Lesson-17

Pasteurization: Batch, Flash and Continuous (HTST) Pasteurizers

17.1. INTRODUCTION

The process of Pasteurization involves heating milk to a certain temperature, holding at that temperature for certain period of time and then immediately cooling to below 4 °C. This is done most commonly in two methods i.e. 1) Low Temperature and Longer Time 2) High Temperature Short Time. The former method is used in most of the Batch processes and involves a multipurpose vat. The later method is used with Plate type of heat exchanger.

17. 2. BATCH PROCESS

The Batch processes are suitable for small capacity. Batch process involves heating to 63°C and holding at that temperature for 30 minutes. For this process, multipurpose vat is most suitable, and its construction is shown in the figure below.

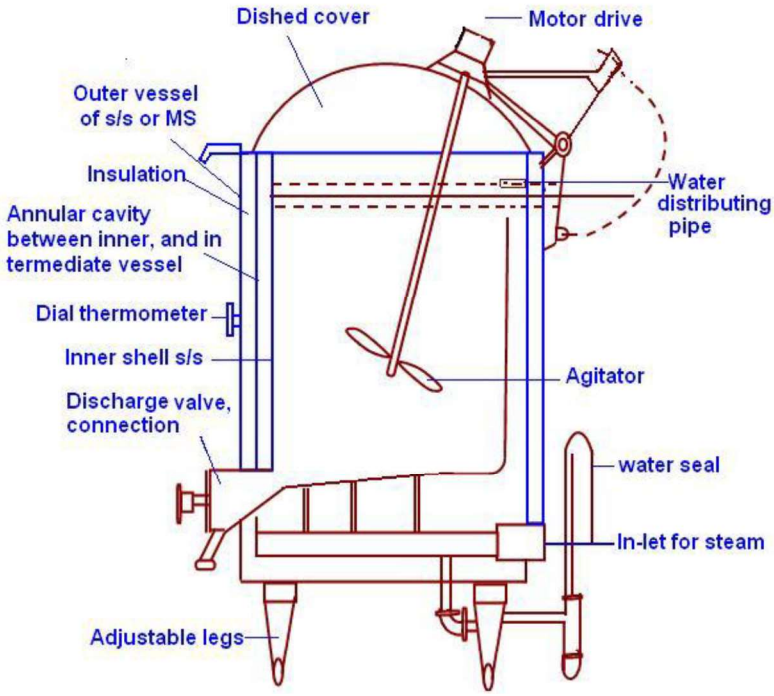


Fig.17.1 Batch pasteurizer

The Multipurpose vat used for Batch pasteurization is a jacketed and insulated tank. It is a cylindrical vessel with double jacket. The tank is heated by circulating hot water or steam in the inner jacked. Slow speed agitation provides uniform heating through the wall. The milk is slowly heated and after reaching the required temperature, is held at that temperature for 30 minutes. Then it is cooled to below 4 °C. The bringing up time and cooling time are not accounted for the pasteurization time.

The time taken for heating and cooling is given as:

$$t_h = \frac{m.c}{A.U} \ln \frac{T_s - T_o}{T_s - T_m}$$

$$t_c = \frac{m.c}{A.U} \ln \frac{T_o - T_{cw}}{T_m - T_{cw}}$$

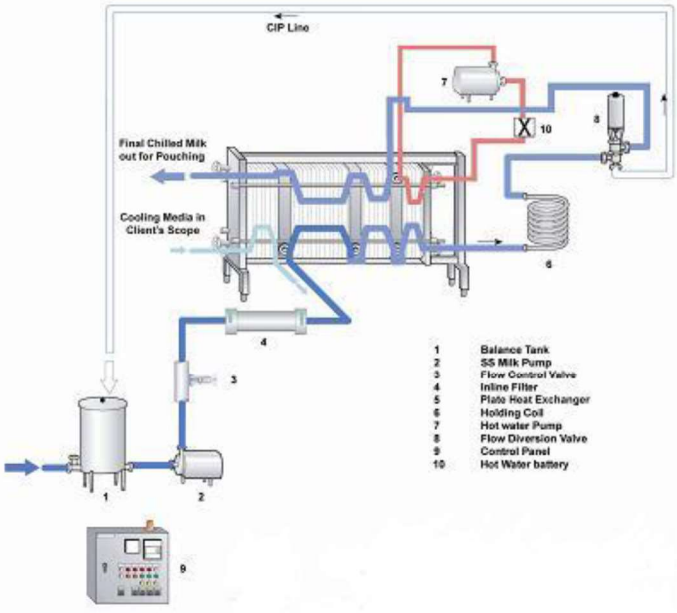
where, t_h, t_c = Time taken for heating or cooling respectively

m = mass of milk
c = Specific heat of milk
A = Area of heat transfer
U = Overall heat transfer co-efficient
T_o = Initial temperature of milk
T_m = Final temperature of milk
T_s = Hot fluid temperature
T_{CW} = Chilled water temperature

17.3 HTST PASTEURIZER

High Temperature Short Time Pasteurizers (HTST), have proved to be the workhorses of processing in Dairy Industry. For milk the time temperature combination used is 71.5°C for 16 seconds, and then immediately cooled to below 4°C. The heat exchanger that can achieve this duty is the Plate Heat Exchanger(PHE).

