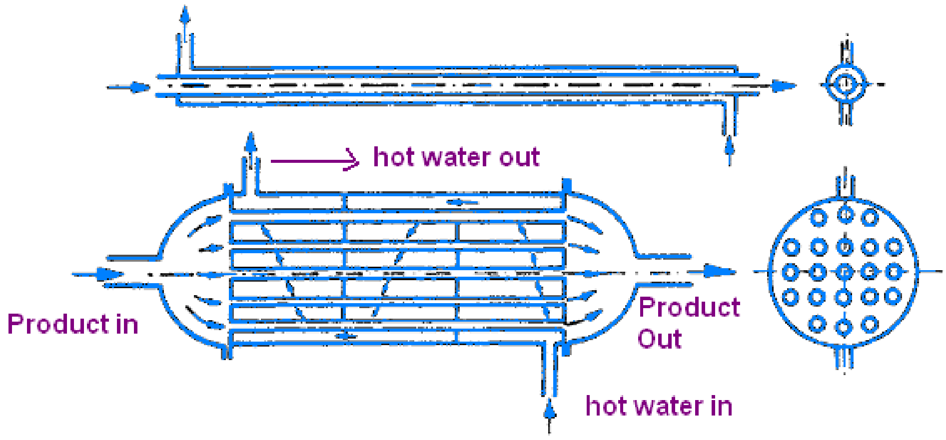


Fig. 29.9 Tubular heat exchanger

The fact that tubular heat exchanger can only be cleaned by flow through methods (usually 1%, HNO3 and 1% NaOH,) is a disadvantage. Deposits on the heating surfaces cannot be seen and are hardly removable by mechanical means.

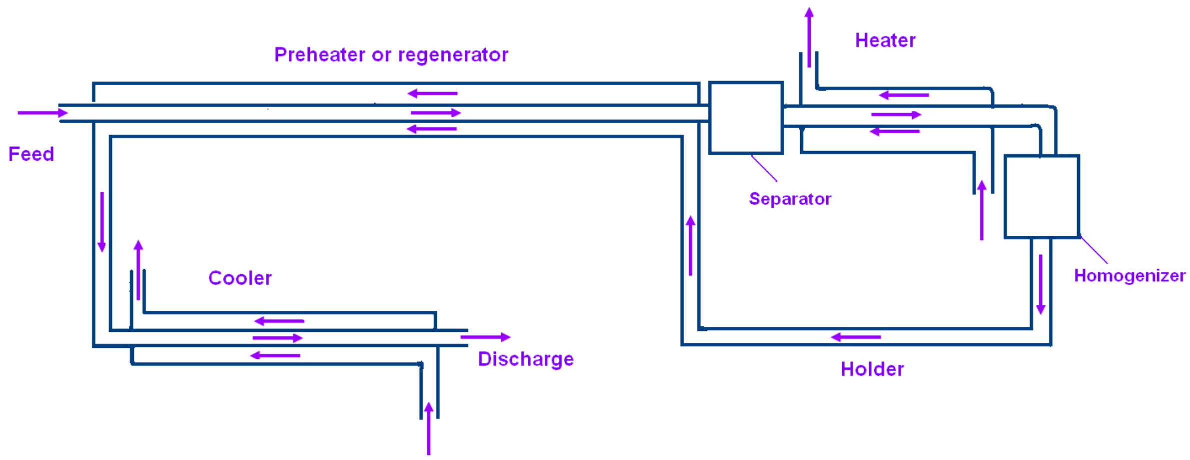


Fig. 29.10 Heating plant with tubular heater

With this type of heat exchanger it is, however, possible to work at high pressures which are of advantage when high temperatures are to be used. Sealing problems do not arise.

Lesson 30
WORKING OF HTST PASTEURIZER

30.1 Introduction

HTST method is also called 'continuous flow' or 'flash' pasteurization. It is modern method of milk pasteurization and is invariably used where large volume of milk is handled. This system gives a continuous flow of milk, which is heated to 72°C for 15s and promptly cooled to 5°C or below.

