PASTEURIZATION

The heating of every particle of milk or milk product to a specific temperature for a specified period of time without allowing recontamination of that milk or milk product during the heat treatment process.

☞ Pasteurization is a relatively mild heat treatment, generally performed at below 100^{o}C, which is used to extend the shelf life of foods for several days (for example milk) or for several months (for example bottled fruit).

☞ This process applies thermal treatment to food products in an effort to improve the stability of the product during storage.

☞ It preserve foods by inactivation of enzymes and destruction of relatively heat-sensitive micro-organisms (for example non-sporing bacteria, yeasts and moulds) but causes minimal changes in the sensory characteristics or nutritive value of a food.

☞ The magnitude of thermal treatment used for process is not sufficient to establish storage stability at room temperature. The criteria utilized in establishing these modest thermal treatments are rather specific and are different for different food commodities.

☞ The severity of the heat treatment and the resulting extension of shelf life are determined mostly by the pH of the food.

☞ In low acid foods (pH>4.5), the main purpose is destruction of pathogenic bacteria whereas, below pH 4.5, destruction of spoilage micro-organisms or enzyme activation is usually more important.

Purpose of Pasteurization Processing

- Public Health Aspect - to make food products safe for human consumption by destroying all bacteria that may be harmful to health.
- Keeping Quality Aspect - to improve the keeping quality of food products. Pasteurization can destroy some undesirable enzymes and many spoilage bacteria in fruit juice.
- For market milk, pasteurization conditions are based on thermal destruction of *Coxiella burnetti*, the rickettsia, vegetative pathogens i.e. brucellosis and tuberculosis; *Salmonella* and *Listeria* organism responsible for typhoid fever, tuberculosis, scarlet fever, polio, and dysentery.
- For high-acid fruits, such as cherries, the pasteurization process is based on successful destruction of yeast or molds.
- For feremented beverages, such as wine or beer, destruction of wild yeasts is the pasteurization criterion.

It is important to note that foods can become contaminated even after they have been pasteurized. For example, all pasteurized foods must be refrigerated. If the pasteurized food is temperature-abused (e.g., if milk or eggs are not kept refrigerated), it could become contaminated. Therefore, it is important to *always*handle food properly by handling it with clean hands, preventing it from becoming contaminated, and keeping it at a safe temperature. Pasteurization typically uses temperatures below boiling since at temperatures above the boiling point for milk, casein micelles will irreversibly aggregate (or "curdle").

The sensible heat required to raise the temperature of a liquid during pasteurization is found using

$$Q = mc(\theta_A - \theta_B)$$

Where,

Q= the rate of heat transfer, W

m= the mass flow rate, kg/s

c= the specific heat capacity

$\theta_A - \theta_B$ = the temperature change

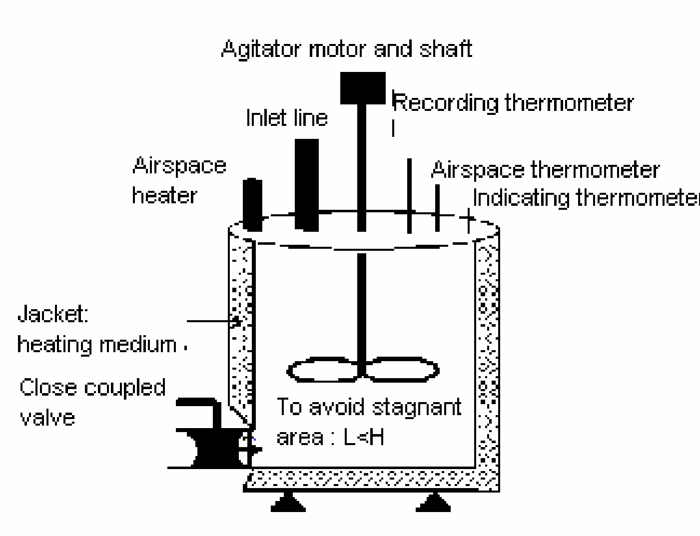
Pasteurization conditions can be optimized for retention of nutritional and sensory quality by the use of high temperature short time (HTST) conditions. For example milk pasteurization at low temperature and longer time losses more vitamins than HTST processing.

Methods of pasteurization

There are two basic methods, batch or continuous.

Batch method

- The batch method uses a vat pasteurizer which consists of a jacketed vat surrounded by either circulating water, steam or heating coils of water or steam.
- In the vat the milk is heated and held throughout the holding period while being agitated.
- The milk may be cooled in the vat or removed hot after the



Vat pasteurizer

holding time is completed for every particle.