The Plate heat exchanger for HTST pasteurizer is made up of groups of plates that are used for heating the milk to the high temperature required, holding at that temperature for the required period and cooling it. The schematic diagram of the pasteurizer is shown below,



17.2 Schematic diagram of pasteurizer
Adopted from JMD Sonic Engg Ltd manual

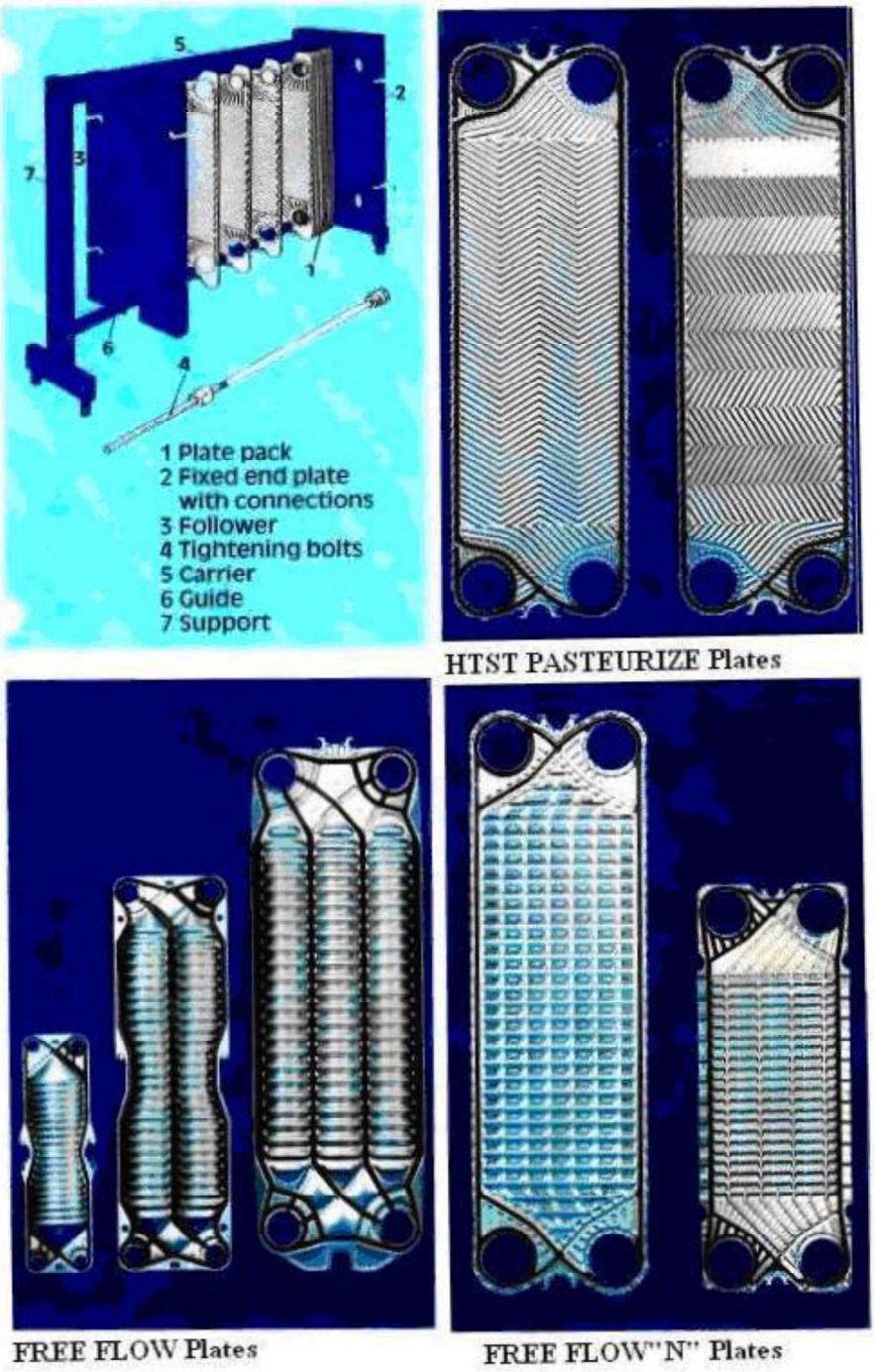


Fig.17.3 HTST pasteurizer

(Adapted from manual of GEA Ahlborn Gmbh &co)