30.2 Operation of HTST Pasteurizer

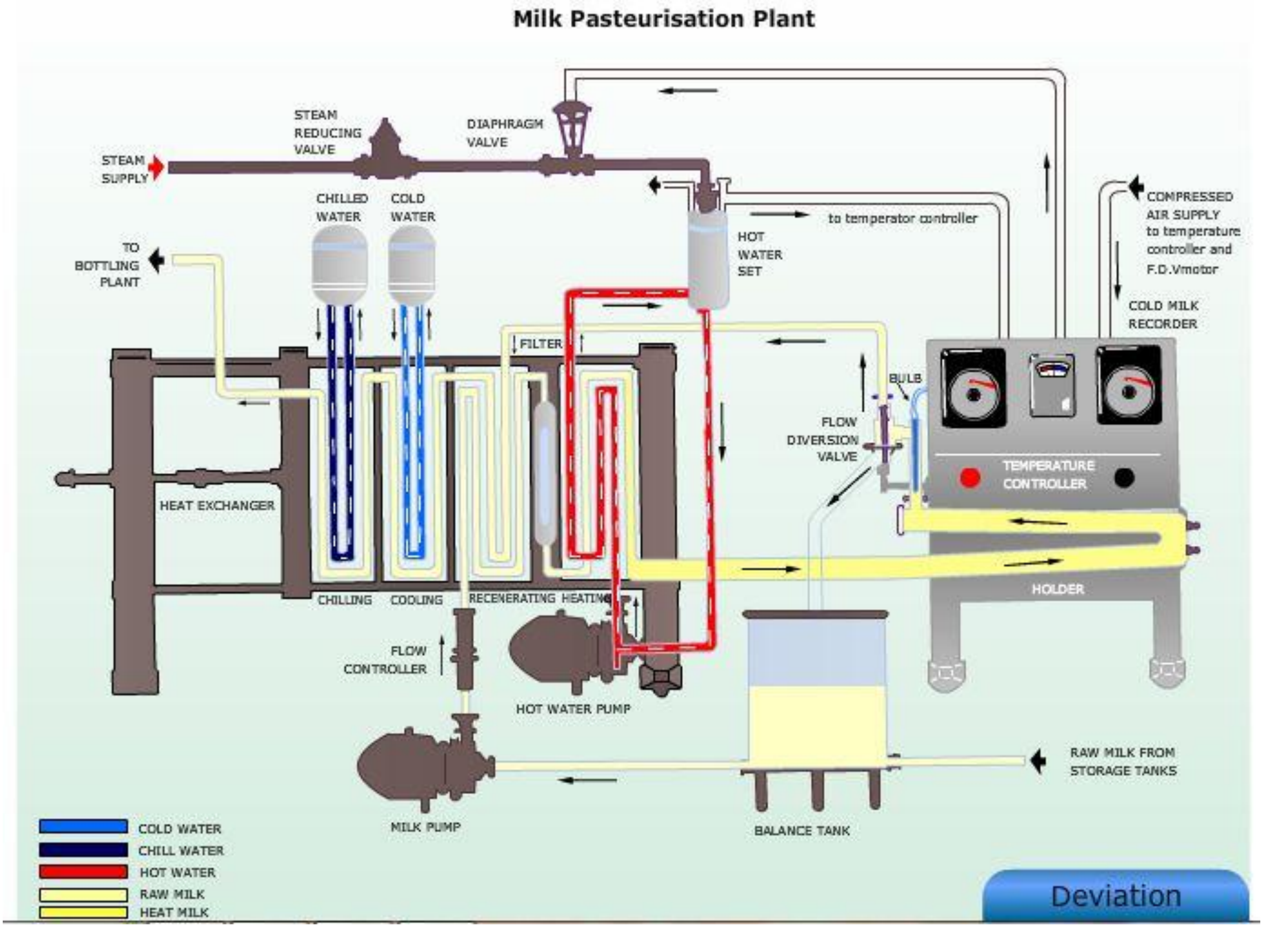


Fig. 30.1 Milk pasteurizer plant

30.2.1 Initial preparation

1. The plant must be sterilized.
2. All water remaining in the plant must be drained.
3. Clean filter clothes/nylon filters should be fitted in the filter.