- As a modification, the milk may be partially heated in tubular or plate heater before entering the vat.
- This method has very little use for milk but some use for milk by-products (e.g. creams, chocolate) and special batches.
- The vat is used extensively in the ice cream industry for mix quality reasons other than microbial reasons.
- In-container pasteurizers are also used for the thermal pasteurization of canned or bottled juices, high-acid fruits in syrup, beer, carbonated beverages, and some other foods, which are subsequently stored at refrigeration temperatures.
- Temperatures lower than 100°C are applied, i.e., the equipment is operated at atmospheric pressure.
- The food containers can be heated by hot water sprayed over the product, by dipping in a hot water bath, or by steam.
- In all cases, cooling is achieved by cold water.
- Carbonated beverages and glass containers are heated and cooled slowly to avoid thermal shock.

Continuous Method

- Continuous process method has several advantages over the vat method, the most important being time and energy saving.
- For most continuous processing, a high temperature short time (HTST) pasteurizer is used.
- The heat treatment is accomplished using a plate heat exchanger**.**
- This piece of equipment consists of a stack of corrugated stainless steel plates clamped together in a frame.
- There are several flow patterns that can be used.
- Gaskets are used to define the boundaries of the channels and to prevent leakage.
- The heating medium can be vacuum steam or hot water.

Types of pasteurization:

Low temperature high time : 63°C for 30 min

High temperature short time : 72°C for 15 second

Ultra high temperature : 131 °C for a fraction of second

Foods are heat-processed to kill pathogenic bacteria. Foods can also be pasteurized using gamma irradiation. Such treatments do not make the foods radioactive. The pasteurization process is based on the use of one of following time and temperature relationships.

High-Temperature-Short-Time Treatment (HTST) -- this process uses higher heat for less time to kill pathogenic bacteria. For example, milk is pasteurized at 161°F (72°C) for 15 seconds.

Low-Temperature-Long-Time Treatment (LTLT) -- this process uses lower heat for a longer time to kill pathogenic bacteria. For example, milk is pasteurized at 145°F (63°C) for 30 minutes.

It is important to remember that the times and temperatures depend on: (1) the type of food and (2) the final result one wants to achieve, such as retaining a food’s nutrients, color, texture, and flavor.

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Milk simply labeled "pasteurization” is usually treated with the HTST method, whereas milk labeled "ultra-pasteurization” or simply "UHT" has been treated with the UHT method.

System six essential components

- Three of the six components are heat exchangers (regeneration, heating, cooling).
- Timing pump
- Flow diversion valve
- Holding tube

Heat Exchangers:

✓ The regeneration, heating, and cooling sections of the pasteurization system are heat exchangers. Most often, plate heat exchangers are used. The plate heat exchanger is divided into three sections, with the middle section serving as the regeneration component, while the sections of the plate heat exchanger on either side are used for heating and cooling.

The *timing pump*

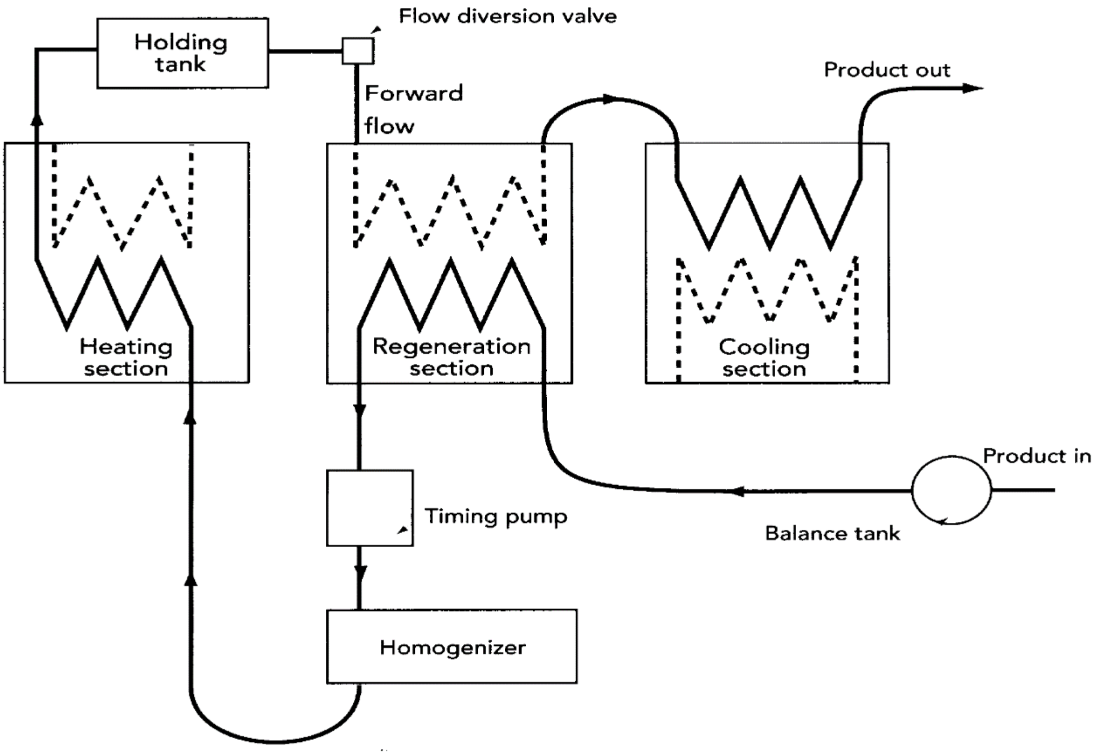
- The *timing pump* is a critical component of the pasteurization system. This pump must be positive displacement and must be set at a flow rate to ensure an established mass flow rate of product through the system as long as the system is operating in forward flow.