It consists of heat exchange plates, frame for hanging the same. End plates along with tightening bolts are provided to keep these plates pressed together, with gaskets in between. The groups of plates are provided in between with connecting plates which make it possible to introduce or exit milk after each of the processes, like Regeneration, heating, holding, and chilling. The plates are made of die-pressed sheet of stainless steel with a corrugated surface, to give turbulence to the flow and thereby achieve maximum heat transmission, even with very low temperature gradient between the heat exchange fluids.

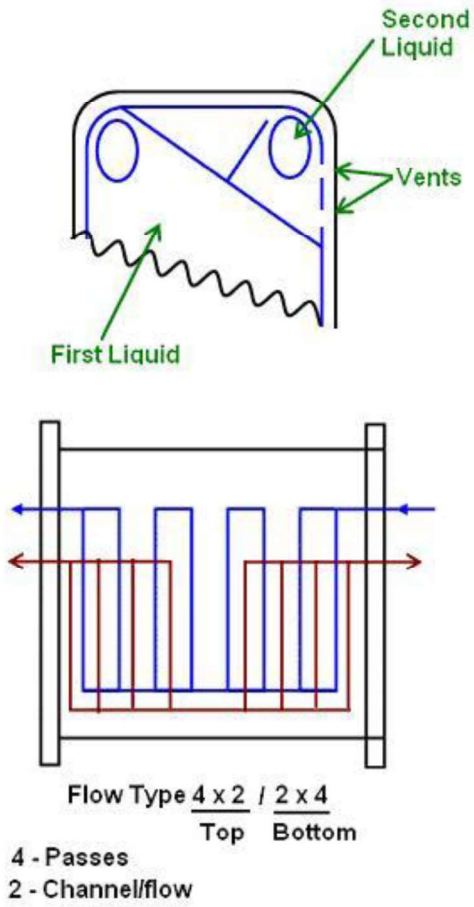


Fig.17.4 PHE

In the PHE the process fluid or service fluid can be passed in many ways through channels connected in parallel or in series, in the same direction or in opposite directions to achieve maximum heat transfer. The thickness of plates is about 0.5 to 1.25mm. The gap between plates is about 3 to 6 mm wide, depending on the design and products handled. The types of heat transfer plates, and their gasket arrangement is shown in fig 17.2.

The arrangement of gaskets makes the flow in a particular direction for the milk and hot or cold water. The plates are of different sizes and configuration of corrugations, and may cater to the needs of wide variety of fluid processing. The manufacturer supplies the plate connection diagram to meet the specific heat exchange duty, which shows the sequence of the plates, arrangement of gaskets, and location of the connections. The nomenclature for the arrangement is explained as below:

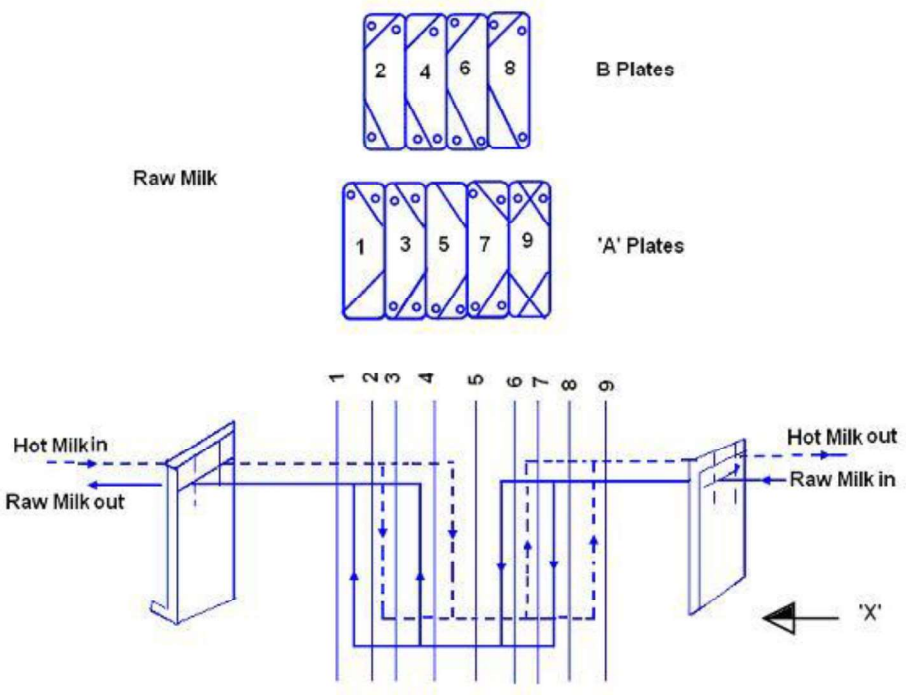


Fig.17.5 Plate connection diagram

In the connection diagram, the flows of liquid are shown. The flows drawn on the left side are running along A- plates and the flow on the right side over B-plates. The A-plates have gasket on the right hand side and B-plates have it on the left. The two types are arranged alternately in the PHE, so the process fluid and service fluid flow in the alternate channels. The plates are usually numbered, so as to make it easier in assembling, and relate to the connection diagram. Any damaged plate can be replaced by an identical spare plate.

The milk from storage tank enters the HTST pasteurizer through a Float Balance Tank, which has a float to control the inflow of milk and maintains a constant level of milk in it. The milk is then pumped from here through a flow control valve, which may be ball valve type. Milk enters the Regeneration section where the incoming raw milk is partly heated by the returning hot milk from holding section. As the heat exchange is beneficial by reducing the load on steam and chilled water requirement, the number of plates is more in this section.

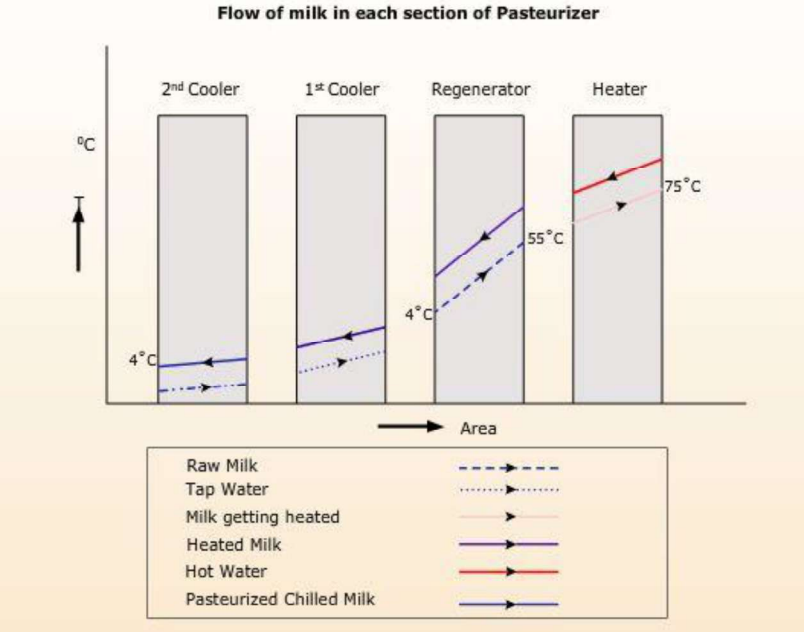
The Regeneration section may be divided in two segments, so that after the first segment, when the milk is about 40°C, milk is lead to duplex filters, which has two sets of vessels with filters, to remove any extraneous material in the milk. The filters are provided with air vents, to remove air in the beginning of the process. The outgoing connection at this stage may also lead to the Cream separator if necessary, as this is the ideal temperature for the efficient cream separation. The return line then enters the second segment of Regeneration section, and the milk is lead through again a connecting plate to the heating section. The connecting plate here is meant to direct the milk flow to homogenizer if necessary.

In the heating section, the milk is heated with hot water, coming from hot-water generator, aided by a hot water pump. The hot-water generator is provided with steam supply, through a automatic steam flow control valve, which gets the signal from the hot water temperature controller of the pasteurizer controls. The flow rate ratio of milk: hot water is in between 1:2 to 1:3, depending on the manufacturer's design. The hot water supply line also has a pressure controlled, outlet for the

condensate which accumulates because of steam supply to maintain the temperature of hot water to about 85°C.

Once, the required pasteurization temperature is reached, the milk is lead to holding section, which has stainless steel pipes of sufficient length to keep the milk to the required time. The flow rate of milk has to be fixed, to meet this requirement. In some of the pasteurizer designs, this section also is of PHE type, though it is not very common.