30.2.2 Steps for starting the pasteurizer

1. Start the air compressor.
2. Switch on the control panel mains.
3. Fill the hot water tank, start the hot water pump and inspect the tank after 2-3 min for the level.
4. Open the air vents.
5. Start flow of the milk to the float controlled balance tank by starting milk pump.
6. Close the air vents when the milk comes out from them.
7. Set the temperature controller at pasteurization temperature (minimum 71.7°C) and adjust the air reducing valve so that the supply gauge registers 1.76 kg/cm2 pressure.
8. Turn on the steam to the hot water system via 'solenoid valve' for controlling steam passage into the heater.
9. Turn on the chilled water/brine as soon as forward flow takes place. Once the chilling temperature is reached, the plant will set itself to forward flow.

Note: The diluted milk that comes out first should not be collected in the balance tank.

30.2.3 Steps for shutting down the plant

1. Ensure availability of sufficient water in the storage tank (approximately, equal to the capacity of the plant).
2. As the last milk leaves the balance tank, tip in the water from the tank.
3. When the last portion of water leaves the balance tank, turn the 3-way valve at the finished milk outlet so that the flow is diverted to the floor.
4. Place a hose in the balance tank and flush the plant thoroughly with water until the discharge from outlet becomes clear.
5. Turn off the chilled water in the cooling sections.
6. Shut off the steam supply.
7. Admit cold water to the hot water tank and run until the plant is cold.
8. Stop the milk and hot water pumps.
9. Turn off the air supply and the main electric switch at the panel.

30.3 Maintenance of Milk Pasteurizers

1. The pasteurizer should be inspected every day for any leakage and for ensuring cleanliness.
2. The filter cloth or filter bag must be changed at regular intervals.
3. Periodical inspection of individual plate surface and gaskets must be done when the pasteurizer is dismantled for manual cleaning.
4. Any loose or broken gasket must be replaced, using proper adhesive.
5. The face of the plate bar and the tightening spindle should be kept lightly coated with grease.
6. All air-operated equipment should be supplied with clean dry air.
7. All recording instruments, thermometers etc. must be checked for accuracy, periodically.

30.4 Efficiency of Pasteurization

Alkaline Phosphatase test is carried out to determine whether milk has been properly pasteurized or not. The test is based on the detection of the activity of enzyme phosphatase, which is present in raw milk, but is completely inactivated at the temperature-time adopted for efficient pasteurization. Enzyme phosphatase is more resistant than the most heat-tolerant vegetative pathogenic bacteria.

When milk containing phosphatase (in active form – raw or underpasteurized) is incubated with, p-nitro phenyl disodium ortho phosphate, it hydrolyses the substrate liberating para-nitro phenol which gives yellow colour under alkaline conditions of the test. The intensity of the yellow color present is directly proportional to the activity of phosphate present in the milk. The presence of yellow color indicates inefficient pasteurization or post-pasteurization contamination with raw milk. Such mixing of raw and pasteurized milk can take place in the regeneration section of HTST pasteurizer.

30.5 Vacuum Pasteurization

The process of heat treatment under vacuum in stainless steel chamber is known as Vacreation. Machine used for vacuum pasteurization is known as Vacreator, which is the registered trademark of M/s. Murray Deodorizers Ltd., New Zealand

30.6 Purpose of Vacuum Pasteurization

1. To kill bacteria including pathogens.
2. Inactivate enzymes.
3. Remove undesirable odours and flavours
4. Remove oxygen

30.6.1 Use of vacreator

This equipment is generally used for vacuum treatment of milk or cream. It was mainly developed for treatment of aged and sour cream meant for butter making. It is an effective means of removing off-flavors particularly due to feed.