The *flow diversion valve*

- The FDV is controlled by a temp.-sensing device located at the exit of the heating section. If temp. is below the desired temp., the valve diverts flow to the entrance point. As soon as the established temp. is reached, the flow diversion valve changes and the product moves forward through the holding tube. This control device ensures safety of product.

The holding tube

- A holding tube has a known-diameter pipe designed to provide an established residence time for product at the pasteurization temp., the critical time/temp. Relationship needed for pasteurization is achieved by the residence time requirement in the holding tube. The length of holding tube ensures the necessary residence time of product.



Schematic of continuous HTST pasteurization system.

Advantages of HTST pasteurization:

(i) Large volume of milk may be processed continuously.

(ii) Automatic precision controls assure positive pasteurization

(iii) The equipment requires a relatively small amount of floor and plant space.

(iv) The system adapts itself well to CIP cleaning.

(v) Filling operations may begin almost simultaneously.

(vi) The HTST method is economical, as it uses regenerator.

(vii) The entire system is simple, requiring little supervisory attention.

(viii) The system imparts less cooked flavour to the milk than does vat pasteurization.

(ix) The capacity may be increased by increasing the number of plates without sacrificing floor space.

(x) It is well suited for regenerative heating and cooling.

(xi) The closed unit keeps the processing losses to a minimum.

Disadvantages of HTST system:

(i) Gaskets require constant observation for possible leakage and lack of sanitation.

(ii) It requires precision instruments of controls.

(iii) Complete drainage is not possible without losses.

(iv) Long run pasteurizers may give rise to serious bacteriological problems; plant should be efficiently cleaned every eight hours to avoid these.

Ultra-high-temperature (UHT) pasteurization

- When temp. exceeding the boiling point of water is used for pasteurization, it is ultra-high-temperature (UHT) pasteurization.
- The system requires pressure control in regions where the product is elevated to temperatures above the boiling point of water.
- In these systems, the pressure control would be maintained throughout the time that the product is in the holding tube.

Milk pasteurization

- Minimum pasteurization processes are based on the occurrence of several microbial pathogens in milk. These pathogens include *Brucella abortis, Myobacterium tuberculosis,* and *Coxiella burnetti*. The impact of these pathogens on human health is recognized in the form of tuberculosis and fever. The minimum pasteurization process has been established as 63^oC for 30 minutes. This process is based on D63 = 2.5 minutes and a Z of 4.1^oC.

The minimum pasteurization process

The process of 30 minutes at 63^oC represents a 12-D process in that the population is reduced by 12 times the D-value of 2.5 minutes. an initial population of 100 pathogens would be reduced to a probability of l0-10 by the minimum pasteurization process. On the other hand, it must be recognized that the populations of these pathogens in raw milk are much below l00, resulting in the probability of survival being significantly less.