At the end of the Holding section, the Flow Diversion Valve (FDV) is positioned, so that, the milk above the set point of pasteurization temperature only is lead to the Regeneration section again, which is called the Forward flow. If it is not, then the milk is lead to the balance tank, which is called the diverted flow. The operation of FDV is explained later, in detail.



temperature profile of milk in each section of pasteurizer 17.1

The hot milk after FDV in forward flow will enter the Regeneration section, and will give off its heat to the incoming raw milk, and then enters the Cooling section. Here, the milk is cooled to below 4°C by chilled water at 1°C, or at times brine (glycol + water) when viscous products have to be cooled. Here also, the flow rate of chilled water is 2 to 3 times that of milk. The flow rate difference has to take into consideration the pressure drop on the service fluid side, ie chilled water or hot water. The difference in flow channels and passes are shown in the diagram below:

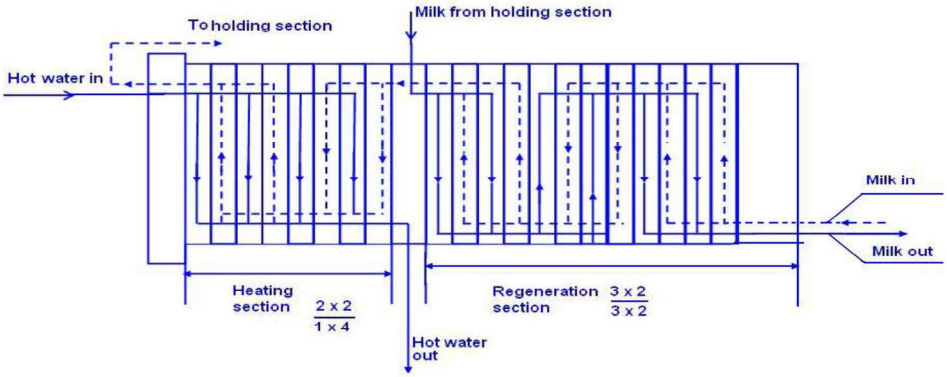
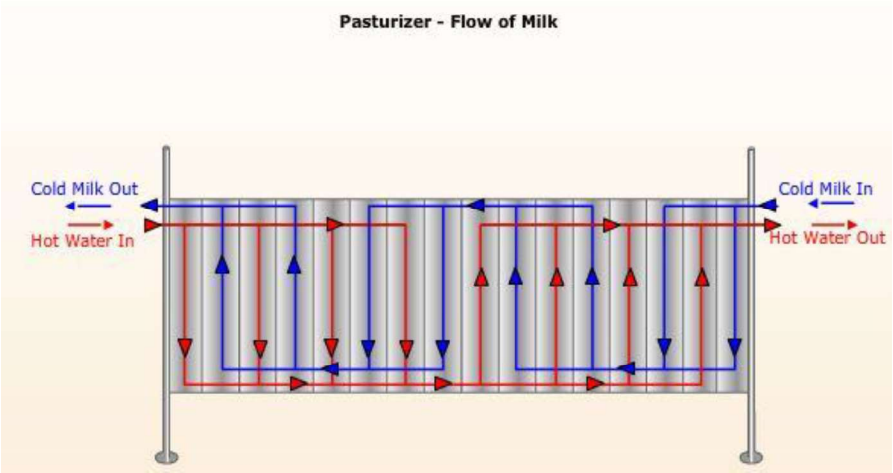


Fig.17.5 Heating and regeneration section



Pasteurizer Flow of Milk 17.2

After chilling to below 4°C, the milk is piped to Pasteurized milk storage tank.

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Lesson-18

Pasteurizer Control, Flow Diversion Valve

18.1 INTRODUCTION

Continuous operation of HTST pasteurizer depends on the monitoring of temperatures, and thereby controlling the flow of milk in diverted or forward flow condition. Further, it is a legal requirement to record the temperature and time of operation of pasteurizer in many of the countries. Most of the instrumentation is now based on digital form and are much more compact as compared to earlier versions of Pneumatic controls.

Commonly used equipment for control are:

1. Hot milk temperature indicator and controller
2. Cold milk temperature indicator
3. Hot milk and cold milk temperature recorder
4. Flow Diversion Valve
5. Visual and audio alarms