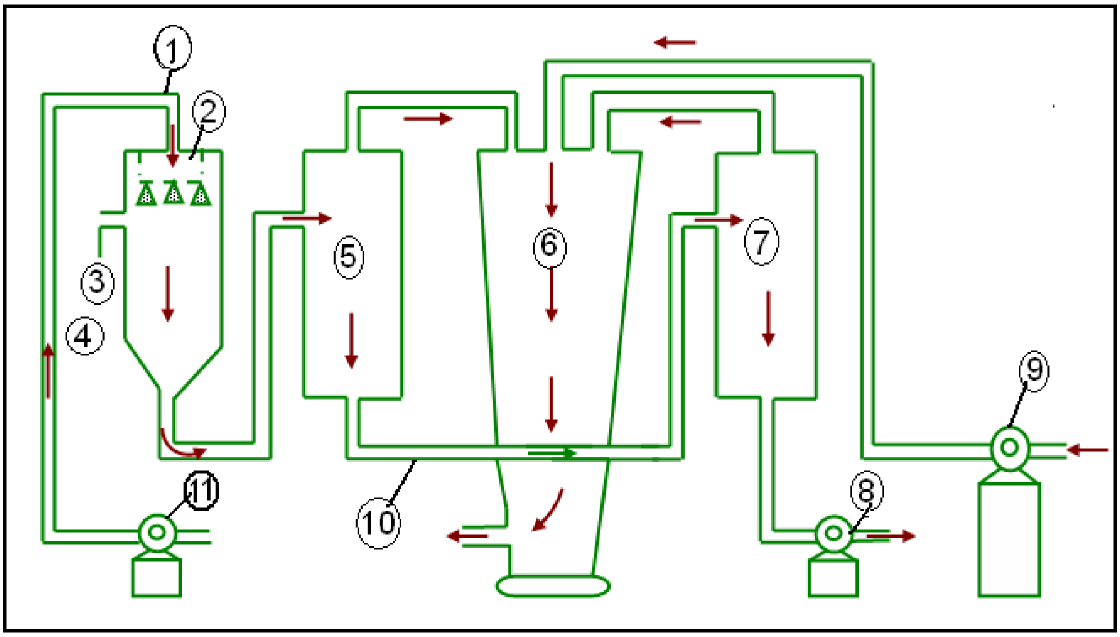
30.6.2 Principle of vacuum pasteurization

Principle of vacreation is mixing milk/cream with steam under pressure and immediately followed by sudden and spontaneous expansion into a finely divided state with a chamber maintained at reduced pressure. This process effects separation of off-flavors along with water vapor due to sudden transition from a compressed state to the expanded state. At the same time, instantaneous cooling effect of the product is an important factor in preserving the desirable characteristics of the product, even when high temperature is adopted.

30.6.3 Constructional and operational details

The vacreator consists of three or five stainless steel vessels connected to one another for steam heating and vacuum treatment with continuous product flow (Fig. 30.1). The first chamber is the pasteurizing chamber. This chamber is operated under vacuum (10-23 cm Hg) which maintains a corresponding temperature of 90-96°C. The cream or milk is admitted at the top through a spray pass and falls in a fine shower through expanded steam. Dry saturated steam is passed from the top along with milk or cream. Then, the product and some free steam are passed from the bottom of this chamber to the top of the second chamber. It enters this chamber tangentially and spirals in a thin film to the bottom.

The temperature of this chamber is maintained at 82 - 71°C under a vacuum of 37-50 cm Hg. Under the influence of high vacuum, the product releases a part of the steam as water vapor, which was condensed into it in the pasteurizing chamber. By controlling the amount of steam used, steam distillation occurs. The effect of steam distillation at this stage is to accelerate evaporation and remove undesirable flavor substances. The vapor resulting from evaporation and steam distillation passes over into the condenser, carrying with it volatile off-flavors. From the second chamber, the product is drawn into the third chamber maintained under still higher vacuum through a second uptake pipe. The product temperature in this chamber is between 38-46°C by maintaining a vacuum of 70-67 cm Hg. In this chamber, remaining water and off-flavor are removed, upon reaching the bottom of the third chamber, the product is discharged by means of a multi-stage centrifugal pump.



1. Feed in pipe 2. Perforated pan 3. Dry saturated Steam 4. Pasteurizing Chamber 5. Second Chamber 6. Vapour Condensor 7. Third Chamber 8. Multistage discharge pump 9. Water pump 10.Uptake pipe 11.Feed pump

Fig. 30.2 Vacreator or vacuum pasteurizier

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