- An additional factor that must be considered is that most pasteurization processes exceed the minimum for pathogens in order to achieve the extended product shelf life achievable by reducing the populations of product spoilage microorganisms.
- The process of 63^{o}C for 30 minutes is a typical process for batch pasteurization of a liquid food product like milk. Most pasteurization processes for liquid foods are accomplished in continuous HTST processes. To determine the HTST process equivalent to 63^{o}C for 30 minutes,
- By accepting the reference temp. as 63 ^{o}C as well as pasteurization temp. of 63 ^{o}C, the lethal rate is equal to 1. The temp. rise and cooling occur rapidly at time zero and the end of 30 minutes.
- The key factor to recognize at this point is that the minimum requirement for pasteurization when considering the impact on a pathogen is a minimum of 30 minutes at the pasteurization temp.
- The lethal rate curve illustrates that the area of the curve is equal to 30 minutes. This represents the holding time at the desired pasteurization temperature.
- Any additional impact of the thermal process, prior to the time the product reaches pasteurization temperature, and after the 30 minutes of holding at the desired temperature, is additional process that is in excess of the minimum requirement.

Design the holding tube

The holding tube must be designed to be of sufficient length to accomplish the desired residence time as established by the minimum process.

Two key factors

- The length of the holding tube
- The velocity of the fastest moving particle within the product flow stream.
- The velocity of product within the holding tube will be a function of the flow characteristics.
- Laminar: the velocity of the fastest moving particle will be 2 times the mean velocity
- Turbulent: the velocity of the fastest moving particle will be 1.2 times the mean velocity

HTST Milk Flow

All HTST pasteurizers consist of five basic components, as shown in Fig. .(a) plate heat exchanger- a series of thin, gasketed stainless steel plates divided into three sections (heater, regenerator, and cooler for heating incoming raw milk and cooling outgoing pasteurized milk; (b) constant level tank-provides a constant level of raw milk to the HTST system; (c) timing pump-a positive displacement pump that establishes the holding time of the time and temperature relationship for pasteurization; (d) holding tube-a length of pipe in which fully heated milk is held for the required holding time and (e) flow diversion valve- a three way valve that will allow properly pasteurized milk to enter the regenerator section of the plate heat exchanger or divert improperly pasteurized milk to the constant level tank for repasteurization. In addition to these five components, a source of steam and/or hot water is required to heat incoming raw milk, a safety thermal limit recorder is needed to activate the flow diversion value in the extent of improper pasteurization, and a cold milk recorder is required to record the temperature of outgoing pasteurized milk. Finally, auxiliary components that may be added to HTST units for additional processing of milk or milk products include a booster pump, homogenizer as a timing pump, stuffing pump, and flavour treatment or vacuum units.

Cold raw milk at 4° C in a constant level tank is drawn into the **regenerator** section of pasteurizer. Here it is warmed to approximately 57° C - 68° C by heat given up by hot pasteurized milk flowing in a counter current direction on the opposite side of thin, stainless steel plates. The raw milk, still under suction, passes through a positive displacement **timing pump** which delivers it under positive pressure through the rest of the HTST system.

The raw milk is forced through the heater section where hot water on opposite sides of the plates heat milk to a temperature of at least 72° C. The milk, at pasteurization temperature and under pressure, flows through the **holding tube** where it is held for at least 16 sec. The maximum velocity is governed by the speed of the timing pump, diameter and length of the holding tube, and surface friction. After passing temperature sensors of an **indicating thermometer** and a **recorder-controller** at the end of the holding tube, milk passes into the **flow diversion device (FDD)**. The FDD assumes a forward-flow position if the milk passes the recorder-controller at the preset cut-in temperature (>72° C). The FDD remains in normal position which is in diverted-flow if milk has not achieved preset cut-in temperature. The improperly heated milk flows through the diverted flow line of the FDD back to the raw milk **constant level tank.** Properly heated milk flows through the forward flow part of the FDD to the pasteurized milk regenerator section where it gives up heat to the raw product and in turn is cooled to approximately 32° C - 9° C.

The warm milk passes through the cooling section where it is cooled to 4° C or below by coolant on the opposite sides of the thin, stainless steel plates. The cold, pasteurized milk passes through a **vacuum breaker** at least 12 inches above the highest raw milk in the HTST system then on to a storage tank filler for packaging.

Holding Time

When fluids move through a pipe, either of two distinct types of flow can be observed. The first is known as **turbulent flow** which occurs at high velocity and in which eddies are present moving in all directions and at all angles to the normal line of flow. The second type is streamline, or **laminar flow** which occurs at low velocities and shows no eddy currents. The *Reynolds number*, is used to predict whether laminar or turbulent flow will exist in a pipe:

Re < 2100 laminar

Re > 4000 fully developed turbulent flow

There is an impact of these flow patterns on holding time calculations and the assessment of proper holding tube lengths.