18.2 DIAGRAM OF PASTEURIZER CONTROLS

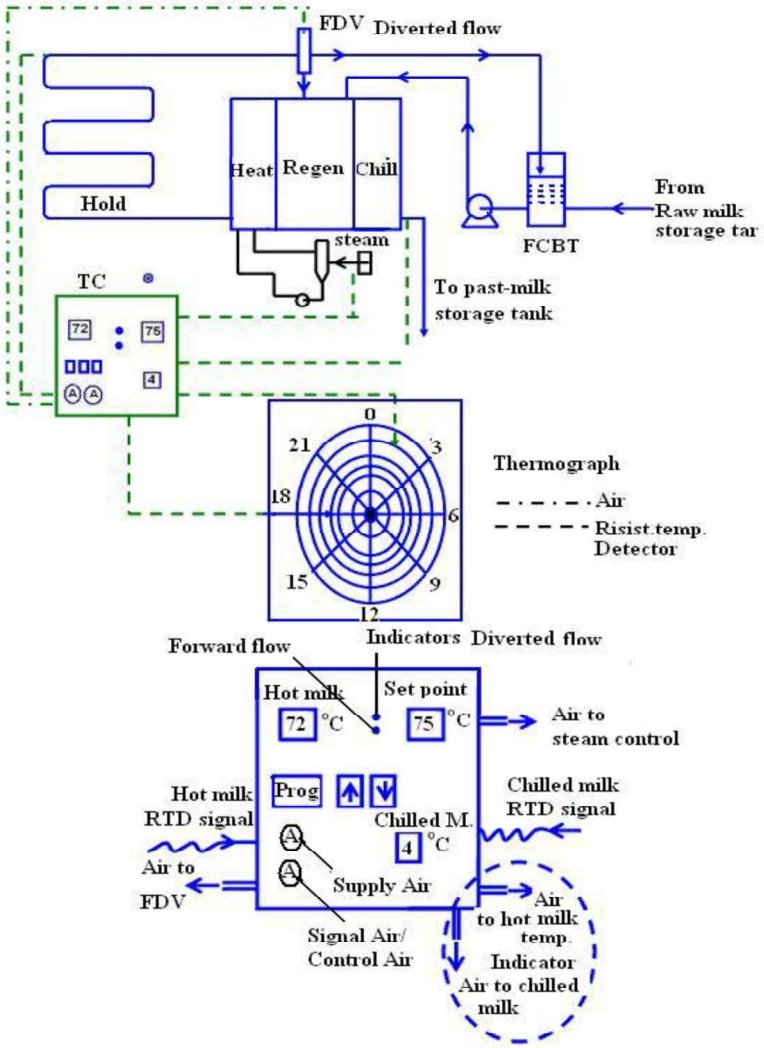

Fig.18.1 Pasteurizer controls

The temperatures of hot milk or cold milk are sensed by suitable sensors. Common among them is the Resistance Temperature Device (RTD), which sends an electrical signal, proportional to the temperature sensed. This signal is received and compared with the Set Point of temperature by the Temperature Controller. Depending on the deviation of the temperature of milk from the Set Point temperature, an error signal is sent, which will range from 4 to 20 mA. The error signal is converted into a pressure signal (of compressed air), by Electro-pneumatic Converter. This signal which is in the form of pressure will operate the final element, like Diaphragm of Steam control valve.

In addition to the control of steam supply to hot water, the signals of sensors are also received by Temperature transmitter, which in turn sends a pneumatic signal to pen drive of Thermograph. The Thermograph is a circular graph, with temperature indicated on concentric circles; the radial lines indicating the time. The graph is placed on a disc, which rotates one full circle either in 12 or 24 hours. The graph forms a legal record of the time temperature combination applied to the processing of the milk.

The controller components are very much standard, and uniform, so that they can be replaced, once their specifications are known. The motive supply air must be 6 kg/cm^2 and which is then reduced to the required pressure depending on the size of the valves to be operated. The air must pass through filter to avoid moisture and oil.

18.3 FLOW DIVERSION VALVE

The temperature sensor of hot milk also conveys signal to the Temperature controller, where, the signal is compared to the Set Point. If the temperature of milk is less than the Set Point, the electrical signal goes to the Solenoid valve, which stops the compressed air supply to FDV. The compressed air, which will be acting against the spring pressure, is now absent. The FDV valve has three openings, one for supply of milk, and two for outgoing milk. When the compressed air is acting, the FDV will be in Forward flow position, while, the absence of air, will push the valve plunger in the FDV to Diverted flow position. It must be noted here that, whenever electric power interruption is there for the plant, the FDV will be in Diverted flow position.

The signal that triggers the Diverted flow condition of FDV is also fed to the visual signal as well as to a hooter, to alert the plant personnel.

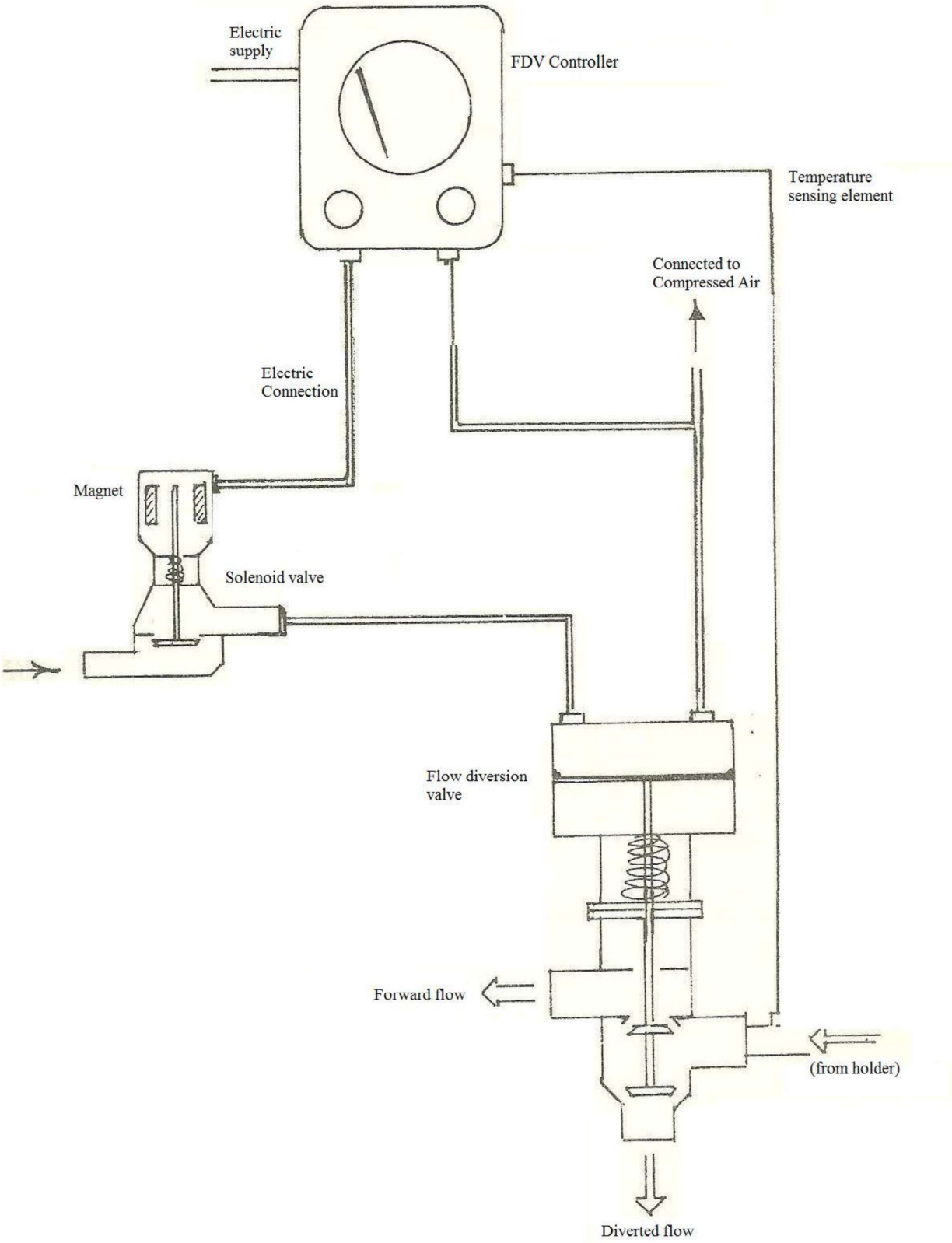

Fig.18.2 Flow Diversion Valve

Lesson-19
Care and Maintenance of Pasteurizer

19.1 INTRODUCTION

The performance of the pasteurizer is an important parameter for the dairy plant as a whole, as this is the heart of the dairy plant. Its efficiency in pasteurizing the milk with minimum of services requirement reduces the cost of operation of the plant. One of the important parameter to judge the pasteurizer efficiency is the Regeneration Efficiency.

19.2 REGENERATION IN HTST PASTEURIZER

Thermal regeneration is a technique devised to reduce service loads and thus improve energy usage. Percentage regeneration may be defined in several ways and due to these different methods; heat exchangers having identical thermal performance may have, seemingly, different regeneration efficiencies

One definition of Regeneration efficiency is "The temperature range through which the product is heated by regeneration, expressed as a percentage of the total heating range".

A simple heat exchanger is considered where a product is to be heated from 5^{0}C to 85°C by 80% regeneration and then finally in a heating section. Having heated the product to 85^{0}C it is held in holding tubes and returned to the regeneration section at 85 °C.

The total temperature heating range is 85 -5 = 80°C

The temperature range through which the product is heating by regeneration must be 80% of 80°C = 64°C.

Thus the incoming product will be raised in temperature from 5°C to 69 °C by regeneration and will be heated from 69°C to 85°C in the heating section. The heated product is then returned to the regeneration section at 85°C where it is cooled regeneratively by the cold incoming product at 5 °C. This can be depicted as follows:

$$\text{Percentage regeneration} = \frac{(69-5)}{(85-5)} \times 100 = 80\% \text{ regeneration}$$

From such a temperature profile diagram.