The holding time is determined by timing the interval for an added trace substance (salt) to pass through the holder. The time interval of the fastest particle of milk is desired. Thus the results found with water are converted to the milk flow time by formulation since a pump may not deliver the same amount of milk as it does water.

Pressure Differential

For continuous pasteurizing, it is important to maintain a higher pressure on the pasteurized side of the heat exchanger. By keeping the pasteurized milk at least 1 psi higher than raw milk in regenerator, it prevents contamination of pasteurized milk with raw milk in event that a pin-hole leak develops in thin stainless steel plates. This **pressure differential** is maintained using a timing pump in simple systems, and differential pressure controllers and back pressure flow regulators at the chilled pasteurization outlet in more complex systems. The position of the timing pump is crucial so that there is suction on the raw regenerator side and pushes milk under pressure through pasteurized regenerator. There are several other factors involved in maintaining the pressure differential:

- The balance tank overflow level must be less than the level of lowest milk passage in the regenerator
- Properly installed booster pump is all that is permitted between balance tank and raw regenerator
- No pump after pasteurized milk outlet to vacuum breaker
- There must be greater than a 12 inch vertical rise to the vacuum breaker
- The raw regenerator drains freely to balance tank at shut-down

Basic Component Equipment of HTST Pasteurizer

Balance Tank

The balance, or constant level tank provides a constant supply of milk. It is equipped with a **float valve assembly** which controls the liquid level nearly constant ensuring uniform head pressure on the product leaving the tank. The overflow level must always be below the level of lowest milk passage in regenerator. It, therefore, helps to maintain a higher pressure on the pasteurized side of the heat exchanger. The balance tank also prevents air from entering the pasteurizer by placing the top of the outlet pipe lower than the lowest point in the tank and creating downward slopes of at least 2%. The balance tank provides a means for recirculation of diverted or pasteurized milk.

Regenerator

Heating and cooling energy can be saved by using a regenerator which utilizes the heat content of the pasteurized milk to warm the incoming cold milk. Its efficiency may be calculated as follows:

% regeneration = temp. increase due to regenerator/total temp. increase

For example: Cold milk entering system at 4° C, after regeneration at 65° C, and final temperature of 72° C would have an 89.7% regeneration:

$$\frac{65 - 4}{72 - 4} = 89.7$$

Timing pump

The timing pump draws product through the raw regenerator and pushes milk under pressure through pasteurized regenerator. It governs the rate of flow through the holding tube. It must be a **positive displacement** pump equipped with variable speed drive that can be legally sealed at the maximum rate to give minimum holding time in holding tubes. It also must be interwired so it only operates when FDD is fully forward or fully diverted, and must be "fail-safe". *A centrifigal pump with magnetic flow meter and controller may also be used (see below).*

Holding tube

Must slope upwards 1/4"/ft. in direction of flow to eliminate air entrapment so nothing flows faster at air pocket restrictions.

Indicating thermometer

The indicating thermometer is considered the most accurate temperature measurement. It is the official temperature to which the **safety thermal limit recorder**

(STLR) is adjusted. The probe should sit as close as possible to STLR probe and be located not greater than 18 inches upstream of the flow diversion device.

Recorder-controller (STLR)

The STLR records the temperature of the milk and the time of day. It monitors, controls and records the position of the flow diversion device (FDD) and supplies power to the FDD during forward flow. There are both **pneumatic** and **electronic** types of controllers. The operator is responsible for recording the date, shift, equipment, ID, product and amount, indicating thermometer temperature, cleansing cycles, cut in and cut out temperatures, any connects for unusual circumstances, and his/her signature.

Flow Diversion Device (FDD)

Also called the flow diversion valve (FDV), it is located at the downstream end of the upward sloping holding tube. It is essentially a 3-way valve, which, at temperatures greater than 72° C,opens to **forward flow**. This step requires power. At temperatures less than 72° C, the valve recloses to the normal position and diverts the milk back to the balance tank. It is important to note that the FDD operates on the measured temperature, not time, at the end of the holding period.

Vacuum Breaker

At the pasteurized product discharge is a vacuum breaker which breaks to atmospheric pressure. It must be located greater than 12 inches above the highest point of raw product in system. It ensures that nothing downstream is creating suction on the pasteurized side.

Auxiliary Equipment

Booster Pump

It is centrifugal "stuffing" pump which supplies raw milk to the raw regenerator for the balance tank. It must be used in conjunction with pressure differential controlling device and shall operate only when timing pump is operating, proper pressures are achieved in regenerator, and system is in forward flow.

Homogenizer

The homogenizer may be used as timing pump. It is a positive pressure pump; if not, then it cannot supplement flow. Free circulation from outlet to inlet is required and the speed of the homogenizer must be greater than the rate of flow of the timing pump.

Magnetic flow meter and centrifugal pump arrangements

Magnetic flow meters can be used to measure the flow rate. It is essentially a short piece of tubing (approximately 25 cm long) surrounded by a housing, inside of which are located coils that generate a magnetic field. When milk passes through the magnetic field, it causes a voltage to be induced, and the generated signal is directly proportional to velcoity. Application of the magnetic flow meter in the dairy industry has centered around its replacing the positive displacement timing pump as the metering device in HTST pasteurizing systems, where with certain products the timing pump rotors reportedly wear out in a relatvely short period of time. In operation, the electrical signal is sent by the magnetic flow meter to the flow controller, which determines what the actual flow is compared to the flow rate set by the operator. Since the magnetic flow meter continuously senses flow rate, it will signal the electronic controller if the actual flow exceeds the set flow rate for any reason. If the flow rate is exceeded for any reason, the flow diversion device is put into diverted flow. A significant difference from the normal HTST system (with timing pump) comes into focus at this point. This system can be operated at a flow rate greater than (residence time less than) the legal limit. However, it will be in diverted flow and never in forward flow.

Another magnetic flow meter based system with an AC variable frequency motor control drive on a centrifugal pump is also possible in lieu of a positive displacement metering pump on a HTST pasteurizer.This system does not use a control valve but rather the signal from the magnetic flow meter is transmitted to the AC variable frequency control to vary the speed of the centrifugal pump. The pump, then controls the flow rate of product through the system and its holding time in the holding tube.

Cooling of milk in a pipe heat exchanger

Milk is flowing into a pipe cooler and passes through a tube of 2.5 cm internal diameter at a rate of 0.4 kg/s. Its initial temperature is 49°C and it is wished to cool it to 18°C using a stirred bath of constant 10°C water round the pipe. What length of pipe would be required? Assume an overall coefficient of heat transfer from the bath to the milk of 900 J/m^2 s °C, and that the specific heat of milk is 3890 J/kg °C.

Now

$$q = mc_p(T_1 - T_2)$$

$$= 0.4 \times 3890 \times (49 - 18)$$

$$= 48,240 \text{ J/s}$$

Also $q = UA\Delta T_m$

$$\Delta T_m = [(49 - 10) - (18 - 10)] / \ln[(49 - 10)1(18 - 10)]$$

$$= 19.6°C.$$

Therefore $48,240 = 900 \times A \times 19.6$

$$A = 2.73 \text{ m}^2$$

but $A = \pi DL$

where L is the length of pipe of diameter D

Now $D = 0.025$ m.

$L = 2.73/(\pi \text{ x } 0.025)$

= <u>34.8 m</u>

1. A stream of milk is being cooled by water in a counter flow heat exchanger. If the milk flowing at a rate of 2 kg/s, is to be cooled from 50°C to 10°C, estimate the rate of flow of the water if it is found to rise 22°C in temperature. Calculate the log mean temperature difference across the heat exchanger, if the water enters the exchanger at 5 °C.

$\Delta T_m = [(50 - 27) - (10 - 5)] / \ln[(50 - 27)/(10 - 7)]$

= 11.79°C.

[11.8 °C]

2. A flow of 9.2 kg/s of milk is to be heated from 65°C to 150°C in a heat exchanger, using 16.7 kg/s of water entering at 95°C. If the overall heat-transfer coefficient is 1300 J/m^2 s^1 °C^1, calculate thearea of heat exchanger required if the flows are (a) parallel and (b) counter flow.

[(a) 53 m^2 ;(b) 34 m^2]

4. A counter flow regenerative heat exchanger is to be incorporated into a pasteurization plant for milk, with a heat-exchange area of 23 m^2 and an estimated overall heat-transfer coefficient of 950 J/m^2 s^1 °C^1. Regenerative flow implies that the milk passes from the heat exchanger through further heating and processing and then proceeds back through the same heat exchanger so that the outgoing hot stream transfers heat to the incoming cold stream. Calculate the temperature at which the incoming colder milk leaves the exchanger if it enters at 10°C and if the hot milk enters the exchanger at 72°C.

[Milk, originally colder, leaves the exchanger at 55.7 °C]