Considering now the heating loads involved and assuming a flow rate of Q then:

(i) Steam load in heating section = Q (85 – 69) = 16Q

(ii) Total heating load = Q (85 – 5) = 80Q

Thus the steam load expressed as a percentage of the total heating load is:

The heat load in the heating section is 20% of the total heating load. Therefore the regeneration percentage (or efficiency) of 80% truly represents 80% of the total heating load.

19.3 PREVENTIVE MAINTENANCE OF HTST PASTEURIZER

The plant should be inspected externally for leakage of all kinds. It should be monitored continuously throughout the process and any abnormalities noted be investigated and rectified. The flow rate of milk and media should be checked by measuring the time to process a known quantity of milk.

19. 3.1 Plates

1. The Pasteurizer should be CIP cleaned regularly after day's operations.
2. The plates have to be cleaned manually periodically. It should be done with nylon or fiber brush or coir. It should never be cleaned with metal wire brushes.
3. The proper tightening and dismantling procedures have to be followed. Care should be taken not to tighten beyond the mark, provided by the manufacturer. The tightening has to be done such a way that plates move parallel to each other and the measurement of length at the top of the plate pack should be same as at the bottom

19.3.2 Gaskets

Gaskets must be of nitrile rubber which can with stand up to 120 ºC. Use of aggressive acid solutions during CIP cleaning might damage the gaskets. They should be replaced as a set instead of one at a time, to prevent misalignment of plates. New gaskets should be tightened to the minimum. As gaskets get older, tightening should be increased just to avoid leakage. While replacing the old gaskets with new gaskets, the remnants of old gaskets should be carefully removed from the gasket groove. Old adhesive, grease, dirt etc. should be removed by acetone and the plate groove thoroughly cleaned and dried. The new gaskets for replacement should be slightly sand papered at the back and should be cleaned and dried. A thin coat of adhesive should be applied to the gasket groove and back of the gasket with a small brush for even distribution. While the adhesive is still sticky, the gasket should be fitted in to the gasket groove. A slight pressure on plate for some minutes will help in the fixing of the gaskets. Excess of adhesive should be removed if any still present.

19.3.3 Frame

The frame having threads and spindle should be lightly coated with grease, to help easy movement of the plates.

19.3.4 Filter

Filter cloth should be checked from time to time for any tear or worn out patches. It should be washed after dismantling. Cloth should be replaced if any damage is observed. So is the case with wire gauge filter screen protecting the filter cloth.

19.3.5 Instruments

All thermometers should be checked periodically for accuracy. All air operated instruments should be supplied with clear dry air. The air filters should be inspected periodically, cleaned or changed

when required. The components of controlling instruments should be replaced when ever damaged or functioning inaccurately. Leakages in the control instruments of steam supply should be checked, as they are susceptible for corrosion because of higher temperatures.

19.3.6 Pumps and motors

The pumps and motors should be thoroughly overhauled once in a year. The shaft seals if leaking should be replaced immediately. Motors if noisy should be checked for damaged bearings. Misalignment is one of the most common sources of pump troubles. Scales in hot water pump should be removed.

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Lesson-20
Solving Numerical

20.1 PROBLEM

Required: Milk pasteurizer, capacity 12,000 1tr/h

Inlet temperature 15^0C
Pasteurizing temperature 85^0C
Outlet temperature 4^0C
Holding time 15 sec. = 50 ltr.
Regeneration 80%
Heat transfer area per plate = 0.375 m^2
Overall heat transfer co-efficient for heating, regeneration and cooling and deep cooling are 2320, 2290, 2100 and 1800 (k.cal/m^2hr °C) respectively

Services Available :

24,000 l t r / h hot water of 90°C
18,000 l t r / h well water of 11°C
24,000 l t r / h chilled water of 1 °C
Branch to centrifuge at about 45 °C. Calculate the number of plates and pressure drop. Make suitable assumptions. For simplification of calculations, take specific heat of milk also as 1.0 k.cal / kg °C.

Solution

Assumption: Neglecting the reduction in volume.
When calculating plate requirement of pasteurizers we normally do not take into account the separation of cream in the centrifuge, which is about 10 %.

Calculation

A regeneration efficiency of 80% means that 80 % of the heat is regained in the regenerating section.
In this case 80 (85 – 15) = 56°C rise in temperature
100
Milk at 15 °C inlet temperature is raised by 56°C in regeneration section, and milk outlet temperature will then be 15 + 56 = 71°C
The milk pasteurized at 85°C will be cooled down by the raw milk by 56°C and the milk entering the cooling section will be 85 – 56 = 29°C
So the complete temperature course will be:
15 – 71 – 85 – 29 – 15 - 4°C. (Assuming a minimum of 4°C temperature gradient between milk and well water)

Pasteurizing Section:
Heating by 24,000 l t r / h water of 90 °C
The LMTD calculations are given below: