DAIRY ENGINEERING

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Course Developers

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Dairy Engineering: 3 (2+0+2)

Sl No	Particulars
Module 1: Sanitary pipes, fittings and Milk handling equipment	
1.1	Materials and sanitary features of the dairy equipment
1.2	Sanitary pipes and fittings, standard glass piping, plastic tubing, fittings and gaskets
1.3	Installation, care and maintenance of pipes & fittings
1.4	Milk storage tanks, Silos, Road Tankers, Rail Tankers
Module 2: Bottle & Cans Washing and CIP cleaning equipment	
2.1	Description, working and maintenance of can washers straight - through can washer
2.2	Bottle washers. Factors affecting washing operations, power requirements of can and bottle washers
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3.2	Principals involved in filtration, Types, rates of filtration, pressure drop calculations
3.3	Gravity settling, Sedimentation, Principles of centrifugal separation
3.4	Different types of centrifuges. Application in Dairy Industry, clarifiers, tri processors, cream separator
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Module 8: Mixing and agitation equipment	
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Lesson-1

Materials and Sanitary Features of the Dairy Equipment

1.0 INTRODUCTION

Pipes, fittings, valves and other milk handling equipment in a Dairy plant play an important role in the maintenance of the quality of the product as well as cost of the plant installation. Some features like the pressure drop, cost optimizations etc are common to the general principles of hydraulics. But there are also some important aspects of the design which are specific to food and dairy industry, because of the hygiene considerations. The special features of that are applicable to the dairy industry are listed below:

1.1 SANITARY FEATURES

- Equipment is easily accessible & readily cleanable either in an assembled position or when disassembled. Removable parts are readily demountable.
- All product contact surfaces are self-draining.
- When assembled, no pipe or fitting threads are exposed to the product. (Eg. Milk storage tank legs, pasteurizer frame etc. Further, the easily cleanable threads like SMS type are preferred over Acme threads.
- All permanent joints are welded and grounded to smooth finish.
- Interior surfaces are smooth and even, especially at joints, thus eliminating crevices and projections.
- Gaskets are eliminated wherever possible. If used, they should be smooth, non-toxic and product resistant. They should not contribute to off flavors in the product.
- Possibility of processing under vacuum, which make the equipment susceptible for external contamination.

o Effective velocity of flow and optimum agitation to prevent surface film formation.

o Pre-heating the product with external devices.

o Providing large vapour space where water to be removed.

o Rapid removal of water vapour.

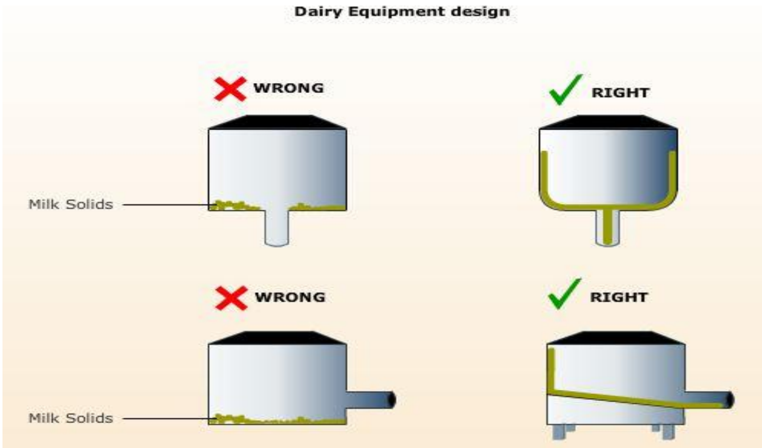
o Avoiding air leaks.

1.2 SPECIFIC REQUIREMENTS OF DAIRY PRODUCTS

Most of the Dairy Equipment:

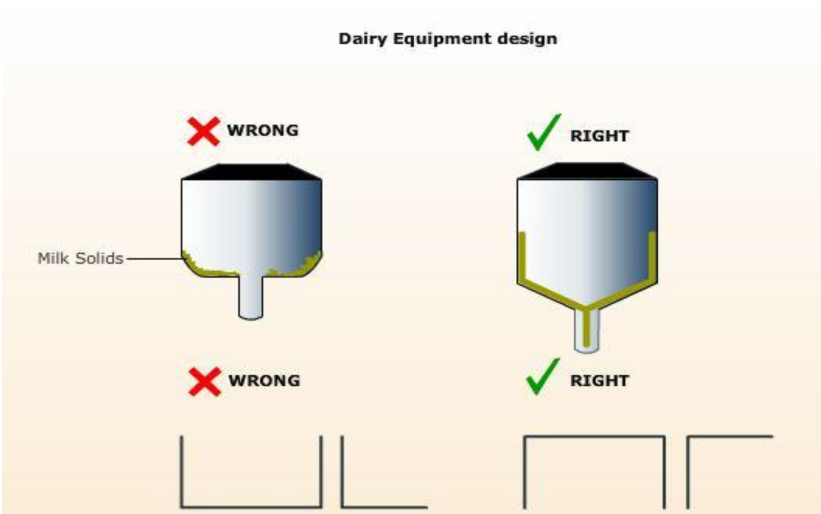
- Are worked continuously throughout the year hence more wear and tear
- Have wide temperature variations during operations
- Have to with stand effects of water, steam, brine, refrigerants cleaning and sanitizing solutions.
- Are disassembled very frequently and hence exposed to damage of components
- Sanitary conditions are of paramount importance in dairy and Food industry. Hence to achieve the above requirements, the equipments must be designed and materials chosen suitably.
- Dust proof, corrosion resistant external surface
- Smooth polished internal surface
- Minimum clearance of 100 mm between equipment base and floor with ball foot
- Absence of sharp corners and edges
- Elimination of vertical dead spaces or passages and capped tees
- Proper slope towards drain points
- Properly ground and polished welds
- Raised edge opening to prevent surface drainage in to container.
- Sanitary type inlet and outlet fittings.

The following diagrams give an indication of the requirements of dairy industry that may differ from general principles of equipment design.

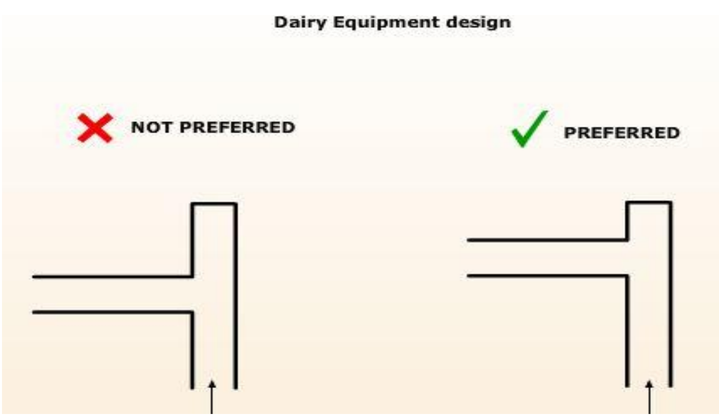


Animation Dairy Equipment Design 1

Even the support and other attachments that are not coming directly in contact with the milk and milk products should be designed to avoid accumulation of dust and soil.



Animation Dairy Equipment Design 2



Animation Dairy Equipment Design 3

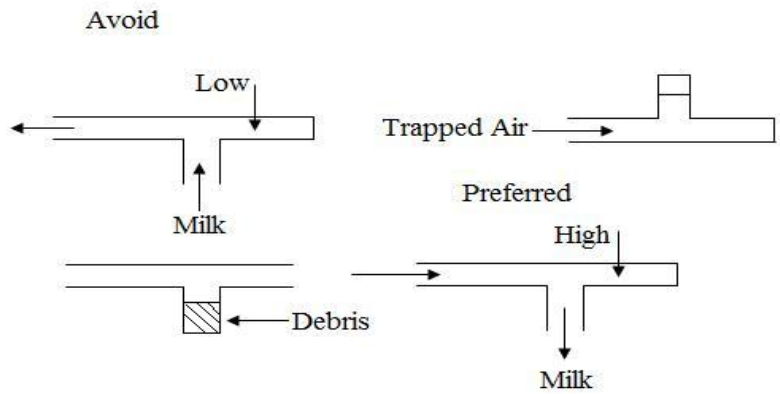


Fig.1.1 Turbulance

Table 1.1Characteristic of different alloys of Stainless Steel:

Chromium Types	Martensitic	Hardenable (403,410,414,416,416Se,420,431,440 series)	400 series contain large amounts of chromium and little or no nickel
	Ferritic	Non-hardenable (405,430,430F,430Se,442,446)	
Chromium-Nickel Types	Austenitic	Non-hardenable, except by cold working (201,202,301,302,302B,303,303Se,304,304L,305,308,309,309S,310,310S,314,316,316L,317,321,347,348)	300 series contain large amounts of chromium and nickel
	Semi-austenitic	Strengthened by ageing or precipitation-hardening	
		Precipitation-hardening	
	Martensitic	Precipitation hardening	

1.3 MATERIALS COMMONLY USED IN DAIRY INDUSTRY

Materials used for the construction of dairy equipment also play an important role in the sanitary design and maintenance of hygiene. They are broadly divided into those parts of equipment that come in contact with the milk and milk products and those which do not come in contact and only act as structural components (supports, insulation and protective coverings) and other service equipment. The commonly used materials are: Iron, Steel,

Stainless steel, Aluminum, Insulation materials, Plastics, Glass etc.

1.3.1 Iron and steel

These are mostly used in the structures that are not coming in contact with milk. Iron added with Carbon is Steel. Depending on the percentage of carbon present, the steel is further divided in to Mild steel, Low carbon steel etc.

Further, Steel with Chromium content more than 10.5% is called Stainless Steel (SS). It is

Table 1.2 Materials used as structural components

Cast Iron	Difficult to weld, brittle in nature Cannot be forged	Heavy equipment beds Main castings of engines Gear box cases	2 to 4.5%
Wrought Iron	Easily welded, tough, ductile, malleable	Chains, Hooks, couplings, rivets, shock loading parts	0.06 to 0.08%
Mild Steel	Highly ductile, malleable, tough, strong, easily welded, possesses magnetic properties, can be cast & forged	Structural elements, building equipment, conveyor frames	0.1 to 0.25%

Particularly used where corrosion is minimum, and where the material is coming in contact with milk and milk products. Different proportions of Nickel are also added.

The Stainless Steels are broadly divided into Martensitic, Ferritic and Austenitic. They are classified into different grades. Of particular importance is the AISI 304 AND AISI 316 grade of stainless steels. AISI 304 is used for construction of pipes, fittings, silos, tanks and vessels. AISI 316 is used for fabrication of plates of plate heat exchangers, CIP tanks, evaporator tubes which needs higher corrosion resistance.

Table 1.3 Chemical composition of AISI 304 and AISI 316 SS

Component	AISI 304 (% max.)	AISI 316 (% max.)	Remarks
Carbon	0.08	0.10	0.04% for Low carbon grades
Manganese	2.0	2.0	Improves wear resistance
Phosphorous	0.04	0.04	
Sulphur	0.03	0.03	Improves machining properties
Silicon	1.0	1.0	Improves resistance to heat & chemicals
Chromium	18 – 20	16 – 18	Harden ability
Nickel	8 – 10	10 – 14	Improves toughness & corrosion resistance
Molybdenum	---	2 – 3%	Increases resistance to corrosion

Aluminum is mostly used for making milk cans, but the trend now is to shift to stainless steel for better hygiene. It is light in weight, insoluble in milk, does not impart any flavor and can be spun into various shapes. But it is porous in nature, making it difficult to weld. Resistance to abrasion is poor, and gives gray stain. The surface is generally given Anodizing treatment in which parts to be treated is made anode and dipped in electrolytic bath (of sulphuric, chromic or oxalic acid) to form a colour less and stable film on the surface.

Plastics have wide range of applications, and are broadly classified into Thermoplastics and Thermosetting plastics. Thermoplastics are manufactured by process called addition polymerization. They are liquids at higher temperature and crystallize readily at low temperatures because of simpler molecular structure. They generally show poor resistance to organic liquids. They are generally straight chain polymers, and have no cross links.

The common items that are used in dairy industry of the above category are Poly Tetra Flouro Ethylene (PTFE), Poly Ethylene (HDPE & LDPE), Poly Venyle Chloride (PVC), Acrylonitrile butadiene styrene (ABS), Cellulose acetate butyrate (CAB) etc. PTFE is used for pump shaft seal.

Thermostetting plastics on the other hand have cross links in their structure, and undergo permanent changes when raised to higher temperatures. Hence, they cannot be recycled. The common items that are used in dairy industry are Fibre Reinforced Plastic (FRP) storage tanks, Epoxy glass, polyester reinforced glass, plastic gears, Phenol formaldehyde, and Elastomers like Polybutadiene and Polychloroprene (Neoprene).

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Lesson-2

Sanitary Pipes and Fittings, Glass Piping, Plastic Tubing, Fittings and Gaskets

2.1 INTRODUCTION

Design and selection of pipes for handling milk and fluid milk products has to be done with same care and attention to sanitary features as is done for the dairy equipment, where the surfaces are coming in contact with the product. The type of material has to be Stainless Steel of grade 304 or 316. As milk flows with high velocity hence, the corrosion due to erosion as well as pitting has to be factored in while designing. In some of the instances, instrumentation for measuring the properties of the flowing fluid will be required, and need special type of pipe fittings. Care also has to be taken regarding the surface finish, both inside and outside of the pipe lines. In general, the following aspects are important in design of sanitary type of pipes.

2.2 GENERAL POINTS TO BE CONSIDERED WHILE DESIGNING AND LAYOUT OF SANITARY PIPE LINES ARE GIVEN BELOW

1. Pipes should be seamless and preferably cold drawn
2. They should softened, descaled and pickled
3. Polished internally and externally
4. Clean, smooth and free from surface defects, straight and free from longitudinal grooving both inside and outside
5. Material for fittings to be same as that of pipe
6. The condensate from the surface of milk pipe lines should not be allowed to fall on places where unhygienic conditions or milk contamination is likely to occur
7. The capacity of the pipe line should be designed to allow the flow within the limits, without much pressures loss

Table 2.1 Outer diameter, thickness and carrying capacities of sanitary pipes

O.D	Thickness	Approx. Capacity (Kg/h)
25.4 mm	1.25 mm	< 2000
38.1 mm	1.25 mm	<7200
50.8 mm	1.25 mm	7200 – 15000
63.5 mm	1.5 mm	15000 – 22700
76.2 mm	1.5 mm	22700 – 36000

Next larger size for heavy liquids, like cream, Ice cream mix.

- Similarly, next larger size if the flow is by gravity
- Criteria for selection is flow velocity and cost

2.2.1 General piping design considerations are also relevant here

1. Piping lengths kept to a minimum
2. Piping layout should not be a hazard or restriction to operator
3. All valves and instruments located so as to be both easily operable and maintainable
4. Pipe layout should be conducive to adequate individual support, and group supports wherever possible.
5. Piping system designed to be drainable with few if any pockets, and provided with adequate drain valves.

2.3 GLASS PIPING

It is generally used where the visibility of the product is important. Due to its brittleness and fragile nature, it has to be again protected by external piping of suitable metal. It is also used in the level gauges, sight and light glasses for milk storage tanks. In certain situations, however, it can be used as an inner liner for the storage tanks or pipelines. The glass should not be of splinter type.

2.4 PLASTIC TUBING

Plastics, in addition to being used as packing material, are also extensively used in manufacture of some of the pipes and flexible tubing. Plastic pipes and tubes have to be of food grade, and should not impart off flavours. Its smoother surface gives lower resistance to the fluid flow, and is light in weight. It should have higher resistance to detergents.

However, it has lower resistance to temperature, and the maximum continuous exposures to heat for various plastics are given below:

Table 2.2 Temperature resistance of various plastic materials for tubing

1	PVC	50°C
2	Polystyrene	65°C
3	Polyethene (linear)	60- 90°C
4	Polypropylene	70 - 100°C
5	Polytetrafluoroethylene	325 - 330°C

While it is less easily wetted by aqueous solutions, it is more easily wetted by fats. This can cause fat to penetrate into the surface. It can be removed by process of extraction and if it is not removed, a rancid odour develops on the surface of the plastic material due to fat decomposition. The consequences can be discolouration, crevice formation, irreversible distortions of shape, bacterial contamination in fine crevices, taints in milk due to released plasticizer.

2.5 GASKETS

The role of Gaskets is to prevent leakage between two metal surfaces. In addition to being flexible, the dairy industry demands them to be fat-resistant, resistant to detergents and sanitizers. They will have to resist, certain degree of heat too in applications like Pasteurizer gaskets. The various applications in dairy industry are SS pipe fittings, manhole gaskets, milk pumps, cream separators, homogenizers, diaphragm valves etc.

The following are the different types commonly used in dairy and their heat tolerance limits:

- Nitrile rubber (NBR): 130 °C
- Butyl rubber(Butyl): 140^{0}C
- Ethelene propelene (EPDM): 165 °C
- Silicon rubber:175^{0}C
- Viton:180^{0}C

To keep the gaskets in place, various methods are used. Glues, gasket cements, mechanical methods are more commonly used. In case of glues and gasket cements, special procedure is needed to fix the gaskets in place. This some times limits their applications for high temperatures.

The gaskets have to be stored in cool and dry place. It should not be exposed to ozone like in electric arc welding applications.

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Lesson-3

Installation, Care and Maintenance of Pipes & Fittings

3.1 INTRODUCTION

Pipelines in dairy industry are of two types, i.e. those which are coming in contact with the milk and milk products, and those which are mainly of service pipe lines. Though we will be considering here only those which are coming in contact with milk and milk products, some of the basic principles will be same.

3.2 INSTALLATION

Well-designed piping systems require a plant layout that provides adequate space around equipment to ensure that the piping and associated valves are arranged in an operable and maintainable fashion, with minimal intrusion into operators' space. Such conditions should be a part of the building's design from its conception. A systematic approach to layout produces a workable end result. The end result should reflect due consideration for the construction, operation, and maintenance factors for every piece of equipment involved.

The first step in installation is to draw the Piping and Instrument diagram (PID) showing the arrangement of the process equipment, piping, instruments, valves and other fittings. It should include:

1. All process equipment, identified by an equipment number. This should be drawn roughly in proportion and the location of the equipment.
2. All pipes, identified by a line number. The pipe size and material should be shown.
3. All valves control and block valves, with an identification number and size should be shown.
4. Ancillary fittings that are part of the piping system, such as inline strainers, steam traps, with an identification number.
5. Pumps, identified by a suitable code number
6. All control loops and instruments, with an identification number.

The Piping and instrument diagram will resemble the process flow sheet. When the diagram is laid out, it is necessary to show the relative elevation of the process connections to the equipment where they affect the process operation; for example, the Net Positive Suction Head (NPSH) of pumps, barometric legs, siphons. Full details of pipe layout are usually shown in a different drawing, known as Piping Isometric Drawing. In all the drawings, standard symbols for the valves, instrument lines etc. should be used. Sloping of lines should ensure complete draining. Sloping of lines of 0.3 to 0.5% is sufficient for post cleaning and gravity flow of low-viscosity fluids.

3.2.1 Sizing of Pipe Lines

Over sizing pipelines increases installation costs, and under sizing increases pressure drop. It is important to know the distinction between pipe and tube here. For tubes, inside diameters vary according to specified schedule or wall thickness; whereas pipes are labeled by their nominal bore, sanitary tubing is labeled by its outside diameter, and has a smaller bore. For example, a 2" stainless steel pipe has an outside diameter of 2.375", and if made of schedule 10S has a resultant bore of 2.157". A 2" sanitary tube has an outside diameter of 2.000" and a 0.065" wall thickness, for a resultant bore of only 1.870". This reduction in available diameter, if overlooked, could be crucial in flow calculations.

The size of the suction pipe of pump should never be smaller than that of the discharge pipe; usually it is one size larger.

3.2.2 Connections

Commonly used methods are flanged connections, welded fittings, and threaded couplings. The important aspect is that these should not only be effective, but also should be easy for cleaning and sterilization. It should not have any cavities that cannot be cleaned. The pockets caused by branches in pipelines should not be more than 6 times the diameter. Preferences are being shown for the welding of pipes and fittings utilizing inert gas to reduce the number of pipe unions so as to minimize potential of crevice areas, which are difficult to clean.

As far as feasible, valves, filters, excessive fittings, horizontal bends, elbows and tee joints should be avoided close to the suction side of the pump.

3.2.3 Valves

Most of the valves installed in plants are used for isolation service, usually referred to as Block valves, to prevent unwanted flow past a given point in a piped system. The remainder are used to control either rate of flow or pressure of the flowing medium, at a particular point in the system, referred to as throttling or Control Valves. The body shapes of Gate and Globe valves render them unclean-able and thus potential sources of contamination. The alternative valve involves a choice between ball, butterfly or diaphragm valves. The ball is frequently favoured because its valve stem is isolated from fluid; it has a quarter-turn operation, and is suitable for CIP cleaning.

3.2.4 Supports:

The tubing should be supported at regular intervals, near valves and to all changes in direction. Materials used for hanger components and floor stand supports should be of stainless steel to avoid external corrosion and galvanic action between dissimilar materials. Rubber insert pads may be used to isolate tubing from the support to reduce vibration. Rigid anchoring should be replaced by floating supports which avoid distortion of tubing systems due to temperature changes.

Table 3.1 Spacing for support of pipe

Size (mm)	Distance betweensupports (m)
50	2.4
75	3.4
100	4.0
125	4.5

3.3 REQUIREMENTS IN PIPE LINES

The pipelines should be clean, free from longitudinal grooving, both inside and outside, should be smooth, free from surface defects, straight, cylindrical in shape when viewed from end, uniform in thickness.

3.4. INSTRUMENTS & FITTINGS

Instruments should be made from materials considered safe for direct contact between the flowing media and the instrument itself, preferably highly polished 316L (grade 316 with <0.04% carbon) stainless steel. The instrument should be connected at point of maximum turbulence and not near stagnant pockets. Connections of pipe should avoid cavities or pockets likely to encourage accumulations of solids.

3.5 MAINTENANCE OF PIPES & FITTINGS

1. Worn-out gaskets in pipeline joints should be replaced periodically, before they become brittle, deformed or loose their shape permanently.
2. During preventive maintenance inspection, distress cracks on walls and footings near the pipe anchors will indicate improper layout with regard to thermal expansion.
3. Check for the supports of the pipelines, whether they firm or if they are dislodged from their installed positions.
4. Check if vibrations, expansions caused by the process equipment like homogenizer, Pasteurizer are prevented from being carried on to pipelines connected to them.
5. Check, if any modification done like expansion, shifting of equipment are not affecting the pipeline installation, and properly supported and connected without any stresses.

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Lesson-4

Milk Storage Tanks, Silos, Road and Rail Tankers

4.1 INTRODUCTION

Milk is stored in a great variety of storage tanks, first near to villages as Bulk milk cooling units, then transported by Road Tankers and then to Raw Milk Storage tanks in dairy plants. Further, it may be transported in Rail Tankers to long distances after processing, to large urban centers. Further, there may be requirement for processing operations like mixing, ripening, culturing, aging etc, which require further special features in storage tanks.

The requirement of modern quality standards, eliminate the use of open vessels. Further, the storage tanks are now made only of Stainless Steel, instead of Aluminum or other similar metals.

4.2 MILK STORAGE TANKS

They are usually cylindrical and mostly insulated. They may be horizontal or vertical types, depending on availability of flour space. For extremely large quantity of storage, Vertical Silo tanks are provided outside the Processing section, to avoid tall buildings to accommodate them.

The inner shell of storage tank is of Stainless Steel, and covered with suitable insulation, and then an outer shell, which may be Stainless Steel or Mild steel. Outer shell of mild steel is used to reduce cost. The outer mild steel shell will be painted to prevent corrosion, which may be of two coats of antirust and two coats of enamel paint of suitable color , especially cream yellow.

The inner shell of storage tank should be smooth in surface finish, and should not have any sharp corners, to aid in proper cleaning. The edges must have a knuckle radius of at least 25 mm. Any welds present should be properly ground, so as to have smooth finish.

The shell will have drain from lowest point, preferably from the center of the bottom. If this is not possible, the bottom of the vessel should be sloped towards the outlet valve side of the bottom to ensure complete drainage. The slope is at least 1:12.5 towards the outlet.

The shell will have other openings like for Agitator, non-foaming type milk inlet, inlet for cleaning solutions through a spray device, air outlet etc. It will also have fittings for sight glass and light glass, for inspection of inside level measurement, to ensure proper cleaning etc. The glass has to be of non splinter type. The opposite end of sight glass will have the level marked by food grade paint, or buffing of the surface to indicate level markings and values marked adjacent to it. The tank is fabricated usually 15% over capacity than the nominal capacity of the tank. The technology of using load cells for remote sensing of measurement of level is also being introduced in most of the modern dairies, linked to automated operation.

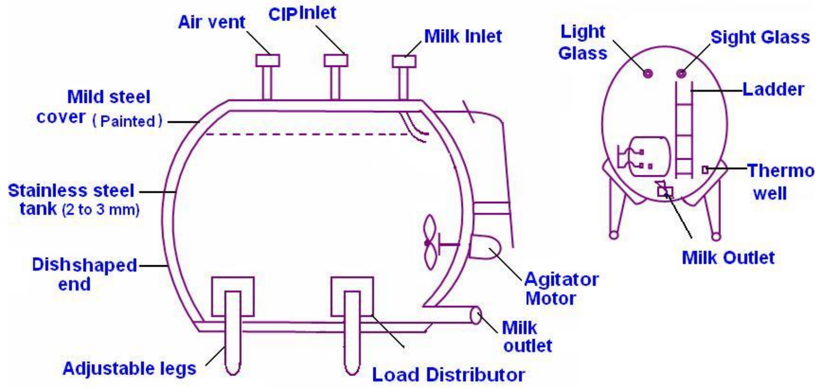

Fig.4.1 Horizontal milk storage tank

Inner shell will also be supported by four legs, through load distributer MS angles, to avoid change of shape or damage to inner shell. The load distributors also will have a lifting eye at top to lift the entire storage tank with cranes. The thickness of shell depends on the size of the tank, to withstand the weight. Usually it is 2 to 3 mm thick for horizontal tanks, and 4 to 5 mm for silos. The ends of tanks are usually dish shaped to give strength and it also gives a greater knuckle radius at the joint of dish end.

Insulation is using thermocol or PUF for lower temperatures. For higher temperature, glass wool or mineral wool is preferred. The thickness should be such that, the increase in temperature of fluid when filled should not rise more than 2°C in 18 hours, under a test condition of 35 °C temperature difference between inside and outside. Average thickness of thermocol insulation provided is between 5 to 10 cm. There should be no hollow space in between the two sheets of SS and MS. In some of the designs however, this gap is provided with a breathing outlet at the bottom, so that the gap does not build up pressure when hot cleaning solutions are used.

The legs may be four or six in number, with adjustable ball feet. Threads of the ball feet are not exposed.

The milk inlet should be non foaming type at the top, with bent tube projecting towards inner wall. For Silos the inlet is also at the bottom, with a non-return valve. The milk outlet will be at the bottom, with a flange type valve fitting, usually with a two way valve. It is usually of 51 mm or 63.5 mm, to allow rapid unloading.

To keep the milk properly mixed, and avoid cream separation an agitator at slow speed is operated, which may be either horizontal, vertical, and in some cases, inclined too. Most commonly, the agitator is vertical, with one or two sets of blades, and is supported at the bottom by bush, so that there is no lateral oscillation. The agitators are connected to motor through reduction gear mechanism, which has oil as the lubricant. It has to be perfectly sealed to prevent oil leaking along with the agitator into the tank.

Tanks are also provided with other essential fittings like manhole, sampling cock, thermo-well, ladder in front to watch through sight glass, CIP pipe line connection with adequate support on top. The manhole is of swing-back type, which is oval in shape and can swing both horizontally and vertically, so that it can be positioned in place from inside. There is a tightening arrangement to prevent leakage from manhole door, once the milk is filled. The sampling cock is positioned at a level such that sampling can be done even up to 5% of the capacity of the tank. It has spring loaded push type of lever, or a screw type of opening. Provision is also made of a Thermo-well, in which the sensing element of temperature indicator can be placed. It is an inclined SS tube, with lower end sealed, and positioned inclined to the inner shell, welded in that position. It is filled with oil or ceramic powder to have a better contact between the sensing element and the wall of thermo-well.

The air vent to the tank is provided to avoid build up of pressure during loading, and development of vacuum during unloading. It is provided with vermin proof cover to prevent dust and insects entering into the tank.

4.2.1 Vertical storage tanks / silos

The vertical storage tanks are mainly used, when the floor space is less, and the roof of processing hall is sufficiently high. Some of the high viscous products like cream or ghee are also preferably stored in this type of storage tanks.

Due to its shape, the manhole is at the top, and a ladder is provided for reaching on to the top. The top is also conical to prevent any accumulation of water or dust. The sight and light glass are also provided at the top. Due to its height, the agitator has to be long, and provided with more than two sets of blades for agitation. An internal ladder is provided to climb down for manual cleaning. Other fixtures like CIP cleaning attachment or spray ball, thermo well, sampling cock, lifting lugs or eye at the top, are provided as in horizontal storage tank. Both the inlet and outlet will be at the side at the bottom level of the tank. The slope is 1:10 towards the outlet so that there is free and complete drainage of liquid. The inner wall may be of Stainless steel sheet of 3mm thickness while outside can be 2 mm. Some of the floors have greater thickness of 5 mm. The tank is supported by four legs with SS ball feet and provision for height adjustment. Silos are vertical storage tanks of large capacity, usually more than 30,000 to even upto 1 lakh liters. The agitation is by compressed air in such case .

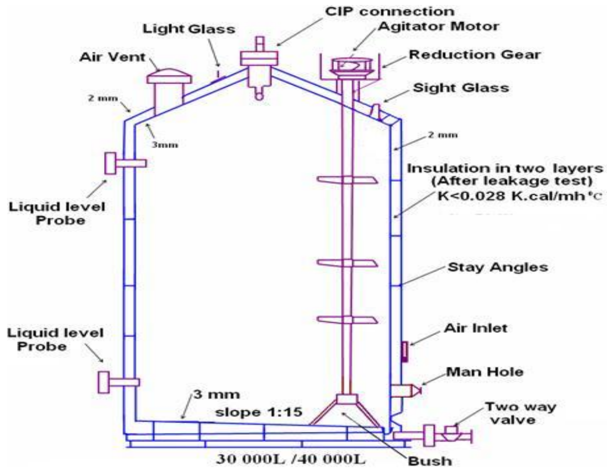

Fig.4.2 Vertical storage tank

The compressed air is passed into it through a filter and a control valve. A pressure gauge is also provided to know the air pressure. The inlet and outlet are fitted to be operated from inside of the processing hall itself, through an opening called alcove. Inlet valve is provided with non-return valve. An overflow line extending to inside of the processing hall is also provided to know if the tank is full.

4.2.2 Road tankers

The milk once collected in milk collection centers, has to be transported to dairy plants by Road tankers. The tankers have to withstand great deal of stress due to vibrations, jerks, exposure to weather, while transporting milk. Hence, the essential features include, thicker SS sheet for inner and outer shells, better insulation, weather proof manhole doors covered with a hood, two or three compartments to prevent rolling over of milk during jerks. Further, the whole structure has to be mountable on the truck, or the articulated trailer, with all the limitations of safe maneuverability during driving. The capacity, mounting and length should be suitable for village roads, which is a severe limitation. The insulation will be a thermocol in two or three layers, with proper seal of bitumen to prevent moisture seepage. The newer road tankers are having PUF insulation material. The barrel of the tankers is preferably oval in shape to reduce the centre of gravity, and is supported by M.S. supports, to be fitted to the chassis of the vehicle. The vehicle will have a ladder at the rear and a walk way (of suitably checkered plate to avoid slippage) to approach the manhole during inspection, sampling and manual cleaning.

4.2.3 Railway tanker

Railway tankers are used for transportation to long distances and are of capacities 20,000 to 40,000, divided into two or more cells. The final structural dimensions should meet the requirement of Indian Railways, suitable for transport by passenger trains. The top of the tank has dust cover, pressure relief valve and vacuum relief valve, manhole door. Manhole door and internal ladder are also provided. The Manhole door is provided with gasket of Acrylonitrile butadiene copolymer or polychloroprene. A dip stick is provided to know the quantity of milk approximately. Insulation is 100 mm thick such that when full, the rise in temperature from 4 °C is only 2 °C in 24 hours, when temperature differential to outside is 35 °C. Outlet size is 63.5 or 76.2 mm, located at centre bottom. Two outer ladders are also provided on each side. The inner vessel should withstand 0.35 kg/cm² pressure, and should be tested for Radiographic and dye penetration test to detect possible leakages.

4.2.4 Other kinds of tanks

There are other types of tanks suited to specific purposes like cream storage tank, ghee settling tank, etc, which are double jacketed. The jacket has SS perforated ring to allow a gentle flow of cold/hot/well water to maintain the temperature of the fluid in the tank. They are usually vertical types, with all the essential features as that of horizontal milk storage tank. Milk reconstitution tanks are again special purpose tanks connected with additional features like funnel with venturi and valve at bottom, circulation pump, potable water inlet to tank. This tank is not insulated, as the temperature is expected to be about 40 °C.

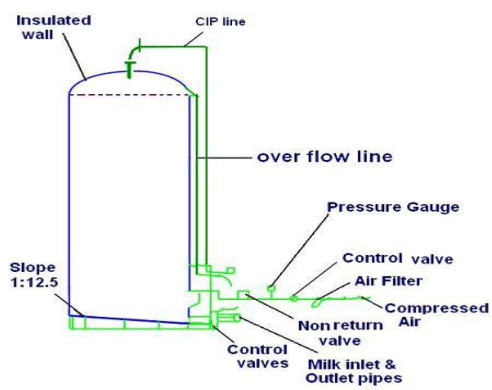

Fig. 4.3 Milk silo tank

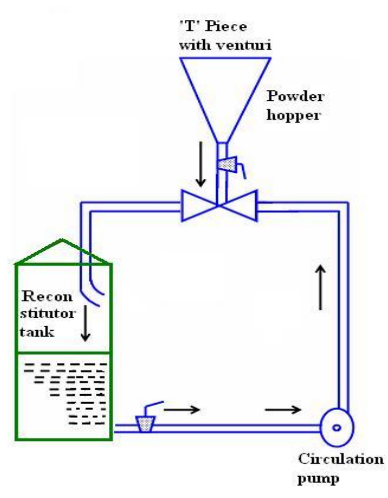

Fig. 4.4 Reconstitution with funnel venturi system

Lesson-5
Description, Working And Maintenance of Can Washers Straight - Through Can Washer

5.1 INTRODUCTION

Milk is procured from villages in cans, and brought to the Dairies or Bulk milk collection centers. At dairies, if the collection through cans is in large quantities, the cans have to be cleaned using mechanical means. If the quantities are less, then it can be done manually, using can washing trough and mechanically operated brushes and steaming blocks. The mechanical can washers are again two types. The smaller capacity ones are Rotary can washers, whose capacity is 3 to 5 cans/min, while the larger capacity ones are Straight-through can washers, whose capacity is about 12 cans/min.

5.2 HAND WASHING OR CAN SCRUBBER

This method is adopted in all milk chilling centres where less number of cans is to be washed. One man can operate this unit conveniently.

Construction of can scrubber is shown in figure and described below:

1. The scrubber machine is made of 10 SWG G.I. sheet or M.S.sheet with totally galvanised.
2. The machine is painted with 'epoxy' paint to avoid corrosion.
3. The can scrubber consists of a tank in which two revolving nylon brushes are mounted on shafts.
4. The extension of shafts are properly encased in sealed enclosures and provided with suitable bearings and lubrication points.
5. Gland packing is used to avoid the leakage through the shaft.
6. A stationary nylon brush is fitted with a bracket on the inner wall for cleaning outside of the cans.
7. Side stationary brush is changeable. It can be fitted on either side of the inner wall.
8. Cylindrical nylon brushes, revolve at a low speed, i.e., 80 to 100 rpm, in opposite directions by a motor and reduction gear unit, give thorough and effective cleaning action on either side of the can..
9. Steam and water connections are given to the tank for making warm water for washing operation.
10. At the bottom of the tank a drain valve is fitted for easy draining and cleaning of the tank.

5.2.1 Preparation: Can scrubber is prepared for can washing as follows:

1. Check the oil level in the gearbox and lubricate the chain over the sprockets for the brushes.
2. Check the rotation of the brushes.
3. Clean the tank and close the drain valve.

4. Open the water valve and fill the tank to the marked level.
5. Add. 0.8% washing soda and 0.2% tri-sodium phosphate to the water.
6. Open the steam valve and raise the temperature of the detergent solution to 55^0C.
7. Start the rotating brushes by switch on the drive motor.

5.2.2 Washing Operation: Washing operation is done as follows

1. First of all can is pre-rinsed with warm water at about 40^0C both from inside and outside.
2. Then can is inserted on the top rotating brush and brushed thoroughly from both sides for 10 seconds.
3. Then can is taken out and rinsed with hot water at about 60^0C.
4. Final rinsing, sterilization and drying of can are carried out on the steaming block.

5.3 STEAMING BLOCK

Steaming block is always used with can scrubber for final rinsing and sterilization of washed cans. The construction of steaming block is as below:

1. The stationary part of steaming block is made of cast iron material and the working parts are of stainless steel.
2. At the base water and steam lines are connected through spring loaded valves and the valves are operated by the pedestal levers.
3. A steam mixing battery is fitted inside the vertical column.
4. The top portion has a concave surface on which a spray nozzle, drain hole, and seat rests for can mouth are provided.

5.3.1 Operational Precautions

1. Steam supply should be given through a steam mixing battery to avoid vibration.
2. If the brushes do not rotate, check the direction of rotation and correct it or tighten the idler wheel, provided on the chain, as required.
3. It will be hard to insert the can on a new brush. Do not cut the nylon bristles to reduce brush diameter in order to reduce the worker's labour. If this is done, the scrubbing and cleaning will be ineffective.
4. Periodically check the lubrication and alignment of gearbox and sprockets to avoid any breakdown.

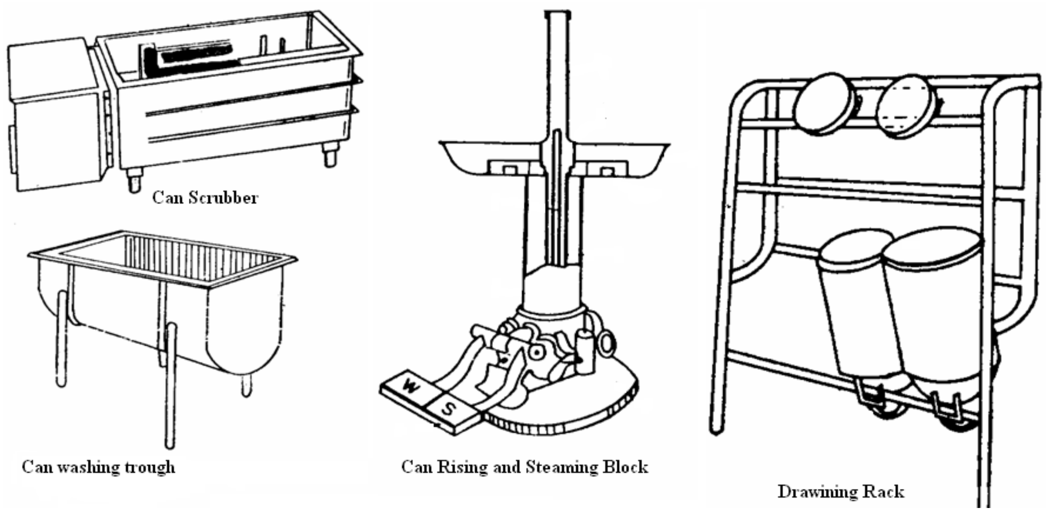

Fig.5.1 Steaming Block

5.4 ROTARY CAN WASHER

Rotary can washer has a revolving platform, with holes on which the cans can be placed in an inverted position. As the revolving platform moves intermittently, the inverted can is jetted by various solutions, as shown in Fig. . Under the platform, a series of tanks, containing washing solutions will be provided. These solutions are forced at high pressure, by centrifugal pumps, through jets placed below and to the sides of the cans. The liquid returns through the platform grating to the respective tanks. The platform is rotated intermittently to ensure that each can receives a constant period of treatment over the jets.

The sequence of operations preceding simultaneously are

(1) loading of can in vertical inverted position
(2) rinsing with warm water (which is drained),
(3) drainage of rinse water,
(4) treatment with detergent solution at high pressure (at 65 to 70 ^{0}C) to soak, loosen and dislodge milk film from can surfaces,
(5) drainage of wash solution back to detergent tank,
(6) hot water rinsing at 65 to 70 ^{0}C,
(7)and (8) blasting with dry saturated steam,
(9) drying of steam condensate with hot air blast, and
(10) unloading of the can, inverting and placing the lid on the can.

The can washer is provided with a stationary canopy with chimney to take away the exhaust steam. The capacity of washer is suitable for small chilling centers, and can wash about 3 to 6 cans / min. The same operator can load and unload the can, thus saving man power.

5.5 STRIGHT THROUGH CAN WASHER

5.5.1 Principles of Operation: Straight through can washer carries the cans through the washer in a straight line by means of a continuously moving conveyor or slide along rail as they move intermittently from one jetting position to the next. The driving unit moves the can forward from one position to the next at regular intervals.

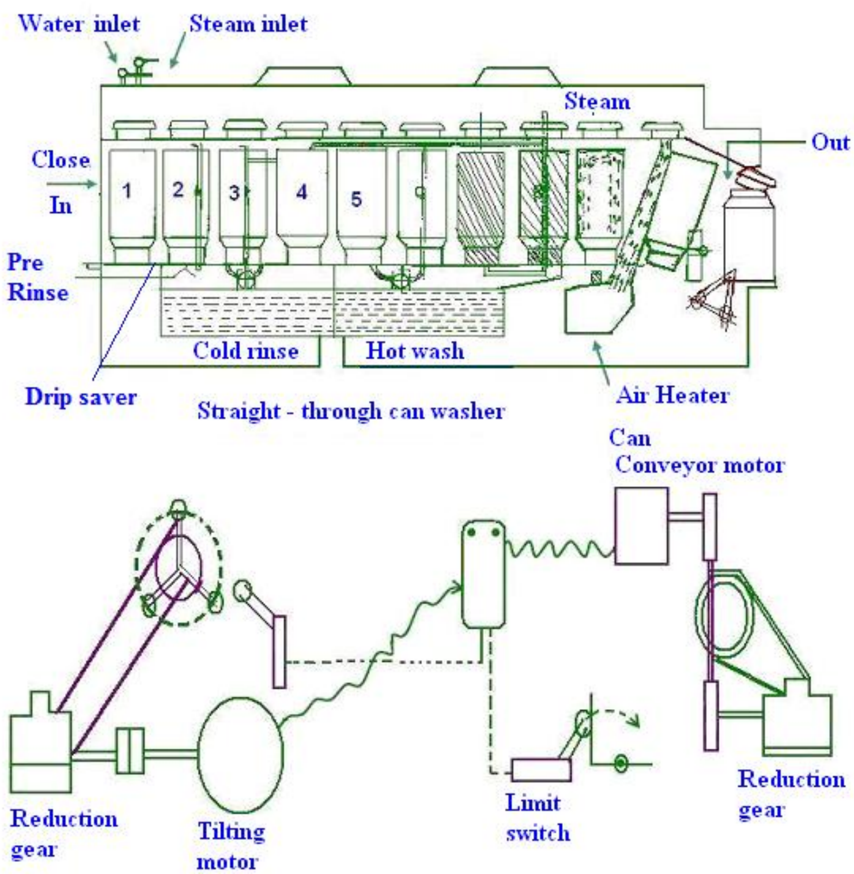

Fig.5.3 Straight – through can washer

5.5.2.1 Draining

Before passing the cans to the can washer, milk, cream or any other fluid is drained out by placing the cans in an inverted position over a drip pan before it is rinsed. Few washers have arrangement of drip saver to collect the residual milk in the can. After draining of the milk the cans are automatically loaded into the can washer in inverted position. The lid of the can is also entered into the can washer for proper cleaning.

5.5.2.2 Pre-Rinsing

Rinsing of can is done by passing water through the jet to clean the milk film remaining in the can at a pressure of about 1.0 to 2.0 kg/cm^2 for 3-6s, so as to remove the traces of milk.

5.5.2.3 Hot Water Rinsing 1

Cans are rinsed by clean hot water. The temperature of hot water is maintained at about 65-70 °C. Temperature should increase at successive stages, as at the sterilization and drying stage the steam and hot air temperature will be higher than 100 °C.

5.5.2.4 Caustic Rinsing

Caustic rinsing is done by passing the washing solution through jets at a sufficient high pressure both inside as well as outside to remove all milk and cream film inside and outside of the cans. Cleanliness of can depends on temperature and strength of washing solution. When using alkaline solution, alkalinity should be less than 0.15 percent. Caustic soda must not be used as detergent, but sodium carbonate and a corrosion inhibitor are suitable as high temperature causes the formation and deposition of milkstone on the can surface. So the optimum temperature of washing solution must be in between 65 °C and 70 °C for 9-18s. After Caustic rinsing the detergent solution is drained.

5.5.2.5 Hot Water Rinsing 2

This is done to clean the washing solution thoroughly. The water temperature in this section is about 85-90 °C and this water is drained after use.

5.5.2.6 Sterilization

Sterilization of can is done by passing dry saturated steam at 110^0C for 5 to 10s. Steaming process sterilizes the cans and increases the can temperature which facilitates the easy and quick drying in the drying section. The temperature, heat content and moisture content of steam influences the effectiveness of steam sterilization.

5.5.2.7 Drying

The main purpose of drying is to prevent the corrosion of metal due to moisture and to check the bacterial growth. The drying operation is accomplished by blowing jet of hot air at 110^0C inside the can. The moisture holding capacity of air depends on its temperature and relative humidity.

The capacity of straight – through can washers varies from 6 to 16 cans per minute. This type of washer is used in large size dairy plants. It is easily accessible for maintenance and cleaning of the inner parts. There is no recontamination of cans either by the washer or by the operator. It occupies more floor space in dairy, and requires close inspection while in operation.

The service requirements of straight-through can washer (6 to 8 cans per minute) is as follows: steam between 0.85 to 1.8 kg per can, water consumption 4.0 to 4.5 L/ can, energy between 1.0 and 2.4 kWh, to operate the machine.

MAINTENANCE

1. The water valves should be opened, cleaned and water pressure (2.0 to 4.0 kg/cm^2) should be checked. If the pressure is not sufficient it may be due to clogged jets and defective pump. The clogged jet should be cleaned and the pump should be checked for defective shaft seals, clogging and worn out parts. The pump strainer, inlet and outlet lines should be checked for the accumulation of lime and scale.

2. The can washer should be cleaned as and when necessary. All the wash sprays, nozzles and strainers should be checked and cleaned.

3. The mechanical difficulties of the can washer are caused by lack of regular and sufficient lubrication, failure to make adjustment for wear, and failure to replace worn out parts. Most of the mechanical difficulties can be avoided by proper, lubrication of the moving parts, making adjustment for wear and replacing the worn out parts immediately.

4. The temperature and pressure of the washing solution, hot water, steam and drying air should be maintained at optimum level. The proper strength of the solution is also a very important factor for proper washing.

5. Heavy scale deposits in can washers are usually the result of inadequate daily cleaning, use of hard water, and the use of solution at inadequate temperature and strength. The scales can be removed by using inhibited acid at a temperature of about 50 °C.

5.6 PREVENTIVE MAINTENANCE SCHEDULE

Maintenance to be done	Frequency
Drain the water from can washer and clean the tanks	Daily
Clean all spray nozzles and openings	Daily
Clean the pump strainers by brushing	Daily
Clean the chain conveyor with hot water after every operation	Daily
Lubricate all the rollers, bearings, bushings, ratchet arms and chain	Daily
Check oil level in the reduction gear box	Daily
Check the function of the dosing device	Daily
Open all the shields after every operation.	Daily
Check the water line and steam line valves for leakage through glands.	Weekly
Lubricate the bearings of hot air blower and exhaust fan by lightening the grease cups	Weekly
Check the suction filter of hot air blower clean or replace, if required	Weekly
Check the leakage through pump glands	Weekly
Check steam and water valves for any leak and spray nozzles and non return	Weekly

valves for proper operation in steaming block	
Check oil level and smooth running of gear box in can scrubber	Weekly
Check shaft, bearings, oil seals, chain and sprocket in can scrubber, repair or replace if required	Monthly
Check the temperature sensing elements in all tanks for any scale deposition	Monthly
Check the function of the steam trap	Monthly
Check and recalibrate the temperature gauges and pressure gauges	Monthly
De scaling of can washer	Quarterly
Check all motors in can washer and scrubber	Yearly
Complete overhauling of all pumps.	

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Lesson-6

Bottle Washers, Factors Affecting Washing Operations, Power Requirements of Can and Bottles Washers

6.1 INTRODUCTION

In olden days the retail milk supply was mostly done by glass bottles, which were reuse type and needed washing operations, before refilled and distributed for milk supply. As the bottles were mostly ½ litre capacity, the numbers of bottles were huge, for supply to even a medium size city. Hence, mechanized bottle washing was necessary not only to clean the bottles in large numbers, but also to do so safely, without harm to the personnel. Bottle washers of various types and sizes were in use, and the appropriate one was chosen to match the requirement of the dairy. Most popular among these bottle washers was the soaker type where bottles are soaked and jetted by an apron carrying bottles in various sections. Among the soaker type, there are again two types, one in which the feeding of bottles and the exit of cleaned bottles are at the same end of the bottle washer, and second in which, they are in the opposite ends. The sequence of operations of a typical soaker type bottle washer is given below.

6.2 SOAKER TYPE BOTTLE WASHERS

In this type of bottle washer, the bottles are loaded in to a continuous conveyor chain that will be having rows of bottle holders. The conveyor chain passes through various stages of cleaning and sterilizing like: 1) Pre-soaking 2) Jetting 3) Detergent soaking 4) Flushing 5) Rinse water jetting 6) Hot water jetting 7) Warm water jetting 8) Cold water jetting. The bottle washers may be of loading and unloading on same end, or it may be on opposite ends. The figure shows the bottle washer of soaker type with loading and unloading on same side (Make: Stork, Holland).

All the changes in direction of the conveyor chain are guided by chain wheels, which are provided with bearing boxes of plastic material. The shafts are made of stainless steel and all bearings in the machine are self lubricating. The temperature of sections where heating is required is supplied with heating coils having steam flowing in it, with condensate drain through steam traps.

The sections are so arranged that there is a time – temperature treatment by each section. The temperature variations never exceed 25 ºC inspite of high cleaning temperatures used in the process. This will avoid any thermal shocks to the bottles, there by reducing breakages. There are no acids involved. The total time taken for the bottle to get cleaned and return after passing through all sections is about 15 to 20 minutes depending on speed of the conveyor chain movement.

6.3 DESCRIPTION OF OPERATION

The bottles are loaded on the loading table, which is a flat chain made of stainless steel. The bottles are loaded by distribution mechanism which guides the bottles in to individual bottle holders of each row. Each row may be having 8, 12 or 16 receptacles, depending on the Bottle washer capacity. The Tipping cradle ensures that the bottles are loaded in inverted position in the receptacles. The Tipping mechanism is also provided with safety switch, which will stop the movement of chain, if any of the bottles gets stuck between the tipping cradle and the conveyor chain. This avoids breakage of bottles when the conveyor moves to receive next set of bottles.

The conveyor chain takes the bottles first in to Pre-soaking section, where the water at 35 ºC, wets the bottle and its inner surface and loosens any leftovers sticking to it. Next it moves to jetting section, where hot water is jetted at 55ºC into bottles to dislodge any particles still sticking to its surface. The chain then moves into Detergent soaking section, where hot detergent at 75ºC will dissolve the fat and any greasy substances on the surface of bottle. The bottles are then flushed out of detergent solution, and move to jetting sections, where the detergent solution is jetted into bottles with force. The bottles then move over water jetting sections, designed to progressively remove the detergent remnants and reduce the temperature of bottle. These involve rinse water jet (65ºC), hot water jet, warm water jets (35 ºC) and then cold water jet (15ºC).

The bottle is then discharged in vertical position by flat stainless steel belt conveyor to bottle filling section, with a hood on the conveyor to avoid any direct exposure to outside contamination. The conveyor is positioned with an observation point where magnifying glass is provided for visual inspection and eliminating any bottles with minor cracks, chipping at mouths or bottom to avoid damage and breakage during filling operation and further crating, storage and loading operations.

6.4 MAINTENANCE

The maintenance of bottle washer is essential, day to day as well as periodical inspection, repair and replacements. The clogging of jets is a frequent problem and this has to be inspected daily, through leak proof inspection doors provided at the sides of the enclosure. Safe lighting is provided inside the bottle washer for this purpose. The steam pressure, water jet pressures are to be maintained. If the motors or pipelines are forming scale, it has to be removed. Spillage of water jets outside the bottles to which they are directed to must be avoided, due to lack of sufficient pressure or excess pressure. The chain conveyor movement should be ensured for smooth movement, without any excess of friction at various wheels provided for change of direction. Steam condensate traps must be inspected for proper operation and draining of condensate. The strainers provided before jetting rows are to be cleaned time to time.

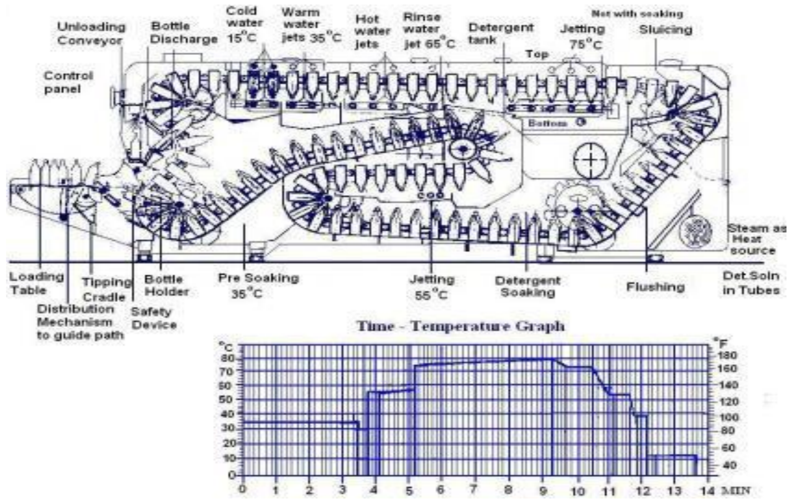

Fig.6.1 Bottle washer (Adopted from Bottle washer manual of Stork company, Holland)

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Lesson-7

CIP and Designing of System

7.1 INTRODUCTION

Cleaning of dairy equipment and its sanitation are of utmost importance in dairy industry. Cleaning-in-Place (CIP) involves circulation or recirculation of appropriate water rinses and chemical cleaning and sanitizing solutions through plants and equipment which is maintained in the assembled state, such that all contaminated contact surfaces cleaned to acceptably high and consistently reproducible standards. It involves use of hotter, stronger and more soil aggressive chemical solution than manual cleaning. Filters and similar equipment should be taken out during CIP cleaning to prevent their damage.

For effective Cleaning the following aspects are important:

i. Design of plant, material used and ancillary equipment should be suitable for CIP cleaning.
ii. Cleaning procedure to be adopted depending on soil type, detergent type, concentration, temperature, contact time, type of surface.
iii. CIP cycle must effectively and automatically controlled with minimum of intervention, or unauthorized alteration
iv. Supervision is important although high degree of automation is available.

The favourable effect of increased temperature in cleaning may be attributed to:

i) Loosening of bond between soil and the surface, and increase in wetting.

ii) Greater turbulence because of decreased viscosity

iii) Increased solubilisation of more soluble constituents of soil e.g. lactose, mineral

iv) Increased chemical reaction rate which greatly increases the cleaning

It is a general observation that the minimum temperature should be about 3 - 5°C higher than the melting point of fat. The maximum temperature will depend upon the temperature at which the protein in the system is denatured.

The turbulence due to velocity of detergent has also a bearing on the cleaning efficiency. A velocity of 1.5 m/s is satisfactory.

The hardness of water must be below 50 – 60 ppm for effective cleaning. Presence of > 3 ppm of Iron and > 0.2 ppm of Manganese in water may even stain the surface. Hard water employed in cleaning leads to sludge or scale formation, which reduces the rate of heat transfer, clogs up jets, and leads to wearing of moving parts. Cleaning becomes difficult at above 200 ppm hardness.

7.2 TYPES OF CIP CLEANING

Depending on the situation and scale, there are two types of CIP cleaning systems. They are single use and re-use systems. Use and throw of the cleaning solutions as single use system is not much in use. Now there are combined systems using advantages of both single use and reuse systems also.

7.2.1 Single use system

It is for cleaning one process circuit at a time with all liquids drained after use. This is generally called De-centralized system of CIP cleaning.
They are for small units close to the equipment to be cleaned. For example this type is used in HTST pasteurizer.

A Typical cycle has

i) 3 Pre- rinses of 20 sec. with gap of 40 sec to remove gross soil contamination.
ii) Cleaning detergent of certain temperature for 10 to 12 min.
iii) Rinse with warm water for 5 min.
iv) Rinse with acid solution, pH about 4.5 to 5.0, for 3 min.
v)Two rinses with cold water.

7.2.1.2 Cleaning media for cold milk equipment

i) Alkaline cleaning media 0.1-0.2% concentration
ii) Surface active and anti – foaming agents are added (up to 0.08%)
iii) Liquid chlorine sanitizing agent is also added up to 50 to 100 ppm

7.2.2 Re – Use CIP system

In this system, which is mostly Centralized Cleaning system, the cleaning solutions like acid, alkali are reused by circulation from tanks storing these solutions. The concentration and temperatures of the solutions is maintained in these tanks. Due to pre – rinses, detergents are not polluted much.

The following cleaning stages used in succession are possible and are used in practice depending on the nature of the soiling matter:

W →C→W

W→C→W→A→W
W→A→W→C→W
W→A→W→C→W→A→W

C= Caustic rinse; A= acid rinse; W= water rinse; water pre-rinse if W at the beginning, intermediate rinse if in the middle and final rinse if at the end.

An acid rinse can be omitted if there is no milk stone deposited, such as in can washing and storage tank cleaning. The position of the acid rinse in the sequence depends on the position of the milk stone, i.e. whether it is above, below or in the middle of the deposit.

For cleaning with acids based on Nitric acid, the concentrations should not exceed 5%. Temperatures of up to 100 °C and contact times of up to 1 hour are not hazardous. Temperatures of over 80 °C should not be used with nitric acid to prevent attack on gaskets.

At times, discolouration of surface (yellow, brown, dark blue) may occur at higher temperatures with alkaline as well as with acid cleaning, but this does not indicate that corrosion has taken place.

7.3 AUTOMATION OF CIP CLEANING

As the operation of CIP cleaning is inherently hazardous and not without danger of leaking and causing harm to men and material, its operation is automated in most of the dairy plants. The tanks and fittings are shown in diagram below.

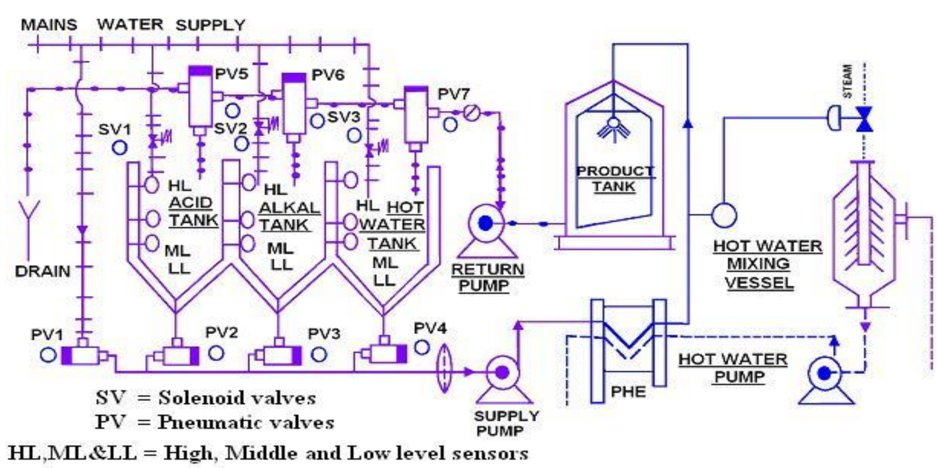
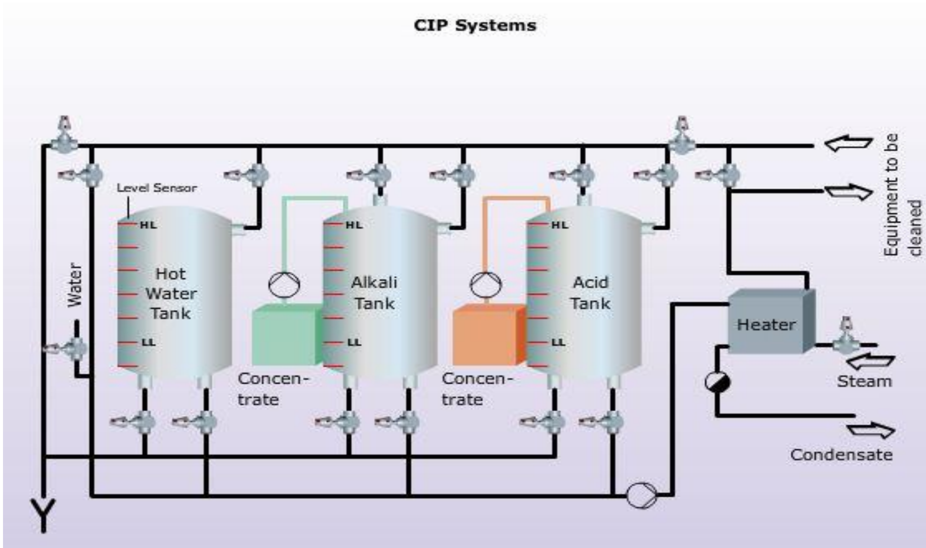


Fig.7.1 Automation of CIP cleaning



CIP System 7.1

The sequence and timing of pumping of solutions are controlled by the PLC controller, which can be programmed. The sequence of cleaning solutions, the time of circulation can be chosen in the program. The operation is possible because of pneumatic valves both at inlet and outlet of the tanks. PHE is used for maintaining the temperatures of the cleaning solutions. The levels and concentration in each tank are sensed, filling up and concentration is maintained automatically, through controlled flow of concentrated cleaning solution, from a separate tank. The method of checking the concentration of cleaning solution is either by periodic sampling of the solution and testing in laboratory, or checking electrical conductivity of the solution on line.

Further, the CIP system must have sufficient pressure to be effective while cleaning the equipment. If two or three tanks are being cleaned, in addition to the pressure, the temperature loss also will be there. Hence, a PHE must also be provided to maintain the temperature to the required level. The hook up of the CIP system to the cleaning circuit of the equipment is shown fig 7.1. A CIP system may be of one or more cleaning circuits. Using a two cleaning circuit CIP system, two sections of a dairy processing plant can be cleaned simultaneously at same time.

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Lesson-8

Mechanical Separation: Fundamentals Involved in Separation

8.1 INTRODUCTION

Separation is one of the important unit operations practiced in Dairy and Food processing. Some of the physical separation processes are Sieving, Filtration, Membrane separation, Gravity separation, Centrifugal Separation etc. They may also be classified broadly into categories of Liquid- Liquid, Liquid – Gas, Solid – Solid, Solid- Gas separations. Each operation would involve specific application for separation.

Some of the common operations in dairy industry are the separation of fat from milk, separation of extraneous matter from milk, separation of fine powder particles from exhaust air of spray drier, filtering moisture from various dairy products etc.

Filtration is the process of passing a fluid containing suspended particles through a porous medium. The medium traps the suspended solids producing a clarified filtrate. Filtration is employed when the valuable component of the mixture is the filtrate.

8.2 GAS-SOLID SEPARATIONS

Gas-Solid separation involves the application of particle mechanics to the design and application of dust-collection systems. It includes wet collectors, or scrubbers, for particle collection. It could involve equipment for removing entrained liquid mist from gases.

8.2.1 Purpose of dust collection

Dust collection is concerned with the removal or collection of solid dispersed in gases for purposes of:

1. Air-pollution control, as in fly-ash removal from power-plant flue gases
2. Equipment-maintenance reduction, as in filtration of engine intake air.
3. Safety or health-hazard elimination, as in collection of siliceous and metallic dusts around grinding and drilling equipment and in some metallurgical operations and flour dusts from milling or bagging operations

4. Product-quality improvement, as in air cleaning in the production of pharmaceutical products and photographic film

5. Recovery of a valuable product, as in collection of dusts from dryers and smelters

6. Powdered-product collection, as in pneumatic conveying; the spray drying of milk, eggs, detergent and the manufacture of high purity zinc oxide and carbon black

Measurements of the concentrations and characteristics of dust dispersed in air or other gases may be necessary (1) to determine the need for control measures, (2) to establish compliance with legal requirements, (3) to obtain information for collector design, and (4) to determine collector performance.

The basic operations in dust collection by any device are (1) separation of the gas-borne particles from the gas stream by deposition on a collecting surface; (2) retention of the deposit on the surface; and (3) removal of the deposit from the surface for recovery or disposal. The separation step requires (1) application of a force that produces a differential motion of a particle relative to the gas and (2) a gas retention time sufficient for the particle to migrate to the collecting surface. The principal mechanisms of aerosol deposition that are applied in dust collectors are (1) gravitational deposition, (2) flow-line interception, (3) inertial deposition, (4) diffusional deposition, and (5) electrostatic deposition.

8.2.2 Cyclone separators

The most widely used type of dust collection equipment is the cyclone, in which dust-laden gas enters a cylindrical or conical chamber tangentially at one or more points and leaves through a central opening . The dust particles, by virtue of their inertia, will tend to move toward the outside separator wall, from which they are led into a receiver. A cyclone is essentially a settling chamber in which gravitational acceleration is replaced by centrifugal acceleration. At operating conditions commonly employed, the centrifugal separating force or acceleration may range from 5 times gravity in very large diameter, low-resistance cyclones, to 2500 times gravity in very small, high-resistance units. The immediate entrance to a cyclone is usually rectangular.

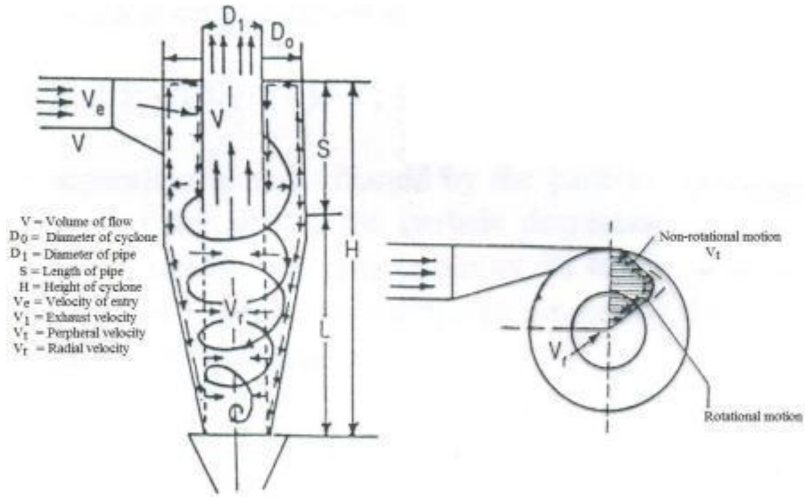

Fig.8.1 Cyclone separator

8.2.3 Venturi scrubbers

The venturi scrubber is one of the most widely used types of particulate scrubbers. The designs have become generally standardized, and units are manufactured by a large number of companies. Venturi scrubbers may be used as either high- or low energy devices but are most commonly employed as high-energy units. The units originally studied and used were designed to the proportions of the classical venturis used for metering, but since it was discovered that these proportions have no special merits, simpler and more practical designs have been adopted. Most "venturi" contactors in current use are in fact not venturis but variable orifices of one form or another. Any of a wide range of devices can be used, including a simple pipe-line contactor. Although the venturi scrubber is not inherently more efficient at a given contacting power than other types of devices, its simplicity and flexibility favor its use. It is also useful as a gas absorber for relatively soluble gases, but because it is a concurrent contactor, it is not well suited to absorption of gases having low solubilities.

Current designs for venturi scrubbers generally use the vertical down flow of gas through the venturi contactor and incorporate three features:

(1)a "wet-approach" or "flooded-wall" entry section, to avoid dust buildup at a wet-dry junction; (2) an adjustable throat for the venture (or orifice), to provide for adjustment of the pressure drop; and (3) a "flooded elbow" located below the venturi and ahead of the entrainment separator, to reduce wear by abrasive particles. The venturi throat is sometimes fitted with a refractory lining to resist abrasion by dust particles.

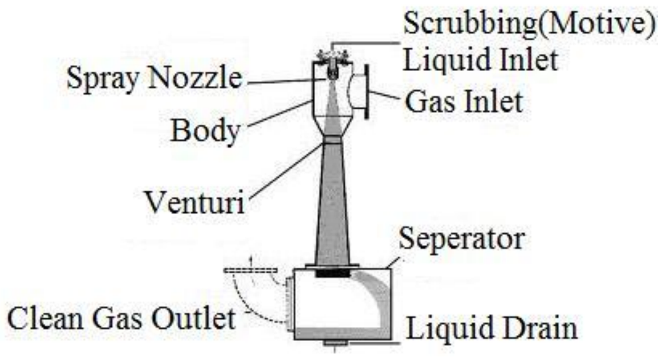

Fig.8.2 Venturi Scrubber

8.3 LIQUID – SOLID SEPARATIONS

These operations involve, the unit operations like Crystallization, Leaching, Gravity sedimentation, Filtration, Centrifugal separation etc. Of these Filtration and Centrifugal separation involve mechanical action in separation.

Sedimentation is the partial separation or concentration of suspended solid particles from a liquid by gravity settling. This field may be divided into the functional operations of thickening and clarification. The primary purpose of thickening is to increase the concentration of suspended solids in a feed stream, while that of clarification is to remove a relatively small quantity of suspended particles and produce a clear effluent. These two functions are similar and occur simultaneously and the terminology merely makes a distinction between the desired primary process results. Generally, thickener mechanisms are designed for the heavier-duty requirements imposed by a large quantity of relatively concentrated pulp, while clarifiers usually will include features that ensure essentially complete suspended-solids removal, such as greater depth, special provision for coagulation or flocculation of the feed suspension, and greater overflow-weir length.

8.3.1 Clarifiers

Continuous clarifiers are generally employed with dilute suspensions, principally industrial process streams and domestic municipal wastes, and their primary purpose is to produce a relatively clear overflow.

They are basically identical to thickeners in design and layout except that they employ a mechanism of lighter construction and a drive head with a lower torque capability. These differences are permitted in clarification applications because the thickened pulp produced is smaller in volume and appreciably lower in suspended solids concentration, owing in part to the large percentage of relatively fine (smaller than 10 mm) solids.

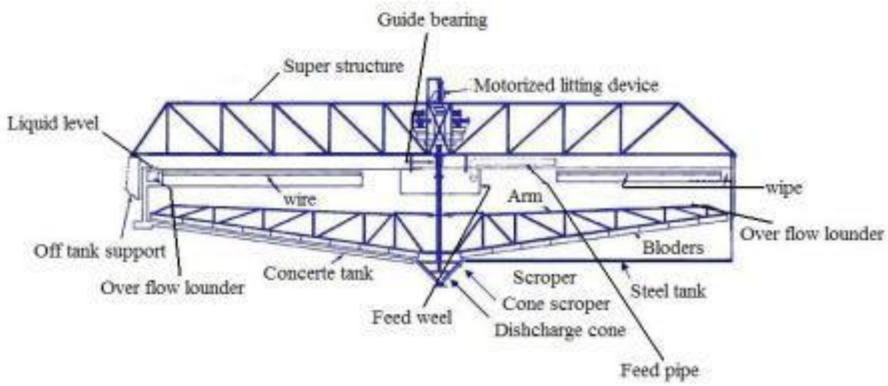

Fig.8.3 Clarifiers

8.3.2 Rectangular clarifiers

Rectangular clarifiers are employed primarily in municipal water and waste treatment plants, as well as in certain industrial plants, also for waste streams.

8.3.3 Circular clarifiers

Circular units are available in the same three basic types as single-compartment thickeners: bridge, center-column, and peripheral-traction. Because of economic considerations, the bridge-supported type is limited generally to tanks less than 20 m in diameter.

8.3.4 Tilted-plate clarifiers

Lamella or tilted-plate separators have achieved increased use for clarification. They contain a multiplicity of plates inclined at 45 to 60° from the horizontal. Various feed methods are employed so that the influent passes into each inclined channel at about one-third of the vertical height from the bottom. This results in the solids having to settle only a short distance in each channel before sliding down the base to the collection zone beneath the plates. The clarified liquid passes in the opposite direction beneath the ceiling of each channel to the overflow connection.

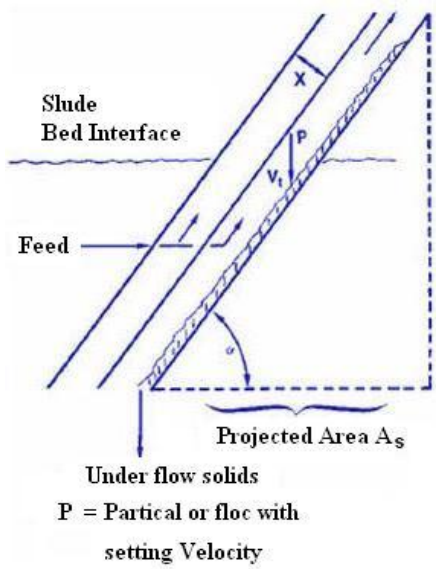

Fig.8.4 Tilted plate clarifiers

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Lesson-9

Principals Involved in Filtration, Types, Rates of Filtration, Pressure Drop Calculations

9.1 INTRODUCTION

Filtration may be defined as that unit operation in which the insoluble solid component of a solid-liquid suspension is separated from the liquid component by passing the latter through a porous membrane or septum which retains the solid particles on its upstream surface, or within its structure, or both. A broader definition could be that the fluid may be a liquid or a gas; the valuable stream from the filter may be the fluid, or the solids, or both. The solid – liquid suspension is known as the feed slurry or 'prefilt', the liquid component that passes through the membrane is called the filtrate and the membrane itself is referred to as the filter medium. The separated solids are known as the filter cake, once they form a detectable layer covering the upstream surface of the medium. Often the feed is modified in some way by pre-treatment to increase the filtration rate, as by heating, re-crystallizing, or adding a "filter aid" such as cellulose or diatomaceous earth.

Filter, must provide a support for the filter medium, a space for the accumulation of the solids, channels for the introduction of the feed. A means of inducing the flow of filtrate through the filter and medium must also be provided.

9.2 CLASSIFICATION ON BASIS OF FORCE

The fluid flows through a filter medium by virtue of a pressure differential across the medium. The flow of filtrate may be brought about by means of gravity alone, by the application of a pressure greater than atmospheric pressure upstream of the medium (pressure filtration), by applying a vacuum downstream of the medium (vacuum filtration) or by means of centrifugal force (centrifugal filtration).

Filtration under the influence of gravity alone is limited in application to slurries containing very free-draining solids or with very low solids contents. It has a very limited use in the food industry but is applied to the water and sewage treatment.

The applications of filtration in the food industry may be considered to fall into three categories. First category is one in which slurries containing appreciable amounts of insoluble solids are present. In such operations, a cake is formed on the upstream surface of the medium and the process is known as cake filtration. The second category is termed clarification and involves removing small quantities of insoluble solid from a valuable liquid. Here the object usually is to produce a clear liquid and the solids are generally unwanted. The third category, often referred to as microfiltration, involves the removal of very fine particles, of the order of 1m or less, and is generally directed at removing microorganisms from liquid foods.

In the Dairy Industry, the application of filtration is during:

1. Filtration of raw milk at dump tank, either at milk collection centre or at chilling centres.
2. During processing, while passing through pasteurizer
3. Reconstitution of milk powder
4. Removal of ghee residues from ghee
5. Separation of whey during cheese manufacture
6. Separation of whey during preparation of Channa

9.3 VERTICAL PLATE PRESSURE FILTERS(FILTER PRESSES)

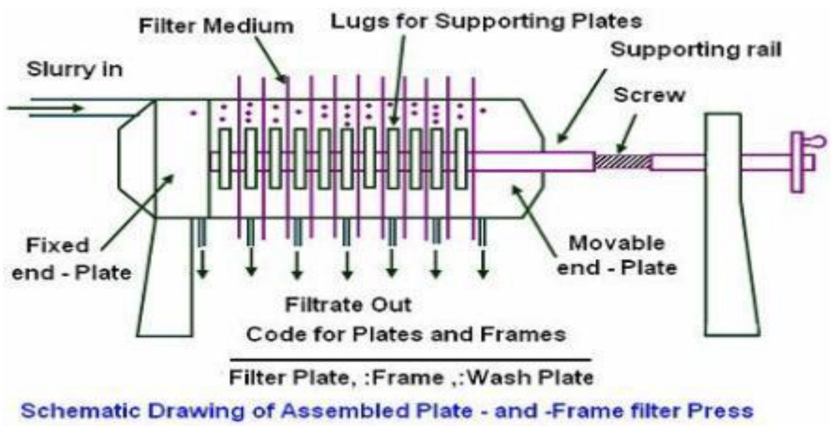

Fig.9.1 Plate and frame filter

A vertical drainage plate supporting a filter medium is the basic filtering element in a vertical plate press. A commonly used design is the plate-and-frame press. In this type of filter grooved plates covered on both sides with filter medium alternate with frames in a rack. The assembly of plates and frames can be squeezed tightly together by a screw, hydraulic or pneumatic mechanism to form a liquid-tight unit. The filter medium also acts as a gasket, preventing leakage between the plates and frames. Both plates and frames are provided with openings at one corner and when the press is closed these openings form a channel through which the feed slurry is introduced. In addition, the hollow centre of each frame is connected by an auxiliary channel to this feed channel.

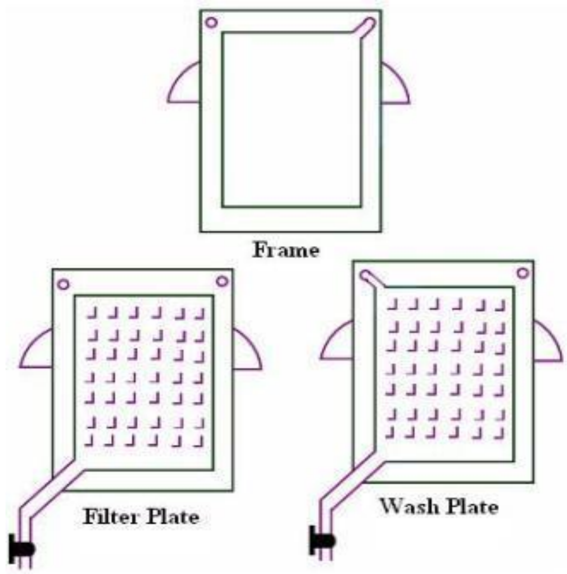

Fig.9.2 Filter plate and wash plate

The feed slurry enters the frames and the cake builds up in the hollow centre of the frames. The filtrate passes through the medium and on to the grooved surface of the filter plates from where it is removed via an outlet channel in each plate. Filtration is continued until the flow of filtrate drops below a practical level or the pressure reaches an unacceptably high level, due to the cake packing tightly in the frames. After filtration, washing of the cake may be carried out by replacing the flow of feed slurry with wash liquid. However, more effective washing is obtained by the use of special wash plates. These are arranged in the press so that every second plate is a wash plate. During filtration these wash plates act as filter plates. During washing, the outlets from the wash plates are closed and the wash liquid introduced on to their surfaces through a special inlet channel. The flow path for both filtration and washing when wash plates are used. The cake is removed manually after opening the press.

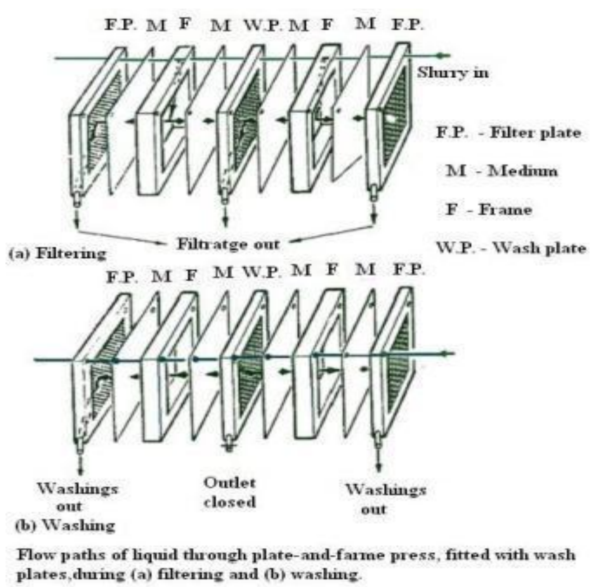

Fig.9.3 Filtering and washing

Another common design of filter press is known as the recessed-plates press. In this filter the cake accumulates within recesses in the plates and no frames are used. The feed is usually introduced centrally and removed via an outlet on the corners of each plate. For washing, the feed slurry is replaced by wash liquid entering through the same inlets. Many other types of vertical plate filters are available. Larger presses have facilities for lifting or moving plates and frames mechanically. Presses may be jacketed for temperature control.

The vertical plate filter has found very wide application is industry. It is simple in design and operation, compact, flexible and can be used to handle a wide variety of types of slurry. It is relatively cheap initially. On the other hand labour costs and filter cloth consumption are high and washing of the cake is not always efficient.

9.4 RATE OF FILTRATION

The basic filtration equation is

The basic filtration equation is

$$\frac{dV}{d\tau} = \frac{(-\Delta P)A}{\mu\left[\sigma\frac{W}{A} + r\right]} \quad \text{-------------(1)}$$

$$W = w.\ V$$

Where, w= mass of dry cake per unit volume of filtrate, kg/m^3 filtrate

$$\frac{dV}{d\tau} = \frac{(-\Delta P)A^2}{\mu[\sigma.W.V + A.r]}$$

$$\frac{(-\Delta P)A^2}{\mu.\sigma.W\left[V + \frac{A.r}{\sigma.W}\right]}$$

Where,

$(-\Delta P)$= Pressure – drop across the filter medium, N/m^2 or Pa

V= volume of filtrate collected in time τ, m^3

τ= duration of filtration, s

A= area of filtering surface, m^2

μ= dynamic viscosity of the filtrate, Pa.s or kg/m.s

σ= average specific cake resistance

W= mass of cake on dry basis, kg

r= resistance of the filter medium per unit area.

(2) Also it can be expressed in other forms. Transposing and integrating equation. We get

$$\mu.\sigma\frac{W}{A}\int_0^v V.dv + r.\mu\int_0^v dV = (-\Delta P).A.\int_0^\tau d\tau$$

Or

$$\mu.\sigma\frac{W}{A}.\frac{V^2}{2} + r.\mu.V = (-\Delta P).A.\tau$$

Or

Lesson-10
Gravity Settling, Sedimentation, Principles of Centrifugal Separation

10.1 INTRODUCTION

Separation of components of immiscible liquids by use of density difference is a well established method. In the dairy industry, the application of centrifugal force is done particularly in separating fat from rest of the milk. It is also being used in separating bacteria from milk.

Different components of milk have the following specific gravities:

Fat: 0.93

Skim milk: 1.036

Whole milk: 1.028 to 1.032 depending on composition

10.2 STOKE'S LAW

The rapidity of separation depends on various factors, and can be estimated by use of Stoke's law for gravity separation modified to include the centrifugal force, instead of gravitational force.

Origins of Centrifugal cream separation are from the fundamentals of particle separation by gravitational forces, due to density difference between various components. If the density of the particle is higher than that of the surrounding medium it sinks and if it is lower it rises. The particle remains in suspension if densities are equal.

Considering the particle in the figure 10.1, the particle is acted upon by two forces, viz. gravitational force and viscous force. The gravitational force pulls the particle down, and the viscous force is resisting the movement of the particle. The particle will come down, if its density is greater than the fluid, and it will move up, if its density is less than that of the fluid surrounding it. The expression for these forces is given below.

The Gravitational Force is expressed as:

$$\frac{\pi d^3}{6}\cdot(\rho_s \quad \rho_f)\cdot g \qquad \text{———————} \quad (1)$$

Where d= Diameter of the sphere

ρ_s = Density of solids.

ρ_f = Density of sphere

g = Gravitational component (acc due to gravity)

The viscous force is expressed as:

Co – efficient of resistance

$$\frac{\pi d^2}{4}\cdot\left(\frac{\rho_s}{2}\right)\cdot V^2 \qquad \text{—————} \quad (2)$$

Where V = Velocity of separation of sphere

Since the movement of particle is generally downward, the co-efficient of resistance can be

$$= \frac{24}{R_e} = \frac{24.\mu}{\rho d v} \qquad \text{——————} (3)$$

$$\frac{\pi}{6} d^{3^3}(\rho_s - \rho_f)\cdot g - \frac{\pi d^2}{4}\cdot\frac{\rho/_f}{2}\cdot V^2\cdot\frac{24}{V.d\rho_f}^{\mu^3}$$

$$\frac{d^2[\rho_s - \rho_f]}{6 \times 3}\cdot g = V$$

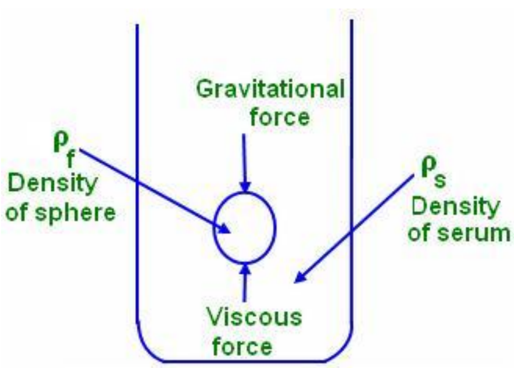

Fig.10.1 Viscous force

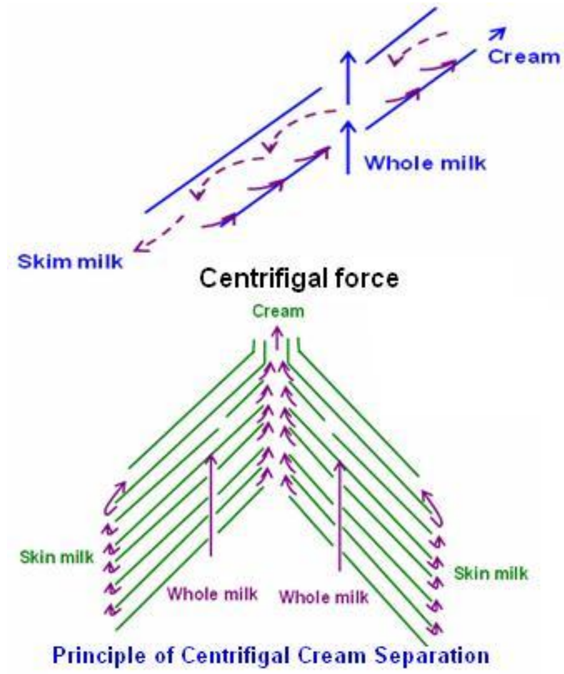

Fig.10.2 Cream separation

10.3 ENERGY OF ROTATING BODY

Calculation of the approximate power required to rotate the cream separator can be done by assuming that the stack of discs along with bowl as a hollow cylinder with uniform density throughout. The weight of the bowl, W can be given as

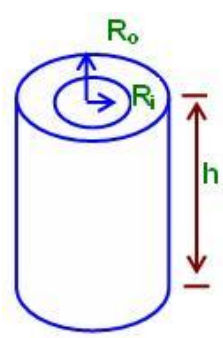

Fig.10.3 Energy of rotating body

10.4 CAPACITY OF CENTRIFUGAL SEPARATOR

The capacity of the centrifugal separator depends on the number of factors again, viz., the number and size of discs, speed of rotation, the viscosity of the fluid etc. An expression for the throughput of centrifugal cream separator is arrived at as shown below

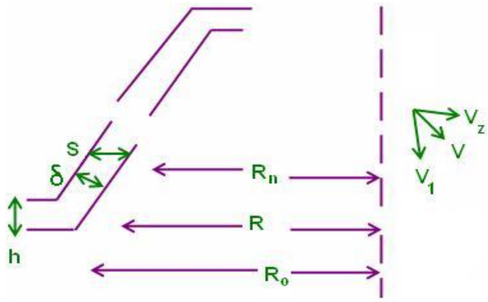

Fig.10.4 Centrifugal separator

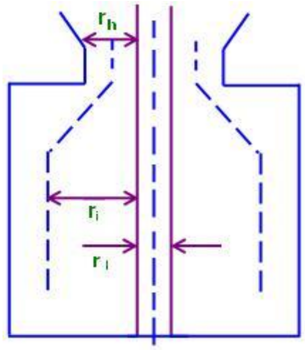

Fig.10.5 Drag force due to volumetric flow

'C' is added to take care of deviation due to

1. Velocity profile is not laminor flow
2. Decrease in cross sectional area due to back flow of lighter phase
3. Non- ideal distribution over the feed inlet circumference
4. Geometric in accuracies in the stacks of discs.

The position of neutral zone or the place where the milk enters the gaps between adjacent discs will influence the ease in separation of the denser and lighter phases of the fluid. In applications like Clarifier, where the component to be separated is the denser particles of dust, extraneous matter, the neutral zone should be towards periphery. In the case of cream separation, the component that is to be separated is the fat, which is of lighter phase, the zone has to be towards centre of the disc, to reduce the distance of travel for the separation.

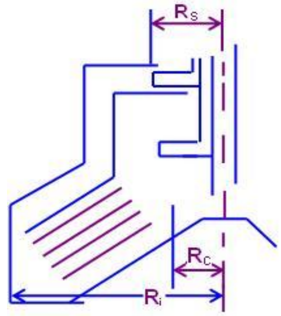

Fig.10.6 Drag force due to volumetric flow Q (m^3/sec

The pressure exerted by the lighter and heavier fluids, when in equilibrium, on the inner wall of bowl is same

The above is possible, only when the level of the lighter and heaver liquid, are different. (about 3 to 10 mm) by fitting overflow lips of different sizes

The distance R_S of the rotating separated milk ring is greater than R_C, the rotating of cream.

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Lesson-11

Different Types of Centrifuges: Application in Dairy Industry, Clarifiers, Tri-Processors, Cream Separator

11.1 INTRODUCTION

Mechanical separation by centrifugal force can be classified in broad terms as below, depending on physical state of the components being separated.

1. Liquid from liquid e.g. cream from milk by cream separator

2. Solid from liquid e.g. Ghee residue from ghee by Clarifier

3. Solids from gas e.g. powder from air by Cyclone separator

4. Gas from liquid e.g. vapours from Concentrated milk in Vapour separator

11.2 THE DIFFERENT TYPES OF CENTRIFUGES CAN BE CLASSIFIED AS

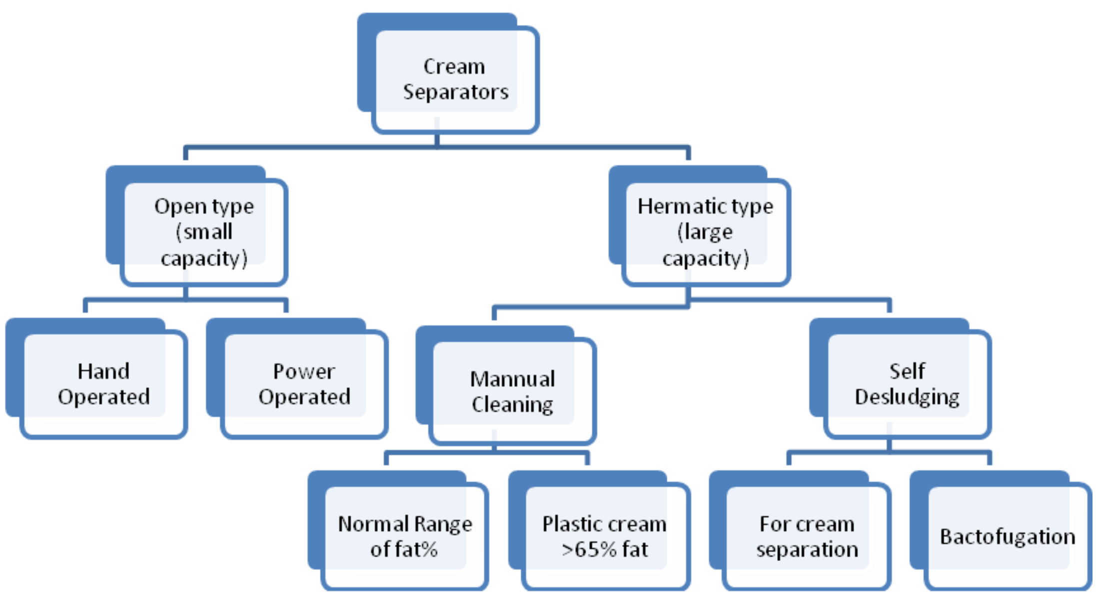
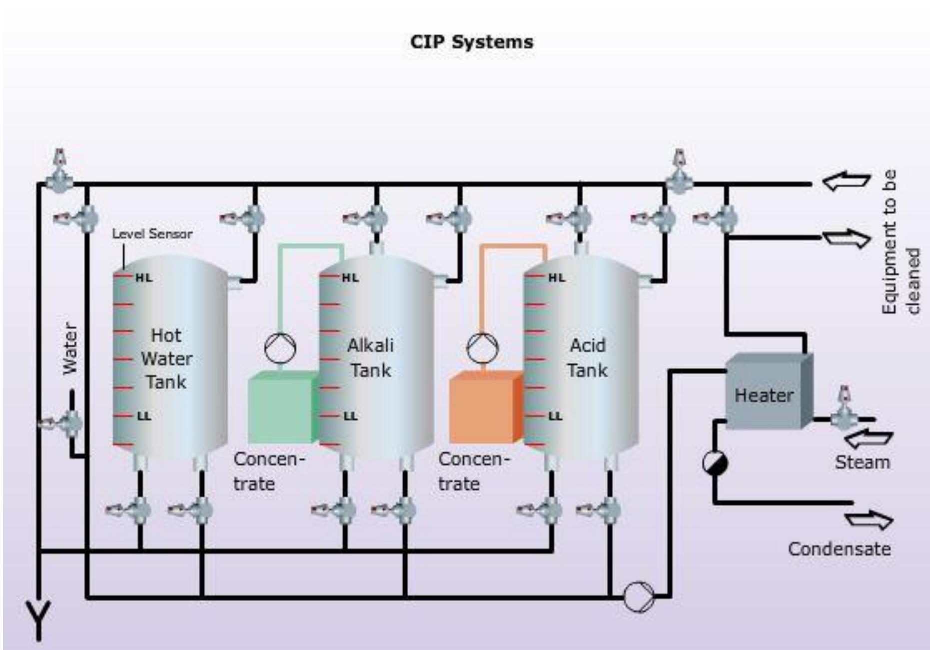


Fig.11.1 Types of centrifuges

11.2.1 Clarifier

One of the important applications of centrifugal force in dairy industry is the Clarification of milk. It is also based on the density difference between milk and the extraneous matter like dust, hair, leucocytes, and other contaminants. The clarifier is also used in separating Ghee from Ghee residue. The separation process is fast and almost complete. The Clarifier has one entry for the milk or the fluid to be clarified and one exit for the clarified material. The clarifier sludge gets collected in the inner wall of the bowl carrying the discs. The discs are conical in shape and are mounted on a spindle that rotates at high speed and have holes to allow passage of milk to the gaps between the clarifier discs. The location of the holes, called the neutral zone is located nearer to the periphery, such that heavier particles that are to be separated is moved more easily.



Milk Clarifying Bowl 11.1

11.2.2 Open type of cream separators

These types of cream separators are fed by milk open to atmospheric pressure, and flow down in separator discs by gravity from a vessel also open to atmosphere. These separators are of smaller capacity, maximum of 1000 lph. They are suitable for sour milk separation and are driven by belt and pulley, powered by small motor. The feed from the vessel flows by gravity through a spout. A float positioned on the top of the inlet prevents entry of air, and allows only milk to enter into the bowl.

The separator disks in the bowl are about 16 to 25 in number, depending on the capacity, and the size . The cream outlet is controlled by a small screw, by which the fat percentage of cream can be varied. As the open type cream separators are not expected to be connected to pasteurizers, and are of small capacity, they are designed to operate with milk not being warmed.

The drive mechanism for the bowl spindle is by a flat belt connected to the driver shaft. The driver shaft is driven by single speed motor. In some smaller capacity designs, the bowl spindle forms the worm and the driver shaft is the worm wheel, which may be driven by hand or by motor connected through a V belt and pulley.

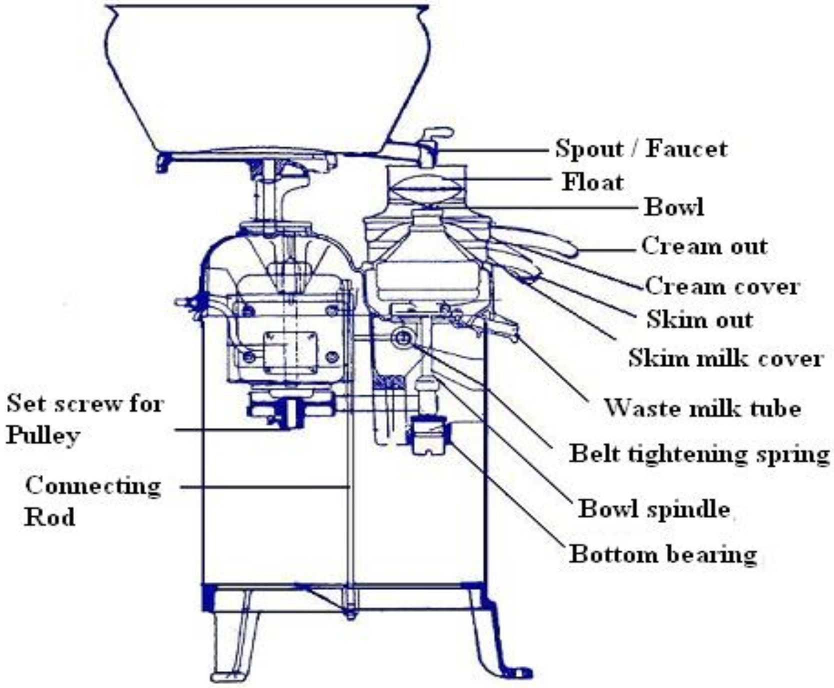


Fig.11.2 Small capacity cream separator

11.2.3 Hermetic cream separator

The disadvantage of open type cream separator is that it is suited for only small capacities and the discharge is to atmospheric pressure. It cannot be linked to pasteurizer so that the separation can be done at the optimum temperature of 40 to 45°C. The other disadvantage is the product being open to the atmospheric contamination and ingress of air, making the product foamy. The Hermatic cream separator is of larger capacity, and both inlet and outlet are connected to pipes, making it possible to operate under completely air tight condition.

Tri-purpose or Tri-process separators are designed for three purposes, to do separation, standardization and clarification in a single unit. Milk contains dust, leukocyte cells etc, which are removed before processing. This function of Triprocess separator is called “Clarification”. Depending upon the requirement, the fat may be removed partially to a fixed percentage known as standardization or completely skimmed termed as cream separation. The control of cream outflow can lead to these variations in operations.

11.2.3.1 Description

1. The separator has horizontal and vertical drive systems for the separator bowl.

2. The horizontal drive system consists of an electric motor, centrifugal clutch and drive shaft with worm wheel.

3. The vertical drive system consists of a shaft , called the bowl spindle on the top of which the separator bowl is mounted. The shaft has teeth to match worm wheel.

4. Power from the motor is transmitted from the worm wheel on the horizontal drive shaft to a worm gear of the bowl spindle.So the bowl spindle rotates at higher speed (say 4 to 5 times higher) than the horizontal drive shaft speed.

5. Precision ball bearings support the drive components and thus eliminate vibration.

6. Also mounted on frame is a hand brake acting on the clutch disc, a tachometer and revolution counter button for speed indication, an oil filter plug and a drain plug, an oil level glass, etc.

7. The bowl consists of two main sections: the body and the hood, which are held together by a threaded lock ring.

8. The disc stack is clamped between the hood and the bell shaped distributor at the axis of the bowl.

9. The gap between discs is about 0.5 mm. The disc wall thickness is about 0.4 mm and angle of inclination to the horizontal is 45 to 60 degrees.

10. The bowl speed is usually 5500 to 6000 rpm.

11. The bearings in the frame are splash lubricated by the worm wheel, which runs partially, immersed in an oil bath in the base of the frame.

12. Separators separate about 98.5 to 99% of fat in milk (0.02 to 0.05% fat in skim milk).

13. Cream outflow from the separator normally represents about 10% of the total milk feed.

14. The feed to the separator is by a pump, in case the supply tank is far away. Otherwise, a centripetal pump with impeller leads the milk suction line into the spindle, from where the milk enters the bottom of the distributor.

15. For the requirement of standardization, the outlet of cream is kept at a higher discharge pressure to that of skim milk outlet. The flow rate of cream is measured by a rotometer.

The internal parts of the bowl and the drive mechanism is shown in figures 11.2 & 11. 3.

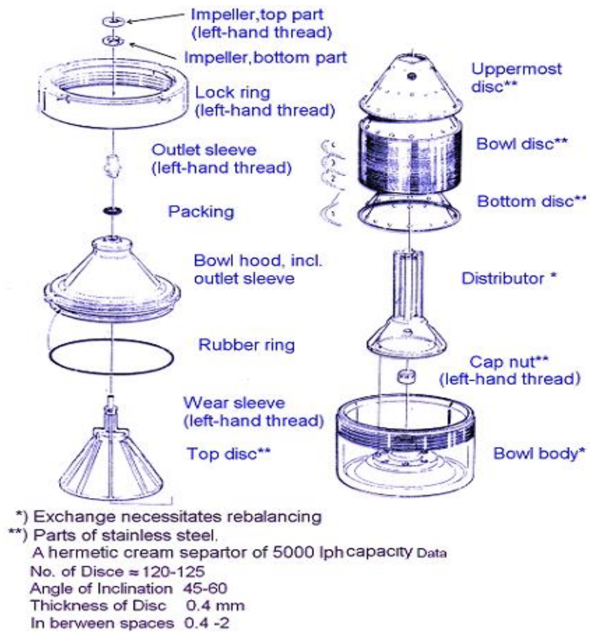


Fig.11.3 Hermetic cream separator (Adapted from Operators manual of Alfalaval Pvt Ltd)

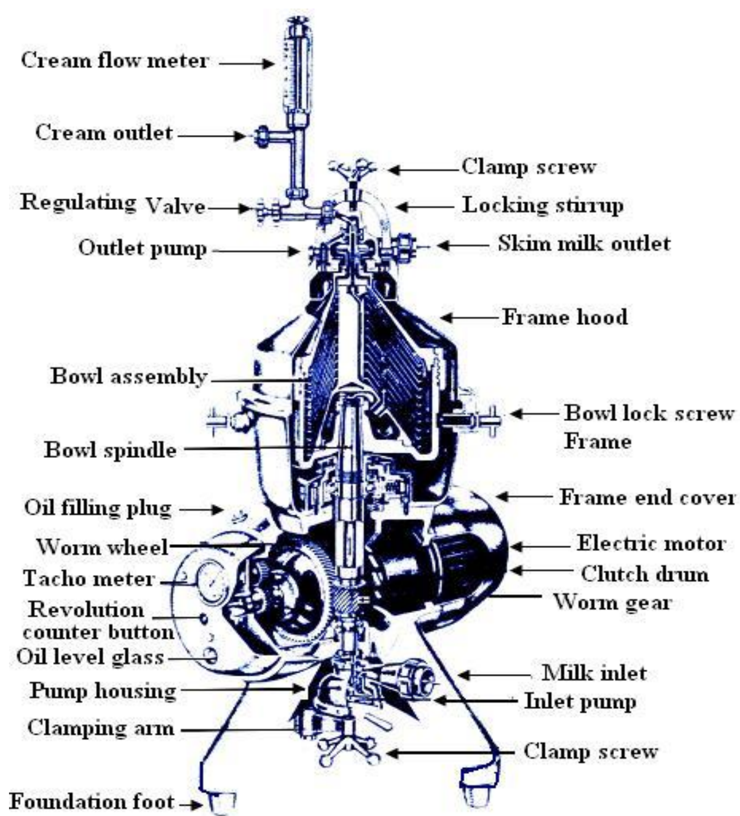
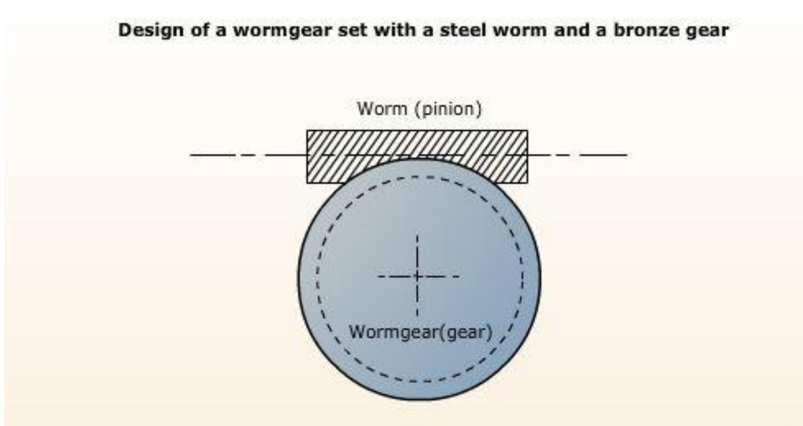
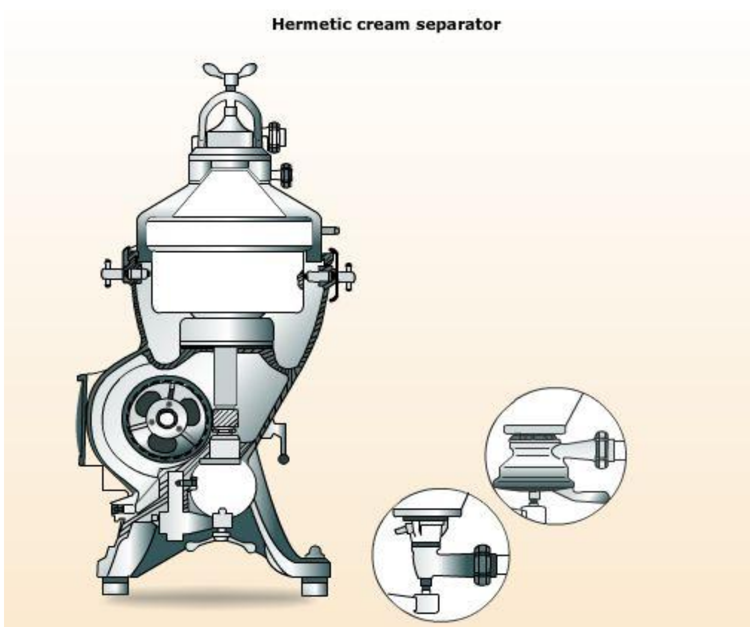


Fig.11.4 Cream separator (Adapted from Operators manual of Alfalaval Pvt Ltd.)



C =	Center-to-center distance
N1 =	Worm teeth number
N2 =	Gear teeth number
φn =	Worm normal press angle
n =	Pinion speed
Cast method	1=sand, 2=chill, 3=centrifugal

Hermetic Cream Separator 11.2



Worm and Worm wheel 11.3

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Lesson-12

Self- desludging Centrifuge, Bacto-fuge, Care and Maintenance of Separators and Clarifiers

12.1 INTRODUCTION

Cream separator and also clarifier, have to be stopped, and dismantled for cleaning often, especially when the quality of the milk is bad. This involves interruption of HTST pasteurization operation also. Hence, a method of ejecting the sediment that is separated during clarification or cream separation was developed. This involved certain changes in the design, especially the lower part of the bowl which encloses the separator discs.

12.2 SELF DESLUDGING OPERATION

The milk sludge, produce during the separation in a separator collects in the sludge space of the bowl, which is designed as double taper. The bottom disk of the sludge space can be controlled hydraulically to be moved downwards, so that the sludge can leave the bowl through the double conical portion, where holes get uncovered. The sludge ejected from the bowl is collected in the upper transmission part consisting of stainless steel, and is fed through the sludge collector to the sterilizing vessel. The sludge collected in vessel is sterilized by adding caustic soda, under high temperature. After the sterilizing process has been terminated, the vessel must be emptied in order to make provision for having space for fresh sludge ejections. The hydraulically controlled bowl opening mechanism can be operated both manually and automatically.

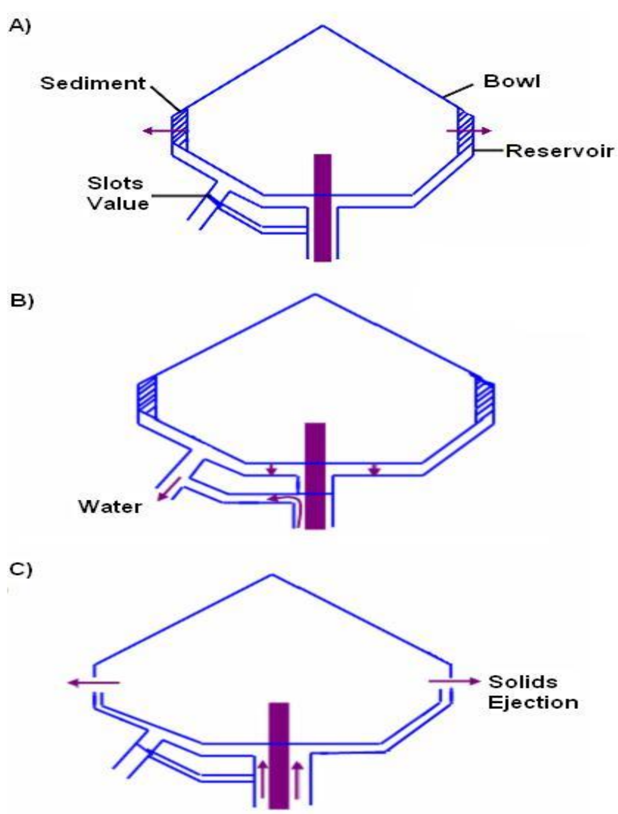

Fig.12.1 Self desludging operation

12.2.1 Control system diagram

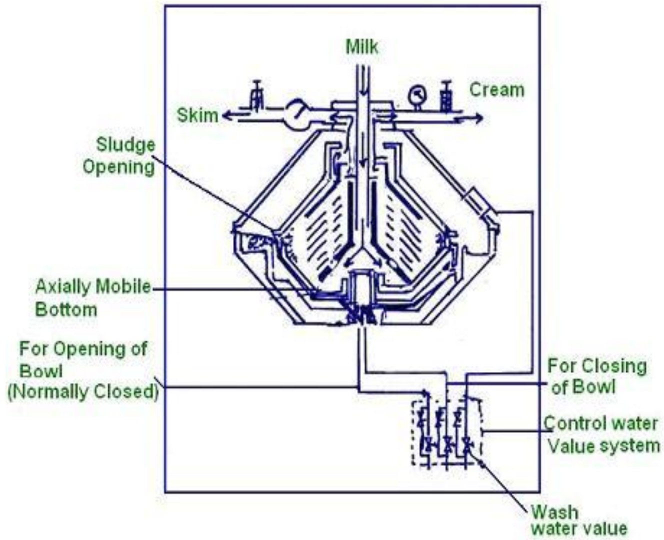

Fig.12.2 Control system

12.2.2 Operation of control system

The removal of the sludge from the bowl is through the openings arranged at the widest circumference of the sludge space, and closed by an axially mobile bottom during the separation process. The opening and closing movements of the mobile bottom valve are controlled by a hydraulic control system. The control system associated with the bowl consists of the mobile bottom valve hydraulically movable in the bowl; the control water feed , the control water valve system with the solenoid and manually controlled valves for automatic and manual control, and the program control system. The bowl control system is operated in normal operation by a preselected desludging program. Any required full desludge operation can be controlled semi- automatically by the valve control cabinet. In the case of current failure or other possible defects, putting the control cabinet or the electrical control valves out of operation, the separation process can be brought to an end by operating the manually-operated valves.

The water used for hydraulic operation must be clean, soft fresh water. The control water pressure also must be sufficient, usually about 2.5 $kgcm^2$

12.3 BACTOFUGATION:

Bactofugation is the process of separation of microorganisms from milk by using centrifugal force.

12.3.1. Advantages

- It is useful when UHT process is being done for the milk
- In the production of low heat powder, both aerobic and anaerobic spore formers can be considerably reduced. The low heat powder is useful in preparation of recombined milk.
- Cheese making for special cheeses using unpasteurized milk e.g Mozarella, Camemberti
- Most of the spores can be removed, and only that component which is around 2.5 to 3.0% of milk will be given the UHT treatment, thereby saving energy and nutritional quality.
- Because only part of the milk is heated, it is economical.

12.3.2 Densities of components

As the separation by centrifugal force depends on density differences, its is useful to know the densities of various components.

Table 12.1 Densities of various milk components

	Density(gm/cc)
Milk	1.028 to 1.032
Skim milk	1.036
Fat	0.93
Bacteria	1.07 to 1.13

As we observe the above values, the bacteria is denser than most of the components, and hence, it can be separated by regular centrifugal process. Care must be taken to safely dispose of the sludge that is separated. A self-desludging type of separator is most suitable.

12.3.3 Effect of bactofugation

By Bactofugation at 50 to 55 °C about 89 to 93% of the bacteria is removed. It be still more effective, if the milk is first clarified and then Bactofugation is performed, eliminating bacteria upto 99%.

Table 12.2 Percentage of components removed by clarifier and bactofugation

	Clarifier slime	**Bactofugal slime**
T.S	18.2 %	16.0 %
Fat	0.03%	0%
Protein	12.8 %	11.3%

12.4 BACTOTHERM

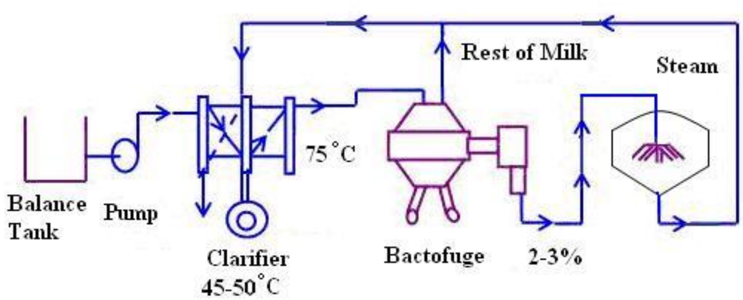

Fig.12.3 Bactotherm Process

12.5 MAINTENANCE OF SEPARATORS AND CLARIFIERS

Centrifugal separators are high speed equipment, with clarifier bowl having discs held vertically by support of bearings. The passage of the fluids like milk, cream, skim milk are separated

12.5.1 General observations in maintenance

1. Rubber gaskets, 'O' rings must be replaced before they wear out
2. Lubrication oil in the oil sump must be of required quality and should be upto appropriate level.
3. Bearings holding the spindle must be replaced regularly, to prevent bending of the shaft itself, in addition to rapid wear out of 'o' rings, drop in efficiency of separation and capacity.
4. Discs should be cleaned with softer material and not with wire mesh, and should be placed on rubber mat during cleaning.
5. The discs should be stored properly without damage.
6. Assembling of discs and other components must be properly done, without causing any vibrations, damage to parts and decrease in capacity.
7. Cream separator should not be run dry without any fluid.
8. No adjustments, assembling, disassemble to be done while the cream separator is revolving.
9. Worn out worm or worm wheel to be replaced before damage to other parts due to jerks, and loss of speed of rotation of bowl.
10. Centrifugal clutch shoe should be replaced to prevent any loss of power transmitted to worm wheel. They have to be roughened from time to time to give grip.
11. Bearings to the shaft of worm wheel should be replaced when worn out.
12. Under no circumstances, the direction of rotation of spindle be changed. This is likely to happen, when motor for the drive is repaired and reconnected with the three phase line, without checking for the direction of rotation.
13. Milk being fed to the separator must match the desired feed pressure recommended.
14. While assembling and disassembling, the nature of the threads whether right hand threads or left hand threads should be taken note of and accordingly done.
15. Under no circumstances, the weight of the connecting pipe lines should strain the separator.
16. Some of the cream separators like self desludging type, the lubricating oil is further cooled by cooling water. It is important that the cooling water should be of sufficient flow and pressure required, as well as soft water type. Under no circumstances, the cooling water by pass valve from the control water line should be closed or disturbed once the flow requirement is set.
17. The cream separation should not be done at too high temperatures than recommended, as the life of the rubber collars, packing etc will be reduced.

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Lesson-13

Solving Numerical

13.1 Problem on Gravitational separation

Calculate the rate of rise of fat globule of diameter 3 microns at 20 °C with a density of solids – not – fat as 1030 kg/m^3 and that of fat globule as 930 kg/m^3 and the viscosity of liquid as 1.79 x 10^{-3} Pa. S

Soln: V = d^2. (r_s - r_f) . g / (18 . micron)

= 3 x 3 x 10^{-12} x (1030 – 930) x 9.81 / (18 x 0.00179)

= 2.74022E-07 m/sec

= 0.00986 m/h

13.2 Problem on Centrifugal separation

For the above problem 13.1 if radius of bowl , R = 0.14 m and RPM is 5500 rpm, determine the fat separation velocity.

Ans: Velocity of separation of fat, V = 0.0933 m/sec or 335.909 m/h

13.3 Determine the Capacity of Hermetic Cream Separator if:

No. of discs	105	
Disc Angle	55	o
Outer Radius, Ro	0.13	m
Inner Radius, Rn	0.075	m
limiting diameter of fat globule,d	1.6	micron
Number of revolutions, n	6000	100 rps
Density difference of milk and fat globule, Δρ	116	kg/m3
Correction factor, C	0.6	
Absolute Viscosity, η	1.04x10^{-3}	0.00104 Pa.s

Solution:

$$Q=C(2\pi)^3 \, z \, \tan\alpha \, (Ro^3 - Rn^3) \, n \times d^2 \, 10^{-12} \, \Delta\rho \, /18 \, \mu$$

Q = 7530 l/h

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Lesson-14

Homogenization: Classification, Single Stage and Two Stage Homogenizer Pumps, Power Requirement for Homogenization

14.1 INTRODUCTION

Homogenizing in the dairy industry is used principally to prevent or delay the formation of a cream layer in full cream milk, by reducing the diameter of the butterfat globules.

The average storage temperature and duration of storage play an important part in determining the requirement of homogenization of milk, whether, as in pasteurized milk, it is stored for 1 to 2 weeks at refrigerator temperatures, or, as in UHT milk, at room temperatures for longer period.

In the past it has been very rare for pasteurized liquid milk to be homogenized, although the flavour of milk becomes fuller by homogenizing. A certain amount of cream was permitted to form to show the consumer clearly the full cream character of the milk. However, Homogenization process has become more common for Toned milk also. Sterilized milk, evaporated or condensed milk and sterilized cream are generally homogenized. Ice cream mixes, milk for yoghurt production and milk for milk powder manufacture are also homogenized.

The purpose for which the following are homogenized is:

Milk, cream, condensed milk	Prevention of cream separation
Coffee cream	Improvement in flavour, increased Whitening power, increase in Viscosity
Yoghurt	a more stable gel
Ice cream mix	less fat separation during freezing
Full cream milk powder	less separation of free fat

14.1.1 Mode of operation

In milk greater part of the fat volume consists of globules with a diameter ranging from 2 to 6 mm. A few fat globules may exist which have a diameter of 10 mm or more. Milk fat contains also a large number of small fat globules with diameters down to 0.1mm, but these do not greatly increase the total volume of the fat. The largest fat globules in liquid milk intended for only a few days' storage need not be smaller than 1 - 2 mm. If sterilized milk is to be made suitable for several weeks' storage, the range of diameter of the fat globules should lie between 0.2 and 0.7mm. Researchers found that the diameter of 0.7 mm is critical for fat clumping. With a diameter less than 0.7 mm the dispersion fat globule-milk serum is stable, since aggregates of fat globules become separated again by Brownian movement. This is not so for formation of clusters at higher fat contents (> 20 %) where the sub-units of the casein micelles keep fat globules together by bridge formation.

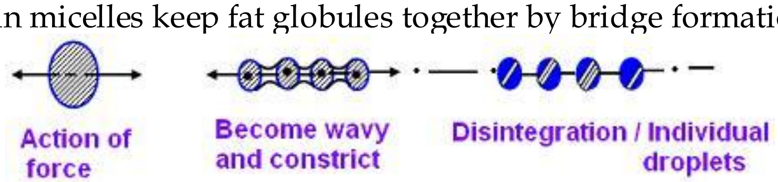


Fig.14.1 Principle of fat globule disintegration

Homogenization divides globules into smaller ones with diameters down to <1 µm, depending on the operating pressure. This is done by forcing all of the milk at high pressures through a narrow slit, which is only slightly larger than the diameter of the globules themselves. The velocity in the narrowest slit can be 100 to 200 m/s. This can cause high shearing stresses, cavitation and micro-turbulence. The globules become deformed, then become wavy and then break up (fig 14.1).

Intense research activities in the last few years have been very successful in elucidating the actual mechanism of homogenization. There is a definite relationship between the Laplace number La, a dimensionless homogenizing pressure, and the degree of particle size reduction, irrespective of whether flow is laminar or turbulent.

$La = \Delta p.d_{mo} / б$

where Δp=pressure difference

d_{mo}= mean initial particle size.

б =Interfacial tension.

When cavitations were suppressed, the degree of homogenization was the same at the same Laplace number, independent of the type of flow. This shows that turbulence is not a decisive criterion for the results of homogenization. However, the effect of homogenizing can be improved if cavitations take place.

According to the theories of flow mechanics, a particle size reduction should only be possible if the viscosity ratio n_{Oil}/n_{water} is less than 4. In the homogenization of milk this ratio is 2 to 4 times larger. Nevertheless, the shearing effect at the homogenizer slit can not be excluded since there are high shear gradients as well as very high velocity gradients which can have an accelerating as well as a retarding action. As soon as a liquid thread is produced by deformation only small forces are needed to break it up. Some research workers established the following proportionality for the mean globule diameter d_m:

Cavitation occurs when the kinetic energy ($m.v^2/2$) increases during flow through the slit and when, according to Bernoulli's equation, disregarding friction and deformation losses, the potential energy (P.v) decreases to such an extent that the static pressure becomes as low as the vapour pressure of the liquid. The pressure distribution during flow through a homogenizer slit is qualitatively shown in Fig.**14.2** Shortly after the liquid enters the homogenizer slit, the initial homogenizing pressure P1 decreases sharply due to the sudden increase in velocity. Depending on the value of the back pressure P2 which exists outside the slit, the pressure can drop to as low as the saturated vapour pressure. P_{2k} shows that a critical back-pressure must be present for cavitation to occur. For the formation of vapour bubbles due to cavitation it is necessary to have a local pressure of less than Pv and gas nuclei to trigger it off. De-gassing of milk can influence cavitation negatively. Cavitation does not take place if the back pressure P_2 is higher than P_{2K} .

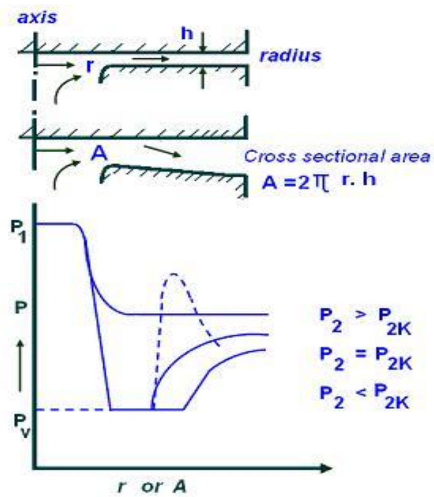


Fig.14.2 Homogenization

Implosion, of cavitation bubbles is one of the main indications of good homogenization. This is shown by a steep rise in pressure. Similar sudden pressure changes are also known to happen in the Laval valve which is of the continuously widening type. There, compression occurs when a uni-phase flow accelerated up to supersonic velocity abruptly changes into sonic velocity. Figure **14.3** shows further that the cross-sectional area of a homogenizer valve behaves like a Laval valve. Using Bernoulli's equation one finds, from the relationship.

$\sqrt{v} \approx 2\ p$

ρ

that the homogenizing velocity can be as high as about 250 mls. The requirements for a compression shock can be fulfilled also in homogenizing, depending on the shape of the slit and the pressure conditions. The intensity of the compression shock depends on the geometry of the slit and it can be influenced as by the value of the applied back pressure .As in the valve with varying gap, the compression shock can also reach a maximum within the homogenizer slit, as shown by the dotted line. These are conditions which give optimum homogenizing results.

It is not known how implosions of bubbles disintegrate droplets. The following hypotheses have been proposed: Extremely high local pressure gradients form during spreading of the shock waves. An overlapping of many shock waves produces cavitation noises. The implosion of a single bubble cannot contribute to the disintegration of the fat globule. According to one of the hypothesis of researchers only the overlapping of shock waves, which cause cavitation noises, stimulates the fat globules to resonate near their own frequencies and disintegration occurs when the critical amplitude is exceeded.

With regard to shear stress, fat globule disintegration occurs mainly in flows which have high shear gradients. Flows which cause cavitation are responsible for pressure fluctuations. Water is required in medium sized homogenizer for cooling of piston rods.

14.2 TYPES OF HOMOGENIZER VALVES AND THEIR PROFILES:

Figure **14.3** shows types of homogenizer valves. Valve plugs are pressed with an adjustable force F onto the corresponding valve seat. In this way the homogenizing slit is formed when the incoming liquid has adjusted to the pressure P_1,

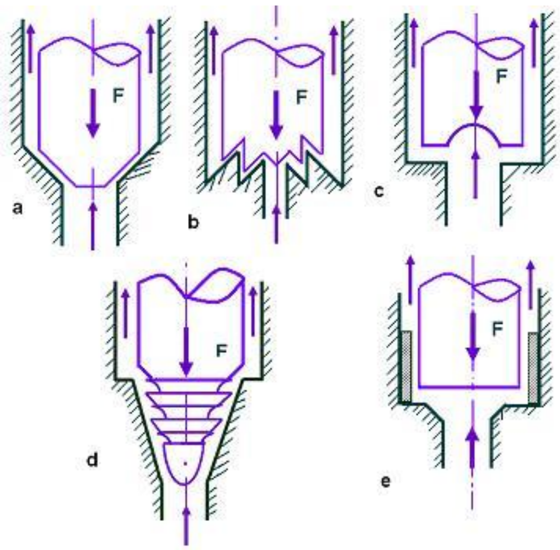


Fig.14.3 Homogenizer valves and their profiles

A conical shape, (b) causes changes in direction due to its profile, (c) shows a simple plate valve and (d) a conical shape but with a grooved valve face which forces alternating stresses onto the liquid to be homogenized, e shows a valve with a breaker ring which has a flat valve face and a conical seat. Changes in the radial cross section can be brought about by means of the cone. By altering the internal diameter of the breaker ring, the back pressure P_2 and therefore the position of the zone of cavitation can be adjusted.

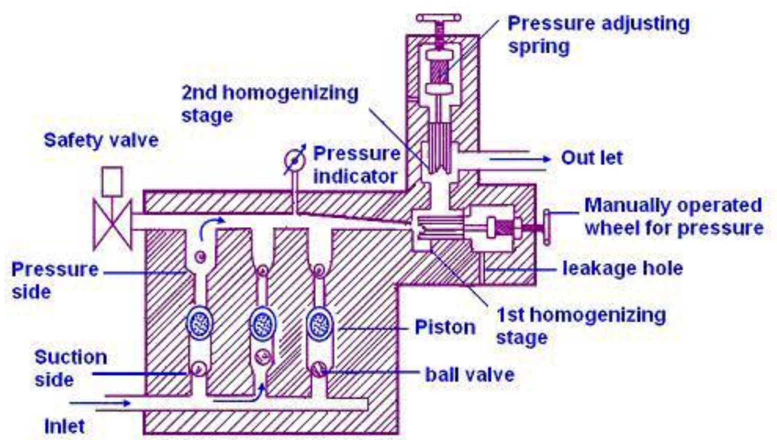
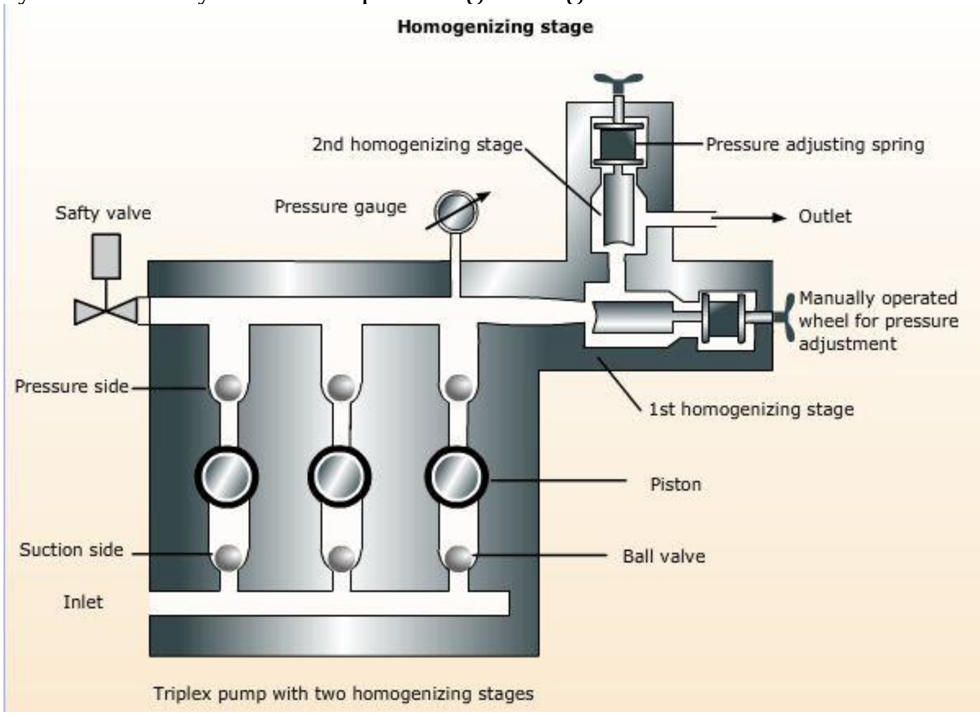


Fig.14.4 Homogenization

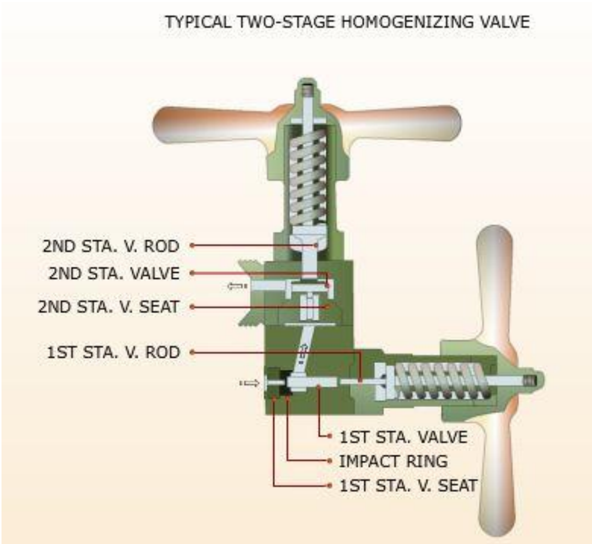
Figure 14.4 shows the mechanism of a 3 stage piston pump with two homogenizing steps joined in series. The 120 phase shift of each working piston respectively, sucks in the liquid while the valves open on their suction side and are closed on their delivery side. The pistons finally force the liquid through the homogenizer value when the value positions are reversed. The required pressure can be regulated from outside by pressure springs while the machine is in the operation. Beside triple stage piston pumps, five- stage ones are often used for homogenizing because of their even feed characteristics.

Two-stage homogenizing is not always necessary. It is used. however, if the broken up fat globules have a tendency to agglomerate after the first homogenizing stage (150 - 200 bar) in order to re-disperse them at 20 - 40 bar in the second stage. By a suitable construction of the valve, both processing stages can be combined, A homogenization procedure of two or several stages has only a slight effect on the mean particle size. In modern homogenizer, the adjustment of pressure is done by pneumatically operated valve.

The throughput through a homogenizer can be regulated by either adjusting the piston stroke of a piston pump or by an infinitely variable speed regulating device.



Homogenizing Stage14.1



Typical Two- Stage Homogenizing Valve 14.2

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Lesson-15

Care and Maintenance of Homogenizers, Aseptic Homogenizers

15.1 INTRODUCTION

Homogenizer is heavy equipment, operating at high pressures. Hence, the care and maintenance is important for the long useful life of machine, and safe operation of this high pressure machine.

The condition of Homogenizer can be known from the extent of breaking of fat globules after homogenizing. The Homogenizing efficiency is found by either direct microscopic method or by cream layer method.

15. 2 VALVES

The homogenizer valves over a period of use, will lose its proper shape, and may form grooves. It needs to be reground or replaced. If the seals of the valves are leaking, they have to be replaced immediately. The faces of the valve and valve seat must be kept in good serviceable condition to retain an efficient homogenization of the product. This can be recognized by the amount of wear that initiates at the bore of the valve and radiates out across the face. If the wear is up to two-thirds of the surface area, relapping of the valve with carborundum paste between faces can rectify this but further wear will allow erosion grooves to appear, recognized by straight lines radiating outward, and loss of homogenization will rapidly occur.

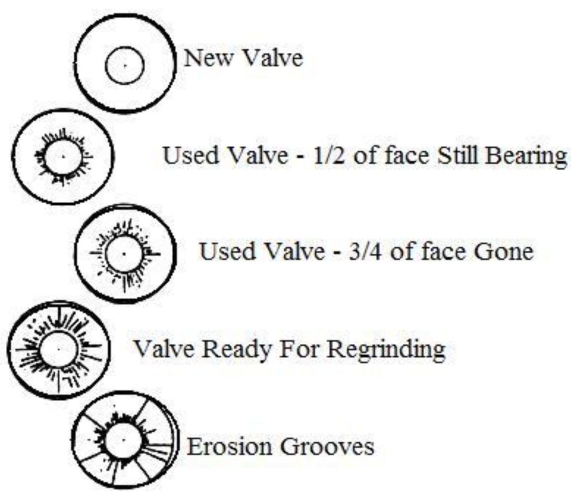


Fig.15.1 Homogenizer valve wear

15.3 PRESSURE GAUGES

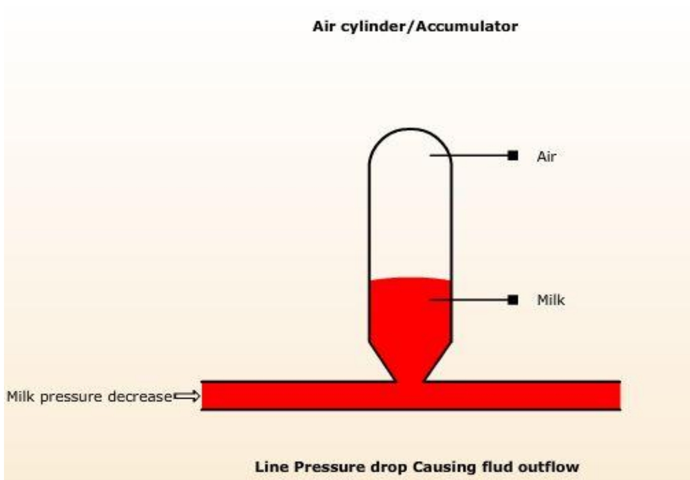
The pressure gauges measuring the pressure of milk must have stainless steel components and should be filled with glycol fluid to reduce corrosion and damping the vibrations. The gauges must be calibrated from time to time. The pressure gauges measuring the oil gauges must also be check for calibration frequently.

15.3.1 Safety Valve

It has to be tested for its setting, and whether it releases pressure at the set point, by use of Hydraulic test pump.

15.3.2 Reducing Pressure fluctuations

Reducing pressure fluctuations in suction side and discharge side is very important in effective operation of Homogenizer, as well as its effect on the related equipment like Pasteurizer to which it is connected. For this, generally, the Air cylinders are fixed both on suction and discharge pipelines connected to Homogenizer. The Air cylinders have air in the vessel that is cylindrical and in an inverted position, connected to the pipeline. As the pressure increases in the pipe line, the air in the cylinder gets compressed, resulting in a slight reduction in the line pressure. In the next stage in the cycle of operation, during suction stroke, the pressure in the line decreases, during which, the air in the vessel, which is at higher pressure related to the line pressure, will now expand, replacing some of the fluid that has entered into the vessel. Thus, the pressure fluctuations in the pipeline are reduced to some extent.



Air Cylinder Operation 15.1

15.4 POWER DRIVE

1. Whenever drive motor is repaired / replaced, the direction of rotation has to be checked, as the same shaft is most probably driving the lubrication mechanism, and would not deliver the lubrication oil at the required pressure, even if the rotation is slow.
2. The bearings, belts are to be replaced when necessary as per the preventive maintenance schedule. The lubrication oil, or the cooling water should not be spilling where belt drive is located, as it would cause slippage and damage to the belt.
3. Replacing V-belts one at a time (when wear is detected on one only) is a risky operation since the new one - being shorter - is likely to carry most of the load. Belts must be tensioned correctly to transfer the drive and prevent unnecessary wear. The following are suggestions on how to do a simplified testing during routine maintenance inspection. When stopped, a correctly tensioned V-belt should, if pressed firmly with the thumb near the mid-point (half way from centre to centre), depress 3/4 of its own thickness for each one metre centre to centre distance.

During assembling and disassembling, the dismantled parts must be kept on table over a rubber mat to prevent damage to the parts as well as to avoid any contamination.

A daily inspection should be made of the oil level visible through the sight glass at the rear of the machine. Lubrication oil should be replaced regularly, as per manufacturer's instructions, and its pressure to be maintained while running the equipment. After draining off any condensate from the oil sump through the pet cock, oil should be added if required, before starting up the homogenizer. The oil should be completely drained and replaced, after every 6 months.

The levelling of homogenizer should also be maintained, as it is likely to get disturbed over the period due to vibrations during operation.

Cooling water should of the quality and flow rate recommended by the manufacturer. The flow to the piston rods should be sufficient, especially if water is cooling the oil.

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Lesson-16

Solving Numerical

16.1 PROBLEM:

Calculate the power consumption of a homogenizer having capacity 10,000 lph, operated at 250 bar pressure.

1. Power Consumption = Pressure. Volumetric rate

E = P . V

V = 10,000lph =10/3600(m^3/s). m^3/s

1m^3 = 1000lt

P = 250 bar =250 x 10^5 kg/s^2m

$$E = \frac{10}{3600} \times 250 \times 10^5$$

=0.69444 x 10^5

≈70kw

16.1.2 In case the inlet pressure, efficiency of pump & motor are considered.

Calculate the power consumption of a homogenizer if the feed rate is 1800 lph and the operating pressure is 200 bar. The inlet pressure of milk is 2 bar, and efficiency of homogenizer is 95%.

Soln:

Electrical Power: $$\frac{Q_{in} \times (P_1 - P_{in})}{3600 \times n_p \times n_{motor}} \text{ KW}$$

When Q_m = feeding rate l/h

P_h = Homogenisation pressure (bar)

P_{in} = Pressure at which milk enters Homogenizer (bar)

n_{pump} =Efficiency of pump

$$= \frac{1800 \times (200-2)}{3600 \times 0.85 \times 0.95}$$

= 122.6 K.W

16.1.3 Find out the increase in temperature after homogenization for the given data below:

C milk = 3900J/kg K

ρ milk=1030kg/m^3

P=250 x 10^{5}kg/s^2.m

Soln:

Increase in temperature of homogenized liquid is proportional to

$E = P.V = V.\ \rho .C.\ \Delta\theta$

Or $\Delta\theta = \frac{P}{C.\ \rho}$ $\Delta\theta = P/C.\ \rho$

$$\Delta\theta = \frac{250 \times 10^5}{3900 \times 1030} = 6.2^0\ C$$

16.1.4 Calculate the final outlet temperature of milk from the homogeniser if the inlet pressure is 2 bar, homogenising pressure 175 bar and milk inlet temperature is 50^{o}C.

Soln:

Another assumption is that for every 40 bar pressure drop, the temperature of milk rises by 1^{o}C,

$$T_{out} = \frac{P_h - P_{out}}{40} + T_{in}$$

$T_{in} = 55\ ^{o}C$

$P_h = 175$ bar

$P_{out} = 2$ bar

$$T_{out} = \frac{175 - 2}{40} + 55$$

= 59. 325^{o}C

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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.

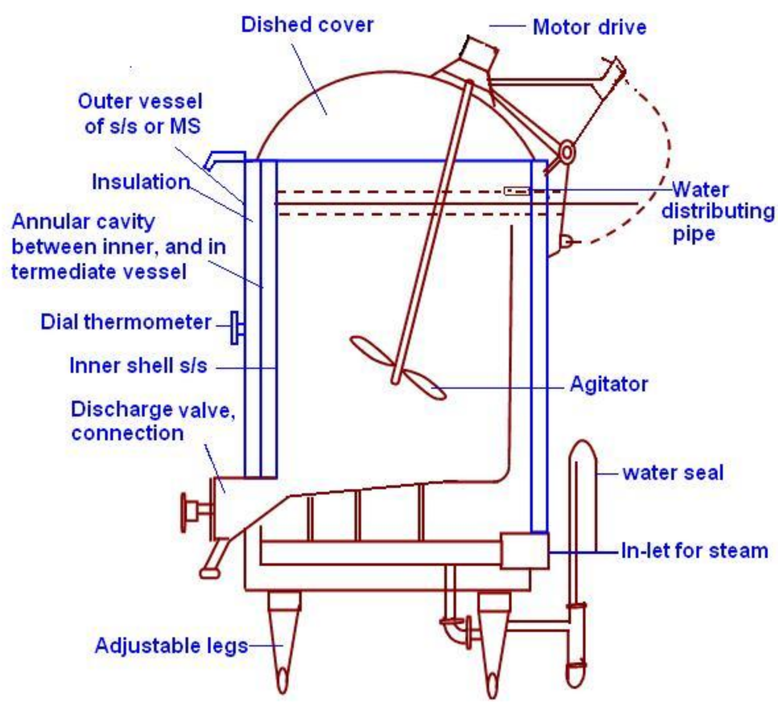


Fig.17.1 Batch pasteurizer

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

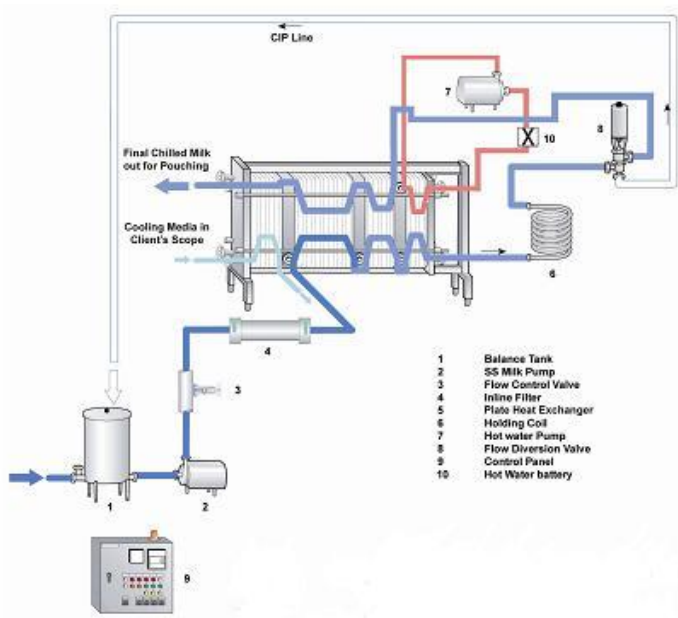
T_s = Hot fluid temperature

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

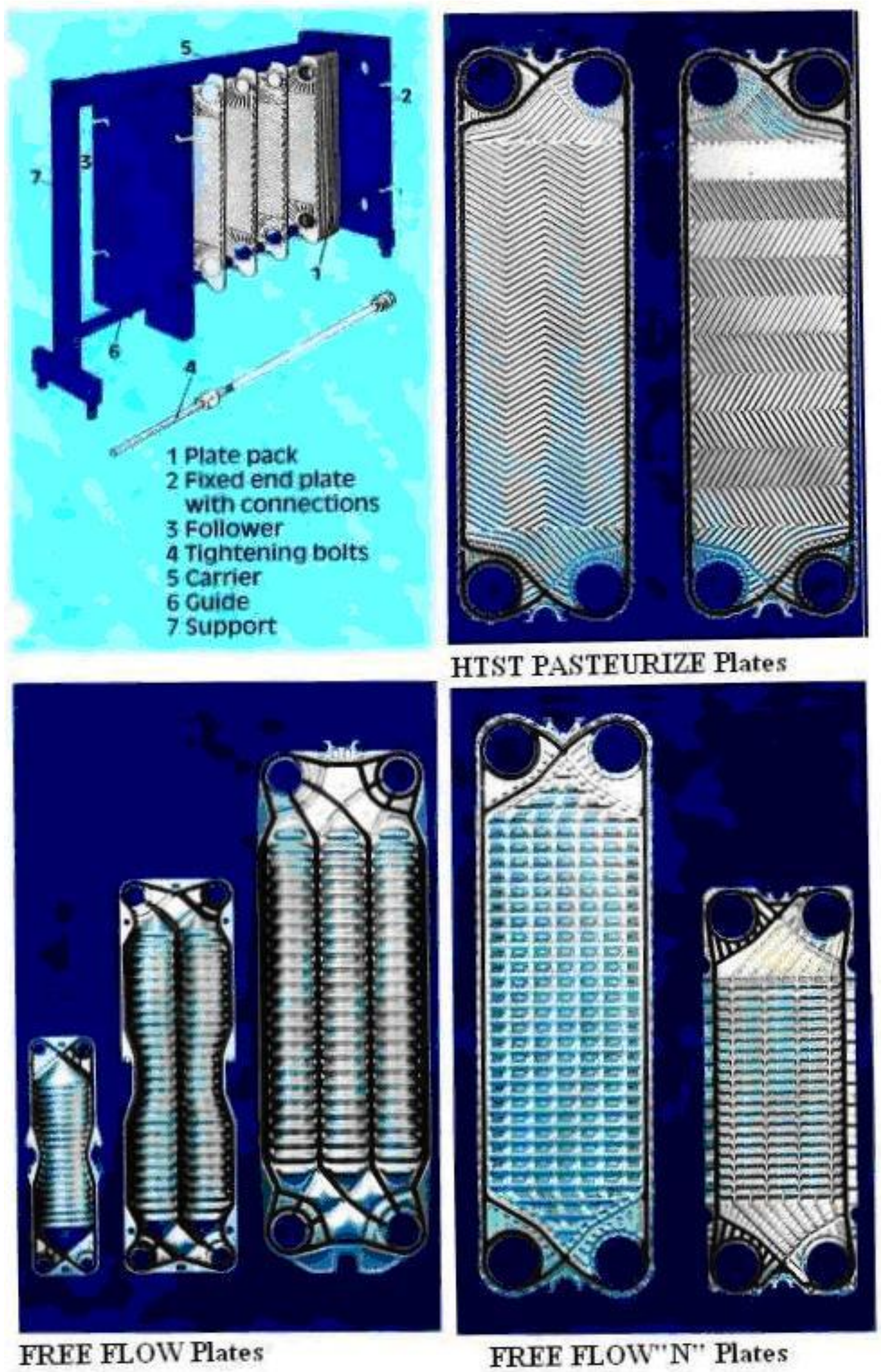


Fig.17.3 HTST pasteurizer

(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.

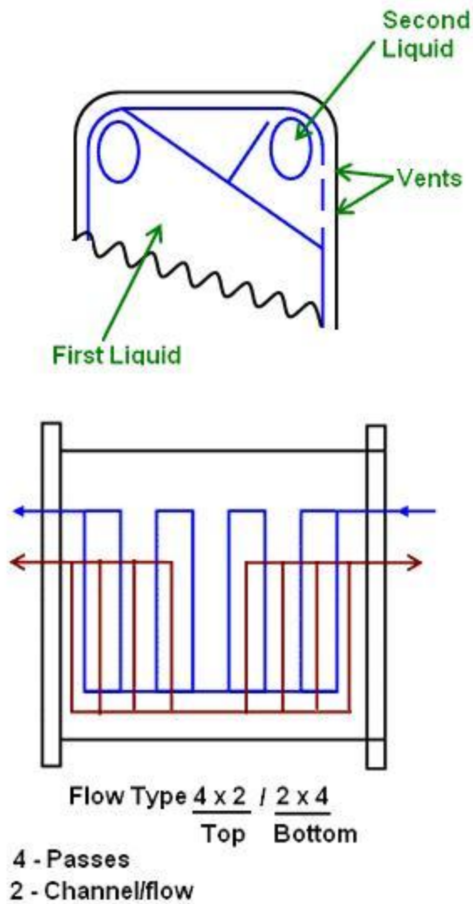


Fig.17.4 PHE

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:

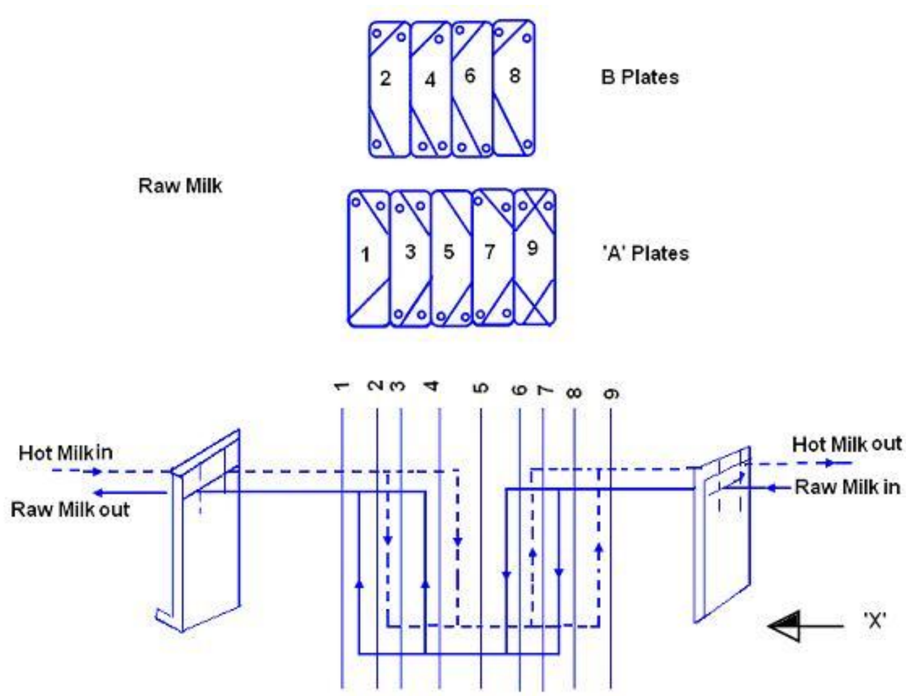


Fig.17.5 Plate connection diagram

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.

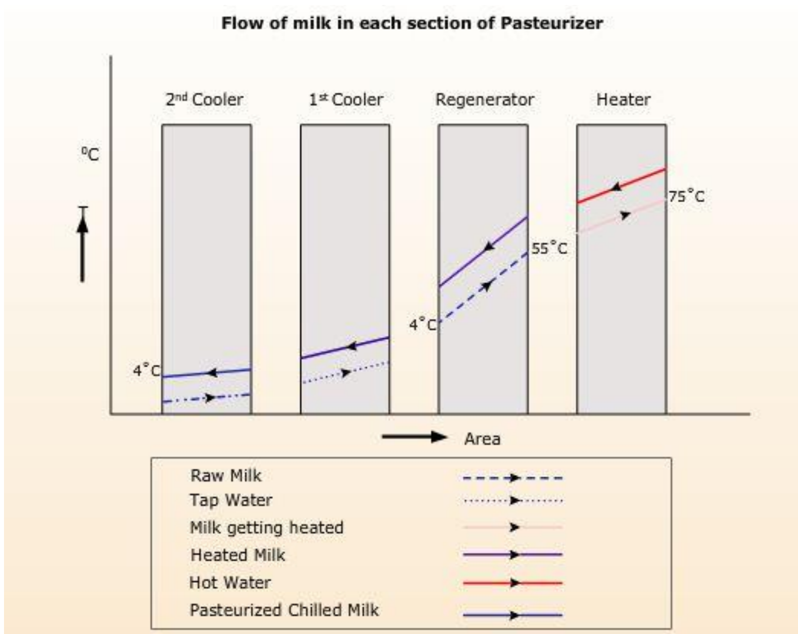
The milk from storage tank enters the HTST pasteurizer through a Float Balance Tank, which has a float to control the inflow of milk and maintains a constant level of milk in it. The milk is then pumped from here through a flow control valve, which may be ball valve type. Milk enters the Regeneration 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:

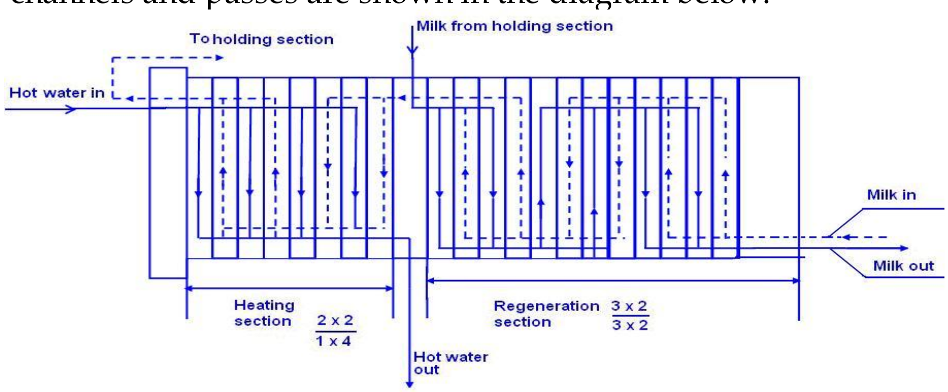
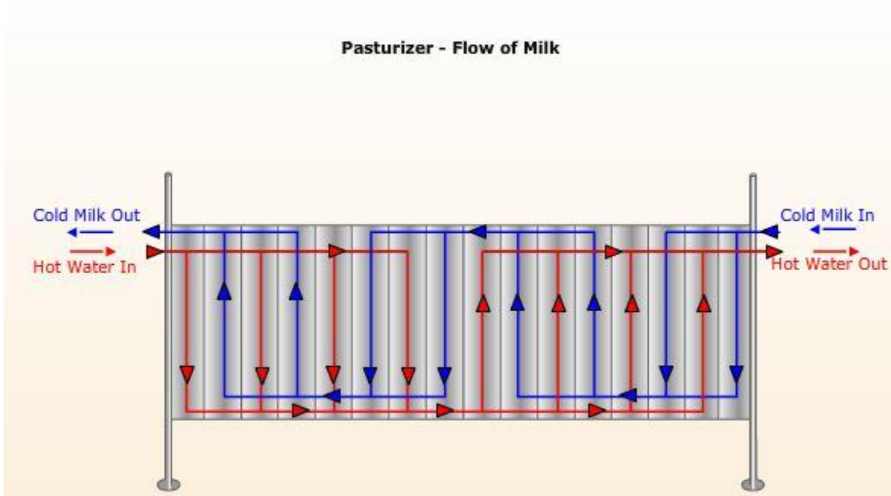


Fig.17.5 Heating and regeneration section



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

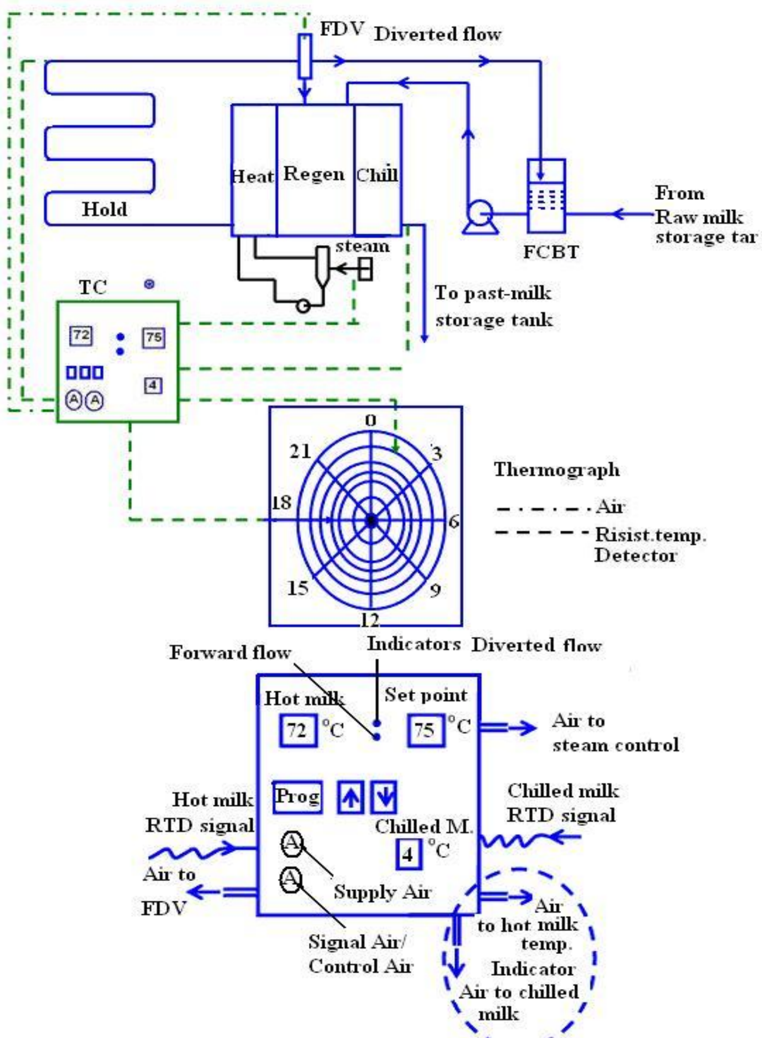

Fig.18.1 Pasteurizer controls

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.

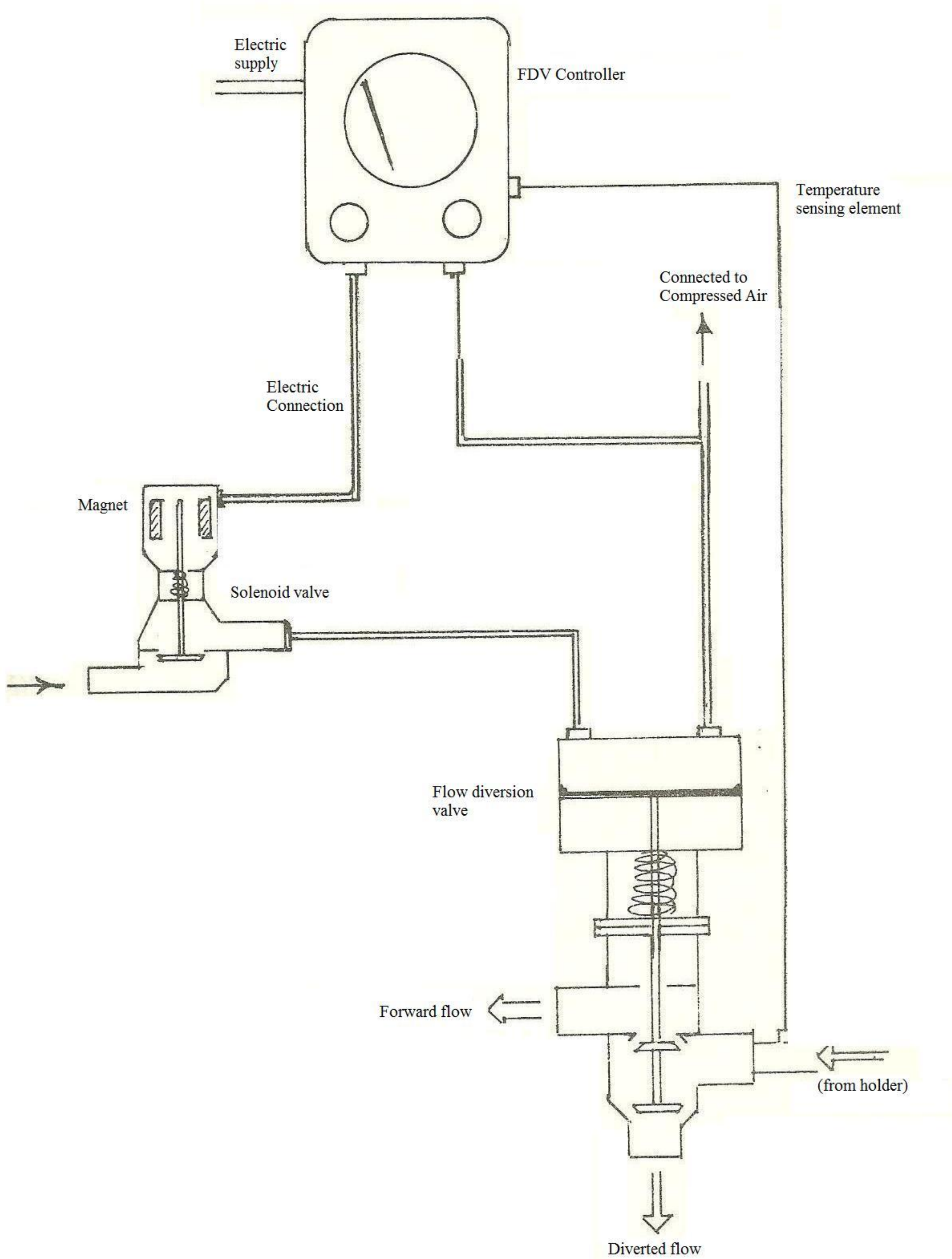

Fig.18.2 Flow Diversion Valve

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

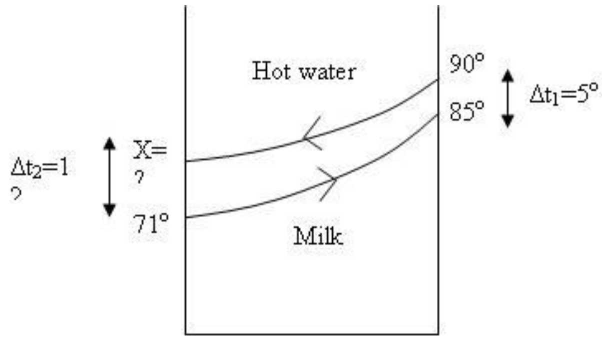
Inlet temperature 15^0C
Pasteurizing temperature 85^0C
Outlet temperature 4^0C
Holding time 15 sec. = 50 ltr.
Regeneration 80%
Heat transfer area per plate = 0.375 m^2
Overall heat transfer co-efficient for heating, regeneration and cooling and deep cooling are 2320, 2290, 2100 and 1800 (k.cal/m^2hr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



Applying heat balance X is calculated (temperature drop in hot water)

24000x1x(90-X) = 12000x1x(85-71)

X = 83

Equation for LMTD (Log Mean Temperature Difference)

Equation for LMTD (Log Mean Temperature Difference)

$$t_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$$

$$t_{LMTD} = \frac{12 - 5}{\ln \frac{12}{5}}$$

$$= 8^{\circ}$$

The LMTD diagram can be represented as:

$$12 \left(\frac{71 - 85}{83 - 90} \right) 5 \qquad t = 8^{\circ}C$$

For heat exchangers heat transfer rate is given as:

For heat exchangers heat transfer rate is given as:

Q= UA t_{LMTD}

Where,

Q = rate of heat transfer

A = Area of heat transfer

t_{LMTD} = Log mean temperature difference

Or

Q= UaN t_{LMTD} ....(1)

Where,

A = area of one plate

N = number of plates

And since,

Q = m s Δt.......(2)

From equations 1 and 2

UaN = m s Δt

N = 12000 ×1 × 14 = 24

0.375 × 2320 × 8

Arrangement 3 × 5 / 2 × 8 = 32 plates.

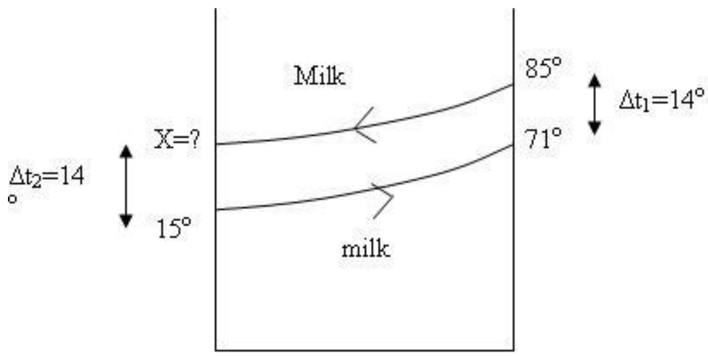
Here,

3 × 5 is for milk (3 passes and 5 channels)

2 × 8 is for hot water (2 passes and 5 channels)

Regenerating Section

The LMTD calculations are given below:



We know,

$$t_{LMTD} - \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$$

Since, $\Delta t_2 - \Delta t_1$ = 14 therefore we take the average value,

$$t_{LMTD} = \frac{\Delta t_2 + \Delta t_1}{2}$$

$$t_{LMTD} = \frac{14 + 14}{2} = 14$$

LMTD diagram can be represented as

$$1 \left(\frac{15 - 71}{29 - 85}\right) 14 \qquad t - 14°C$$

We know,

UaN t_{LMTD} = m s Δt

N = 12000 × 56 × 1 = 56

0.375 × 2290 × 14

Arrangement 6 × 5 / 6 × 5 = 61

However, in the entering range 15 – 71 a branch to the centrifuge has to be provided as close as possible to 45 °C.

Each group means a rise in temperature of 71-15/6 = 9.3^{0}C

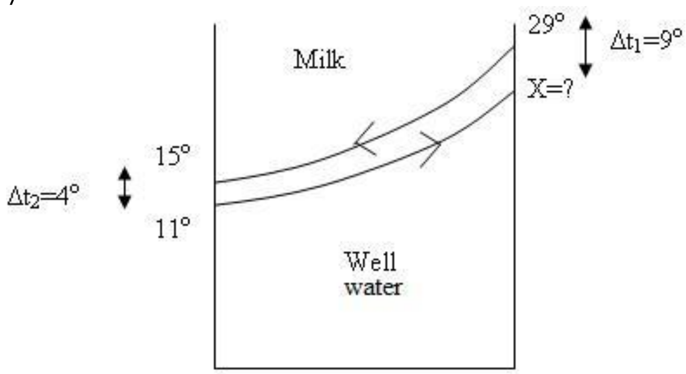
If we make a branch after 3 groups the temperature there will be approximately 43°C.

Arrangement reg. section I: 3 × 5 / 3 × 5 = 31 plates

Reg. section II: 3 × 5 / 3 × 5 = 31 plates

Cooling

By means of 18.000 l t r / h well water of 11 °C.



$M_wS_w\Delta t = M_mS_m\Delta$

18000 x 1 x (11-X) = 12000 x 1 x (29-15)

X = 20^o

$M_wS_w\Delta t = M_mS_m\Delta$

18000 x 1 x (11-X) = 12000 x 1 x (29-15)

X = 20°

$\Delta t_1 = 15 - 11 = 4$

$\Delta t_2 = 29 - 20 = 9$

$t_{LMTD} = \dfrac{\Delta t_2 - \Delta t_1}{\ln \dfrac{\Delta t_2}{\Delta t_1}} = 6.1°$

LMTD diagram can be represented as:

$9\begin{pmatrix}29-15\\20-11\end{pmatrix}4$ $\qquad$ $t = 6.1\ °C$

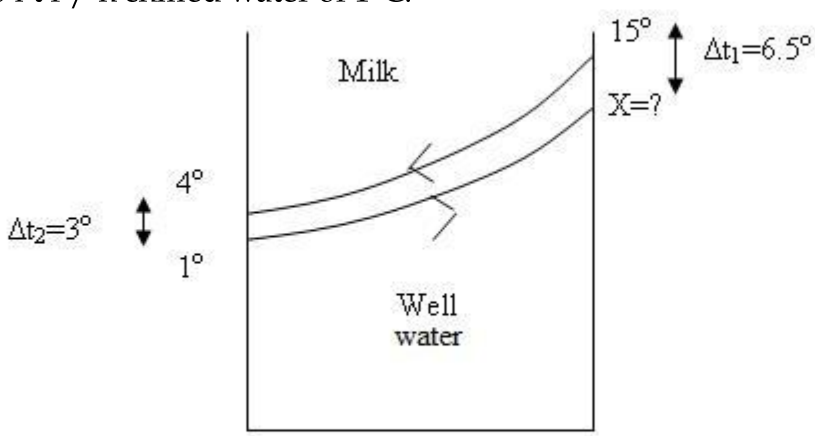
We Know,

$UaN\ t_{LMTD} = m\ s\ \Delta t$

N = 12000 × 14 × 1 = 35
0.375 × 2100 × 6.1
Arrangement 3 × 6 / 3 × 6 = 37

Deep Cooling

By means of 24.000 l t r / h chilled water of 1°C.



$M_mS_m\Delta t = M_cS_c\Delta$
12000 x 1 x (15-4) = 24000 x 1 x (X-1)
X = 6.5°

$M_mS_m\Delta t = M_cS_c\Delta$

12000 x 1 x (15-4) = 24000 x 1 x (X-1)

X = 6.5°

$\Delta t_1 = 4 \quad 1 = 3$

$\Delta t_2 - 15 - 6.5 - 8.5$

$t_{LMTD} - \frac{\Delta t_2 - \Delta t_1}{\ln\frac{\Delta t_2}{\Delta t_1}} = 5.25°$

LMTD diagram can be represented as:

$$8,5\begin{pmatrix}15-4\\6,5-1\end{pmatrix}3 \qquad t = 5.25\,^{\circ}C$$

$$N = \frac{12000 \times 11 \times 1}{0.375 \times 1800 \times 5.25} = 36$$

$$\text{Arrangement} \quad 3 \times 6 \;/\; 3 \times 6 \quad = \quad 37$$

= 5.25°

Arrangement 3 × 6 / 3 × 6 = 37

Pressure Drops

Milk 15 × 1. 12 + 6 × 0.78 + 28 × 0, 1 + 3 (holding section = 27. 3 mwc

Hot water 2 × 1. 75 + 3 × 0.19 = 4. 1 mwc

Well water 3 × 1. 75 + 4 × 0. 11 = 5. 7 mwc

Chilled water 3 × 3. 00 + 4 × 0. 19 = 9. 8 mwc

20.2 PROBLEM :

Calculate the number of plates in each section of HTST pasteurizer, for the following data:

Milk Hot water Chilled water

1. Flow Rate 10,000lph 30,000 lph 30,000 lph
2. Inlet temperature 4°C 85°C 1°C
3. Outlet temperature 4°C
4. Overall heat

Transfer coefficient

'U' k.cal/m^2 hr °C 2320 2290 1800

Area of each plate is 0.375 m^2; Regeneration Efficiency: 80%; Past. Temperature: 75°C

Soln:

Regeneration Section

$$\text{Regeneration} \quad \frac{80}{100} = \frac{(x \quad 4)}{75 \quad 4}$$

$$X = 60.8$$

Heat balance between raw milk and heated milk

10,000 x 0.93 x (60.8-4) =10,000 x 0.93 x (75-x)

X=18.2 °C

Note: Remember that rate of heat is different than the heat balance

Heating Section:

Heat gained by milk = Heat lost by hot water

10,000 x 0.93 x (75-60.8) =30,000 x1 x (85-X)

Chilling Section:

Heat lost by milk = Heat gained by chilled water

10,000 x 0.93 x (18.2-4) = 30,000 x 1x (X-1)

X=5.7

Heat gained by raw milk in Regeneration section is rate of transfer in that section
10,000 x 0.93 x (60.8-4) = $UA\Delta T_{LMTD}$

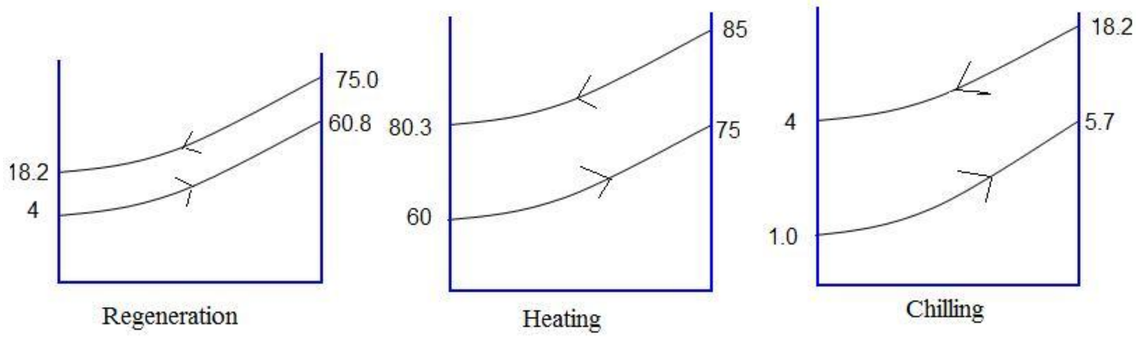


Fig.20.1 Temperature profiles in various section of pasteurizer

$$\Delta T_{LMTD} = \frac{(18.2-4)-(75.0-60.8)}{ln\frac{(18.2-4)}{(75-60.8)}} = 14.2$$

$$= \frac{(80.6-60)-(85-75)}{ln\frac{(80.6-60)}{(85-75)}} = \frac{(19.4-10)}{ln\frac{(19.4)}{(10)}} = \frac{9.4}{ln(1.94)} = \frac{9.4}{0.66} = 14.24$$

$$= \frac{(4-1)-(18.2-5.7)}{ln\frac{(3)}{(18.2-5.7)}} = \frac{(12.5-3)}{ln\frac{(12.5)}{(3)}} = \frac{9.5}{ln(4.16)} = \frac{9.8}{1.42} = 6.75$$

Balancing the heat exchanged to the Rate of heat transfer equation, Regeneration Section: Chilling section Heating section

Balancing the heat exchanged to the Rate of heat transfer equation,

$$n = \frac{10{,}000 x 0.93 x (60.8 - 4)}{2290 x 0}.375 x 14.3 \quad = \frac{10{,}000 x 0.93 x (75 - 60)}{2320 x 0}.375 x 11.21 \quad = \frac{10{,}000 x 0.93 x (18.2 - 4)}{1800 x 0}.375 x 6.75$$

=43.3 or 44 plates =11.26?12 = 29

Answer: The number of plates required in Regeneration, heating and chilling sections are 44, 12 and 29 respectively.

Role of Correction Factor

The above calculations using LMTD, may not be the true representative of counter current flow, as the milk and service fluid are differing in the flow rates. To control the pressures on both sides to be equal, the flow in the channels is made unequal. When the milk and service fluid flow is in the ratio of the range of 0.66 to 1.5, it is possible to have equal number of passes on both sides of the exchangers making the flow to be counter current. When it becomes necessary to go for unequal passes due to large differences in flow rates, it becomes necessary to apply significant correction factor to take into account the non-counter current flow situation.

The extent of LMTD correction depends upon several factors, including the number of NTU/pass and number of channels per pass. Correction factor is required also because, in the end zones of plates, heat is transferred only on one side, and with even number of plates, one fluid has an extra stream or passage over the other.

? T LMTD cross flow = F X ?F LMTD

$$F = \frac{\log_e\left(\frac{1-P}{1-P.R}\right)}{(R \quad 1)\log_e\left(\frac{(R)}{R + \log_e(1-P.R.)}\right)}$$

Where, $R - \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}}$

$$P - \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$

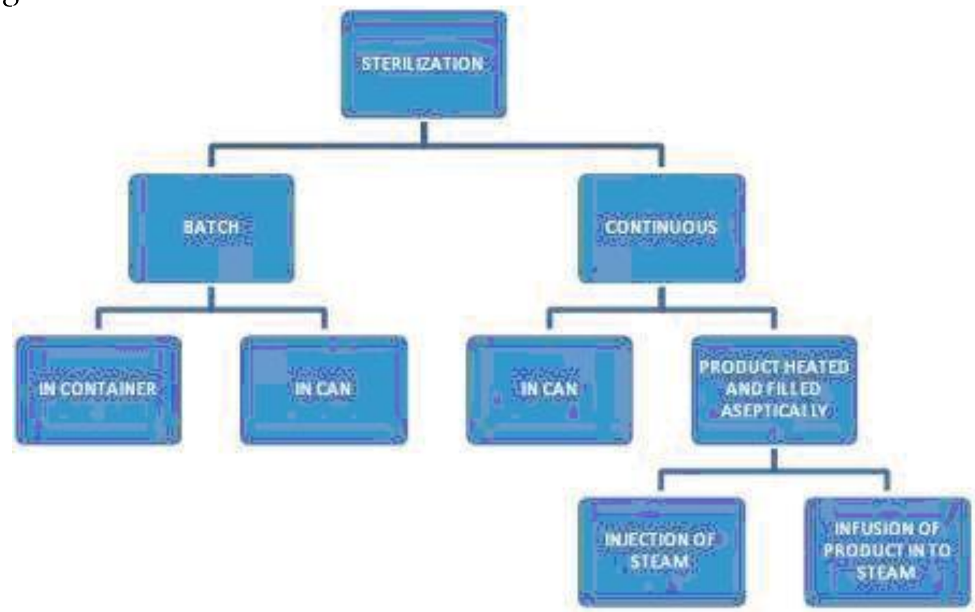
Lesson-21

Different Types of Sterilizers, In- Bottle Sterilizers, Autoclaves

21.1 INTRODUCTION

Sterilization is the term used for process to destroy all the microorganisms present, both vegetative forms and spores, or at least make them incapable of growth in the product, so that a long keeping quality is obtained without refrigerated storage.

The term"sterilized" here does not imply that the product is sterile in the strict microbiological sense. It has been clear for many years that absolute sterility cannot be obtained by any heat treatment processes. If the treated product is incubated at appropriate temperature, spoilage will be noticed at some parts. This spoilage can be reduced by increasing the time-temperature of the heat treatment process. However, this will cause undesirable chemical changes, color, flavour and or nutritional changes.



Typical time – temperature combinations for in-container sterilization processes are 105-120 ^{0}C with effective processing times of 10-30 minutes, the higher temperatures being associated with the shorter times. This sterilization effect can be obtained by using much higher processing temperatures like 135-150 ^{0}C, with shorter holding times of about few seconds. These processes cause much less chemical changes as a result of heat treatment than that of conventional sterilization processes. The higher temperature processes are frequently considered as different processes, which have been given the description "Ultra High Temperature "(UHT). With in-container processes, with limited heat transfer rates, do not allow sufficiently rapid change of product temperature. Therefore UHT processing involves the treatment of product in continuous flow in a heat exchanger.

Packaging of UHT milk has to be done in aseptic condition. In comparison to In-can sterilized milk, UHT milk cannot completely inactivate the more heat-resistant, proteolytic enzymes, particularly when initially present at high concentrations.

21.2 BATCH STERILIZATION EQUIPMENT

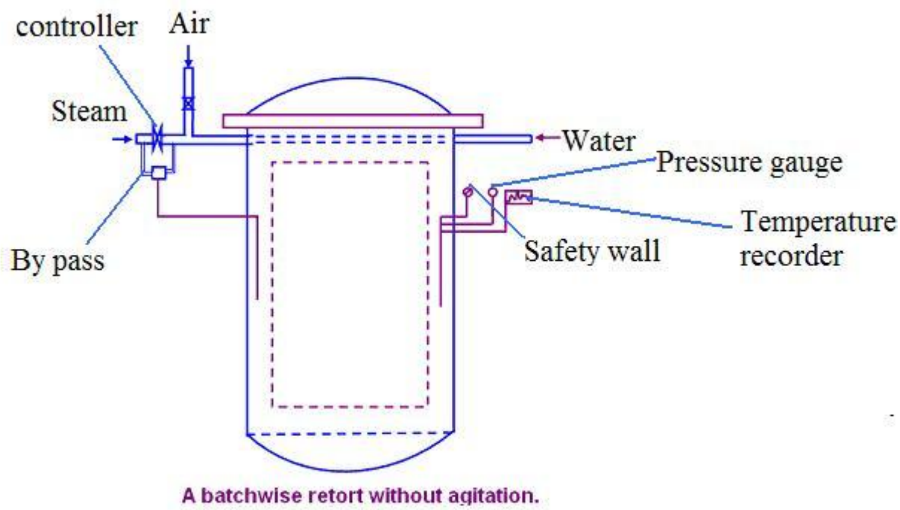


Fig.21.1 Batch sterilization equipment

The Batch Sterilization equipment, usually called Retorts, consists of a cylindrical tank, under pressure, into which the cans containing the food products, placed in cages are lowered. Steam flows into the retort from the top. After heating, cooled water is sprayed into the retort. To prevent the pressure in the cans from becoming higher than that in the retort itself, compressed air is blown into the retort to compensate for the pressure drop, and when the temperature is reduced to below 100 °C the retort may be opened.

The advantage of this type of sterilization equipment is the flexibility with regard to package size and the relative ease to maintain constant temperature. However, the operation of loading is laborious, and the heating is slow because of not agitation of the inside liquid.

21.3 CONTINUOUS IN-CAN STERILIZATION EQUIPMENT

These are more suitable to larger capacity of handling. It has basically three sections. In the first section, the cans are heated, in the second section the cans are cooled under high pressure and in the third section they are cooled at atmospheric pressure. The cans are transported in a helix positioned on the periphery of a barrel, and when they have been transported one revolution of the barrel they have at the same time been moved one step along the retort. Simultaneously, the can rotates around its own axis. The effect of this is a flow pattern in the package enhancing heat transport in liquids. As shown in figure the cans are transported from one zone to another.

There is high pressure in the sterilizer to prevent differences in pressure in the can and sterilizer. The disadvantage with these sterilizers is the limitation on the size of the cans, as they are built for one can size and only small difference in size can be accepted in the equipment.

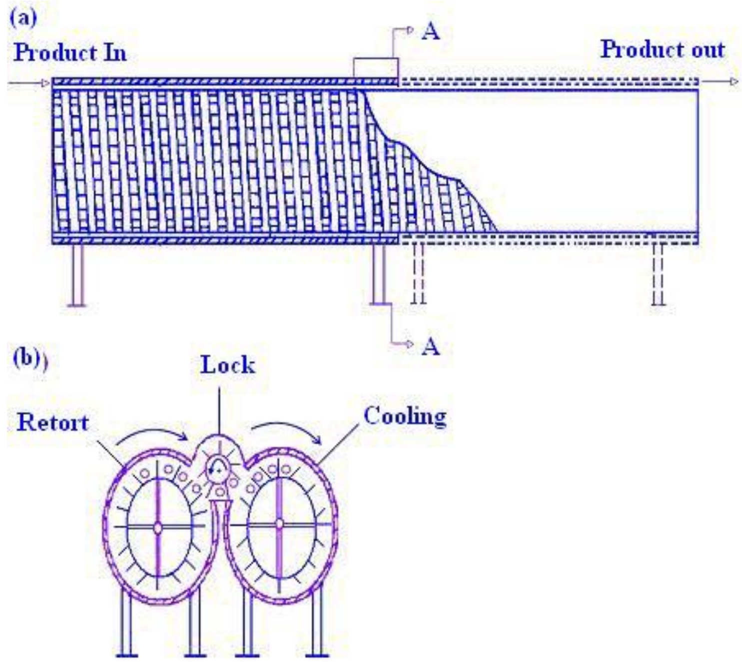


Fig.21.2 Continuous sterilization equipment

21.4 HYDROSTATIC STERILIZER

A Hydrostatic sterilizer consists of a chamber equipped with steam injection. The chamber is connected to two water columns (barometric lock) which are used to adjust the pressure in the chamber. If the height of the water columns is changed the stream pressure is changed and thus the maximum temperature obtainable also changes. The normal height of water column to get 121^{0}C temperature is 13.7m. These sterilizers are often very tall. A conveyor, suitable to size of can, travels through the steam chamber carrying the cans. The sterilization time may be changed by varying the speed of the conveyor. The flexibility and the capacity are the major advantages of this type of sterilizer. The height and cost are the main disadvantages.

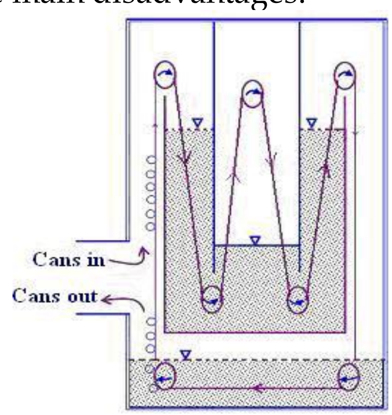


Fig.21.3 Hydrostatic retort

21.5 HYDROLOCK STERILIZER

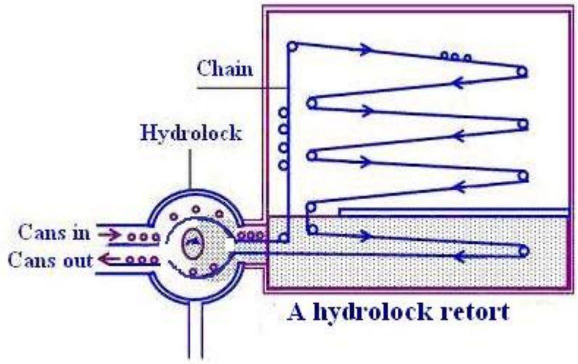


Fig.21.4 Hydrolock retort

This equipment consists of a continuous sterilizer that has a rotating pressure lock, called hydrolock, which is partly submerged under water. The cans pass the hydrolock into a preheating chamber filled with water. They are then transported into the steam chamber. The bottom part of this chamber contains hot water thus further heating the cans. The cans are then transported to the upper part of the chamber containing steam and here sterilization takes place. The product then passes through a cooling section. Hydrolock sterilizers are flexible but they are rather large and costly. Leakage in the rotating valve of the hydrolock is common.

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Lesson-22

Continuous Sterilization Plant, UHT Sterilization

22.1 INTRODUCTION

Sterilization at higher temperatures is usually referred to as UHT sterilization. The heating to this high temperature for only few seconds, demands that the heating and subsequent cooling has to be as quick as possible to reduce heat damage. The other factors like cost, the technical expertise in handling and maintaining sterility are also important.

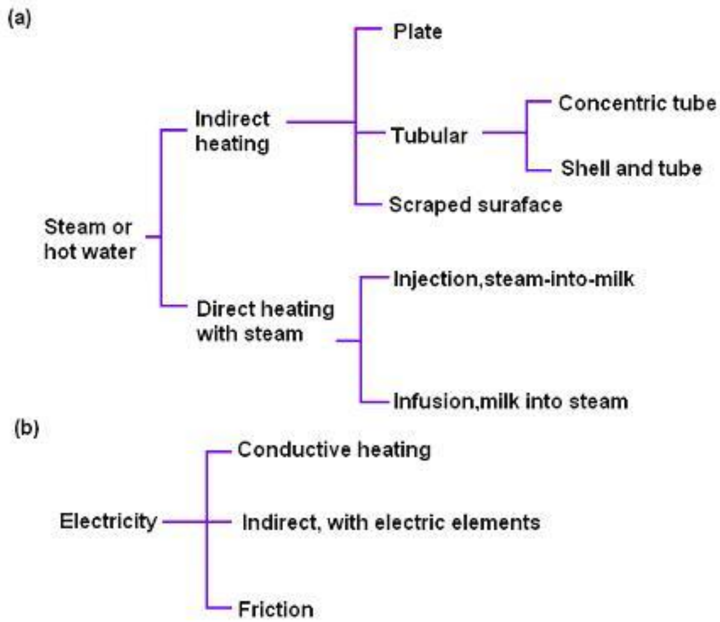

Fig.22.1 Classification of UHT plants and heating energy source

22. 2 INDIRECT HEATING

This type of heat exchanger can consist of an assembly of plates, or tubular or a combination of both. If the product is very viscous, use of Scraped-surface heat exchanger is necessary. As the product in the plant must not boil at the highest pressure, a back pressure must exist which is equal to the vapour pressure of the product at this maximum temperature. At a temperature of 135 °C, a back pressure of about 2 bar is needed. Further, to avoid bubbling of any dissolved air, at least 1 bar over and above the pressure determined by the sterilization temperature is needed. Another factor is the hydrodynamic pressure drop resulting from the product being pumped through the heat exchanger. Hence, the highest internal pressure in the heat exchanger may reach 6 - 8 bars.

22.2.1 Plate Heat Exchanger

Generally, plate heat exchangers are limited to lower temperatures, but, here the special design considerations are required as the operative pressures have to be higher.

To withstand the severe conditions of temperature and pressure, the gasket materials used with plates for UHT plant must be more sophisticated. Nitrile rubber is suitable for temperatures up to about 138°C. For higher temperatures, up to 160°C, resin-cured butyl rubber or EPDM (Ethylene

Propylene Diene Methylene) or silicon gaskets are suitable. Gasket performance is also limited by the adhesion of the gasket to the stainless steel plate. A safer option will be with plate and gasket designs where gasket is not bonded to the plate, but is held in place mechanically and so can be replaced easily when necessary. High internal pressures, and varying high temperatures within the heat exchanger, may cause flexing and distortion of the stainless steel plates. Hence the designs are such that multiple contact points between adjacent plates are provided, to give mutual mechanical support and increase the rigidity of the whole plate pack.

In the sequence of operation of the UHT plant, the heat exchangers can be of regeneration between milk to be heated and the milk already heated, as in normal pasteurizer. A more efficient one is where an entire water circuit takes care of the heat exchanges progressively. (Refer fig. 22.2)

1. Balance tank 2. Positive displacement pumps 3. First plate heat exchanger
4. Holding tube (110 to 115^{0}C) 5. Second heating section 6. Holding tube (14^{0}C)
7. First cooling section 8. Homogenizer 9. Second cooling section
10. Cold water cooling stage 11. Restrictor 12. Steam heat exchanger
13. Sterilization cooler 14. Back pressure wall

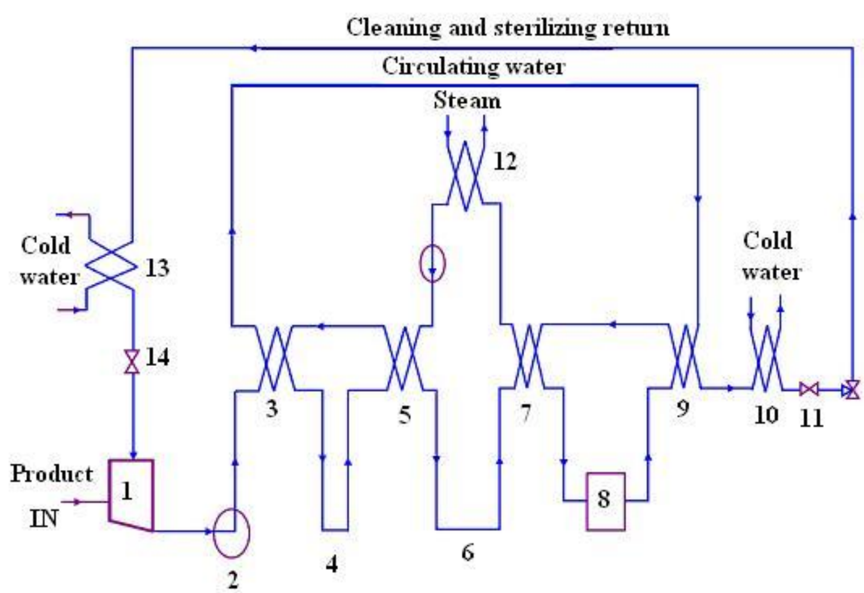

Fig.22.2 Developed plate-type indirect UHT Plant

The untreated product is pumped from balance tank by centrifugal pump to the first plate heat exchange section. The end of this heating section, at a temperature of 110-115°C, there may be a holding tube to provide a few seconds holding to reduce fouling of heating surfaces later in the plant. The next heating section brings the product to the final sterilizing temperature of about 140°C, where it is held for the required holding time in the holding tube. It is then followed by a cooling section which cools the product to homogenization temperature of about 55°C to 75°C.

The homogenizer being positioned after the sterilization process will have to be of the type of Aseptic type of homogenizer. It is generally considered that if milk has to be processed, the homogenization is before the sterilization process, while if it is products like cream, then the homogenization is preferred after sterilization.

After aseptic homogenization, the product passes through a further cooling heat exchanger section, and finally through cold water cooling stage to bring the product to the required outlet temperature. A restrictor is placed after this to provide back pressure required in the plant.

The heat is transferred between product and water circulating in the counter-current flow in a closed circuit. The water in this circuit is heated to a little above the required sterilization temperature by steam under pressure in a heat exchanger section. The low differential of not more than 3°C, reduces the amount of fouling on the heat exchange surfaces, and allow longer operating times before the heat exchanger is shut down to be cleaned. The level of regeneration in such a plant can be above 90%, and the operating energy costs are correspondingly low, as compared to plant where heat exchange in regeneration is between milks.

22.2.2 Tubular Heat Exchanger:

Tubular heat exchangers used as components of UHT plants are mainly of two types, concentric tubes, or some form of shell-and-tube heat exchanger.

The concentric-tube systems are formed by assembling two or three stainless steel tube lengths one inside another with a spacer, often a spiral wire, in each inter-tube space to maintain them concentric. The multiple tubes are then wound into a coil, for assembly into an outer cylindrical housing for hygienic and mechanical protection. The two-tube system is used for simple heating and cooling, where the product flows in the centre tube and the heating or cooling medium flows in the annulus, and it is also fused for regenerative heat exchange where product flows in both spaces.

The triple-tube system is used for the final stage of heating to the sterilization temperature, where the product flows in the annulus between the inner two tubes and the heating medium flows in the centre tube and in the outer annulus. In this way, the available heat transfer area is doubled and the rate of heating is increased. Triple tubes may also be used in final cooling sections, especially where cooling rates are restricted by high product viscosity so that increased transfer area is used to compensate for reduced transfer coefficients.

A Typical flow diagram for an indirect UHT plant using concentric tube heat exchanger sections is show in fig 22.3. The product is pumped from the balance tank (1) by a centrifugal pump, (2), through the steam-heated sterilizing heater which, during products sterilization, is inactive. The product is first heated in the regenerative heater (4) by the outgoing product. Connections are made to the homogenizer (5) at a suitable temperature point within the regenerator.

A valuable characteristic of all tubular heat exchangers is that the tubes carrying the product are strong enough to withstand the full pressure required for effective homogenization. It is therefore possible to install the high-pressure reciprocating pump of the homogenizer before the sterile section of the plant and quite independently of the position of the homogenizer valve. The hygienic problems of installing a homogenizer after sterilization lie with the pump, not with the homogenizer valve, and the extra complication and cost of a sterile homogenizer arises from modifications that have to be made to the pump to avoid bacterial contamination. If the homogenizer pump can be included before the sterile section, it need not be of aseptic design. Furthermore, if the heat exchanger can withstand the full homogenizing pressure, the homogenizing valve can be put at any point downstream from the pump, even after the sterile section. In fact, in a plant of the type shown, two homogenizing valves may be fitted, one at (5) in association with the homogenizer pump and one after the sterile section where the product is at a suitable temperature during cooling, e.g. at (5a). The product can therefore be homogenized before sterilization, after sterilization, or both.

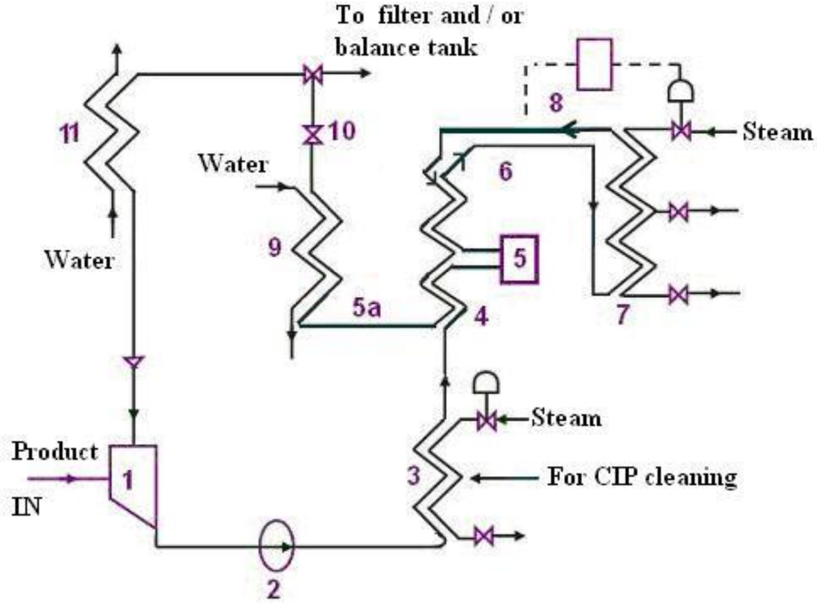

Fig.22.3 Typical concentric-tube indirect UHT plant

After the first homogenizing point at (5), heating continues in the regenerator (6) and then in the stem-heated section (7) to the final sterilizing temperature. After the holding tube, (8), the product returns to the regenerator for cooling. Final cooling to the outlet temperature is in a water-cooled section (9). Back pressure is maintained by an orifice plate or back pressure valve at (10).

The required sterilization temperature in the holding tube is maintained by a controller (C) which senses the temperature in the holding tube and varies the steam supply to the final steam heating section (7) as necessa

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Lesson-23

Continuous Sterilization Plant, UHT Sterilization

23.1 DIRECT HEATING SYSTEMS

There are certain disadvantages in the indirect heating system, especially the fouling of heat exchange surface. To overcome this, a system where the heating medium viz. Steam, is directly brought in contact with product to be heated. This eliminates the following disadvantages of Indirect heating system.

1. Thickness of heat exchange wall slows down the rate of coming up time, cooling rate.
2. Fouling of heat transfer surface, and thereby reducing the operating time.

The product is first raised to 80-85 °C by Indirect heating system, and then the product is raised to sterilizing temperature of 140-150 °C by direct injection of steam. The temperature rises rapidly, but also causes dilution of product due to steam condensing in to the milk, almost to an extent of 10% or more. Hence the holding section coming later will have to be designed for greater capacity to this extent. After the designed holding time at the sterilization temperature, expansion cooling follows. The vacuum in the expansion vessel will normally be controlled at a level corresponding to a boiling temperature little above that of the product before mixing with steam. This will result in removal of exactly the amount of water added as condensed steam.

The general sequence of operations in Direct Heating Systems is shown is figures below:

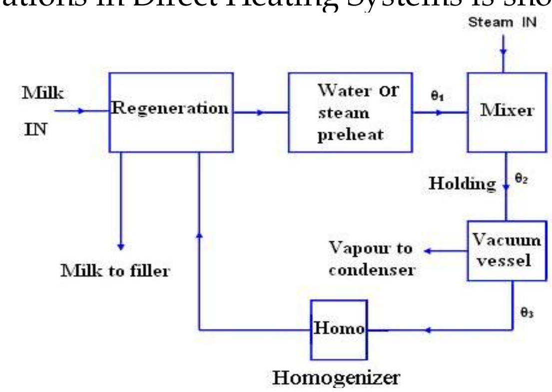


Fig.23.1 Diagrammatic representation of a direct-heating system

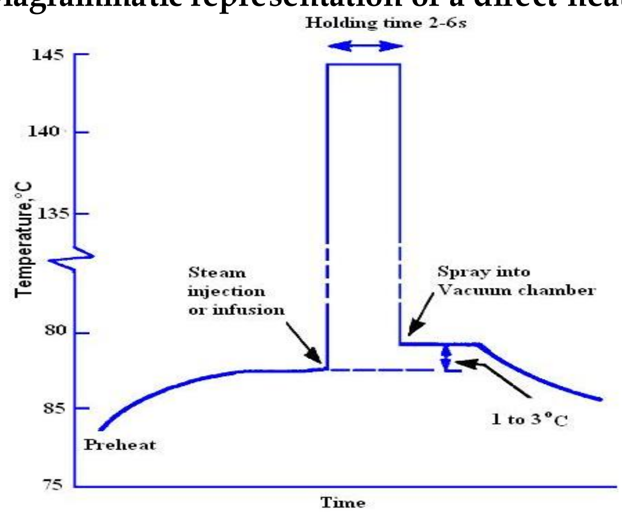


Fig.23.2 Time -temperature relationships during direct heating

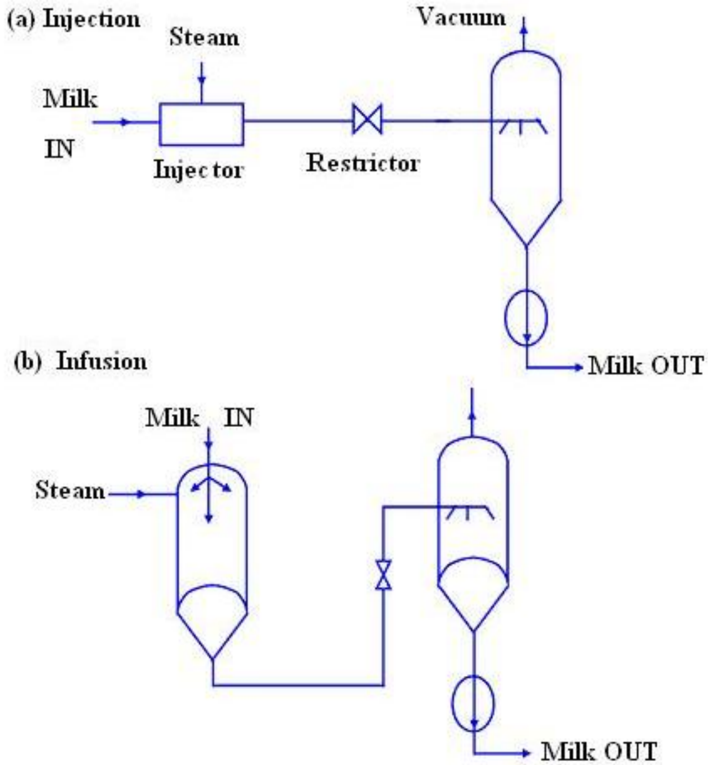


Fig.23.3 Diagrammatic representation of injection and infusion system

However, depending on the method used for mixing the product with steam to achieve the final sterilizing temperature, the heating systems are classified as 1) Injection system 2) Infusion system.

23.1.1 Injection System

In this system, the steam at a pressure higher than that of the product is injected into the product stream through a suitable nozzle, and is condensed to give the required temperature. There are many different injector designs, for meeting the basic requirement of keeping the steam and product thermally separated as far as possible until they reach the mixing zone. This will prevent surface fouling of the injector.

The important requirement in these systems is the rapid condensation of steam, to prevent the passage of bubbles of uncondensed steam into the holding tube, which would reduce the effective holding time at the sterilization temperature. The rapid condensation is achieved by introducing the steam into the liquid in the form of small bubbles or in the form of a thin sheet. It is also essential that sufficient back pressure in the liquid is maintained, above that needed to prevent boiling, at the steam injector.

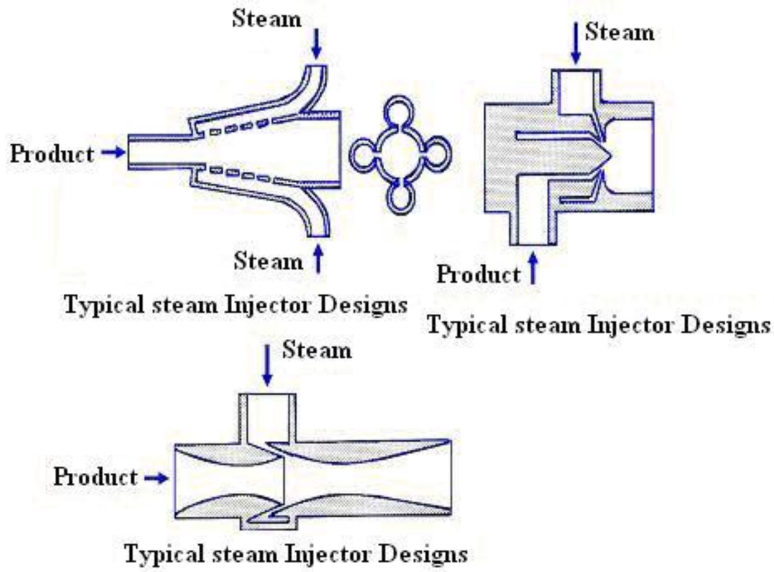
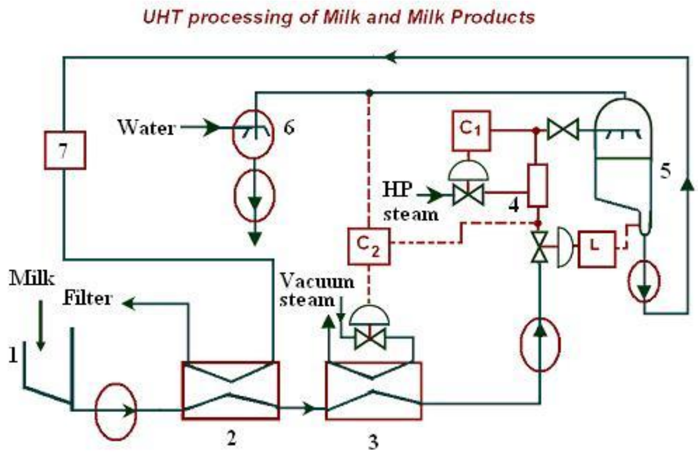


Fig.23.4 Typical steam injector designs

Another design requirement is to keep the pressure difference between liquid and steam to be as small as possible, as this will require lower pressure of steam, and consequent savings in production of steam. Figures above show three possible designs of the injectors. In the first, the product tube takes the expanding part of a venturi. The steam is supplied through four tubes which surround the product tube. A series of small orifices along the lines of contact of the steam tubes with the product tube allow the steam to enter the product in small bubbles. Some of the orifices are drilled radially, and some may be drilled at an angle to encourage swirl and turbulence in the product to increase the rate of condensation.

The second design has steam being injected at a sharp angle across the flow of the product, which is itself in the form of thin inwardly directed cone. This causes a rapid mixing and condensation. The third design has the product pass through a venturi and the steam is injected in the expansion section of the venturi where the product pressure is rising. The steam is injected in a thin annulus around the product. A second venturi section causes further fall and rise of pressure within the injector and enhances condensation and rapid heat transfer.

The product flow and arrangement of sections in a typical steam-injection type of UHT sterilizer is shown in figure below:



1. Balance tank 2. Pre Heating section 3. Heat exchanger(75 to 85^{0}C)
4. Steam injector 5. Expansion vessel 6. Condenser 7. Homogenizer

Fig.23.5 Typical injection type UHT plant

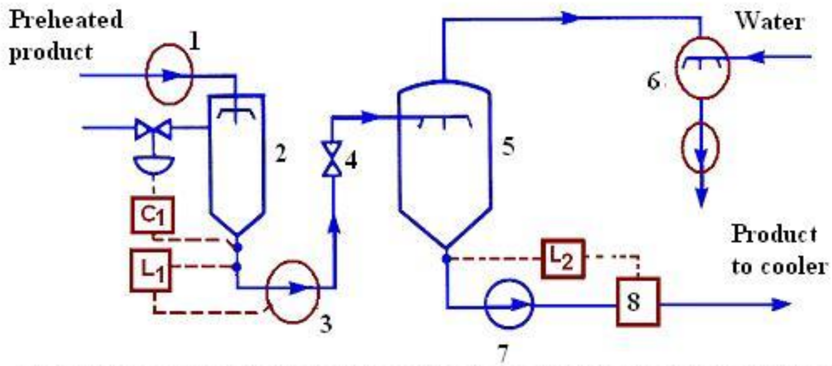
The product is pumped from a Float Controlled Balance Tank (FCBT) through a heating section where it is preheated by outgoing product. It is then further preheated to a constant temperature in the approximate range 75-85 °C in a heat exchanger by condensation of steam under vacuum or by hot water circulation. The temperature of the product at the outlet of this pre-heater is controlled by controlling the heating vapour supply or the temperature of the hot water. A high-pressure pump then supplies the product to the steam injector and the holding tube, where the pressure must be high enough to prevent boiling of the product. An adequate back pressure to prevent the product from boiling is required at this stage.

The sterilized product is then lead to Expansion cooling vessel, which is kept at a suitable vacuum by the condensation of the released water vapour in a condenser. The vacuum corresponds to a boiling temperature of about 1-2 °C higher than that of the product at the outlet of the final pre-heater. This temperature difference will ensure that condensed steam, in the form of water vapour is removed. A restrictor valve at the end of the holding tube retains the high pressure in the injector and holding tube, and as the product enters the expansion vessel, it boils and is rapidly cooled. The product is then lead from the bottom of expansion vessel, to an aseptic homogenizer through a pump. The homogenization after sterilization stage prevents formation of casein aggregates and associated defects. The matching of flows in the different sections is important to meet the defined holding time for the process. It is essential to maintain balance between water addition as steam and water extraction as vapors from the expansion vessel, by maintaining adequate difference between the temperature of the product before mixing with steam and after expansion cooling.

A closed circuit is used for plant cleaning and sterilization, in which the cleaning solutions return to the balance tank through a sterilizing water cooler and restrictor valve. By not applying vacuum to the expansion vessel during this operation, a full sterilizing temperature is achieved.

23.1.2 Infusion System

This system is similar to injection system in all aspects except for the method of mixing of product with steam. The infusion is done by dropping heated product into a steam pressure vessel with a conical base. The size and proportions of the vessels differ, as do the methods adopted for distribution of the product into the steam. Two designs of infusers are shown below:



Infusion heating and expansion cooling stage of an Infusion-Type UHT sterilizer

1. Pump 2. Infusion vessel 3. Positive displacement pumps 4. Restrictor 5.Expansion vessel 6. Condenser 7. Aseptic pump 8. Aseptic Homogenizer

Fig.23.6 Infusion –type UHT sterilizer

In the first one the product is supplied to a hemispherical bowl with a loose circular disc closing the top. The product flows from the space between the bowl and the loose disc to form a thin umbrella with access to the heating steam from both sides. If the product has particles, the loose disc can lift to allow particles to pass out of the bowl with liquid. The other distributor has product flow in a series of parallel and horizontal distribution tubes. These have thin slits along the bottom, from which the product falls in thin, laminar free-falling films.

Shape of the infuser contributes to the volume of pool of product in its base, and this increases the holding time as determined by the dimensions of the holding tube and the flow rate through it. Further, for operational stability the steam pressure at the infuser should be at least 0.5 bar above that equivalent to the sterilization temperature.

Table 23.1 Comparison of Direct Heating and Indirect Heating

S. No.	Direct Heating	Indirect Heating
1	High rate of heating / cooling	Thicker walls in between slowdown the rate of heating/cooling
2	Ideal temperature for short time	Coming up time and cooling time is longer
3	Viscous products can be processed	Cannot handle viscous products easily
4	Free from fouling of heat exchanger	Fouling of heat exchanger surfaces
5	Can operate for long hours without cleaning	Shorter operating time due to fouling
6	Cost is high due to special fabrications and design	Standards items like pipes, which are mass produced, hence cheaper
7	Operation cost high due to less regeneration (60% only)	Regeneration as high as 90%
8	More pumps & control systems,	Single product pump
9	Some parts after sterilization tend to be under low pressure, and hence ingress of contamination	No such problems

Lesson-24

Aseptic Packaging and Equipment

24.1 INTRODUCTION

The product from any UHT sterilizer has to be filled into individual containers for storage, distribution and sale, for commercial use. This process of filling should not lower the sterility level. Satisfactory aseptic filling is an essential part of any system to give a commercially sterile product from a UHT process. In fact most of the spoilage is due to contamination after UHT processing.

Scientists suggest that an overall spoilage level after incubation of all filled containers of 1 in 5000 should be attainable in commercial practice. It is observed that most of the contaminations are due to failure in aseptic filling system. It is found to be more difficult to design and operate a good and reliable aseptic filling system than a good and reliable UHT sterilizer.

An aseptic filling system must meet a series of requirements, each of which must be satisfied individually before the whole system can be considered satisfactory. These are:

1. The container and method of sealing must be suitable for aseptic filling, and must not allow the passage of organisms into the sealed container during storage and distribution.
2. The container, or that part of which comes into contact with the product, must be sterilized after it is formed and before being filled.
3. No contamination should occur while container is being filled.
4. If any sealing is needed, it must be sterilized immediately before it is applied.
5. The closure must be applied and sealed within the sterile zone.

24.2 METHODS OF CONTAINER STERILIZATION

The sterilization performance required for different containers depends on the probable number of organisms existing in the container before sterilization. A sterilizing process giving about 3 to 4 decimal reductions of resistant spores is adequate to give a single survivor in about 5000 containers of 0.5 to 1 litre capacity.

Different methods of sterilizing agents are there, like saturated steam, Dry heat, Hydrogen Peroxide, other chemical sterilants, UV irradiation, and combination of above.

24.2.1 Saturated Steam

It is one of the most reliable sterilant with minimum of objections. It has however to be under pressure to be at high temperatures that are required here. A pressure chamber must therefore be used, with the container or container material to be sterilized entering and leaving the chamber through suitable valves. Air, if present in a steam pressure chamber interferes with the transfer of heat from the steam to the container surface. Hence, any air entering the containers must be removed and not allowed to accumulate. Condensation of the steam during heating of the container surface produces condensate which may remain in the container and dilute the product.

In addition to cans being sterilized, filling systems using steam have also been designed in which polystyrene thermoformed cups and polypropylene preformed cups are sterilized by steam under pressure.

24.2.2 Dry Heat

Dry heat can be applied either in the form of a hot gas or as hot non-aqueous liquid such as glycol. Dry heat can reach high temperatures at atmospheric pressure, which simplifies the mechanical design of sterilizer system. However, dry heat desiccates microorganisms and makes them more resistant. Much higher temperatures are therefore needed for thermal inactivation by dry heat than for inactivation in similar time by wet heat. Temperatures of the order of 200°C may be needed if the sterilization time is not to be very long. The high temperatures needed for satisfactory sterilization by dry heat mean that containers which are heat sensitive cannot be used.

24.2.3 Hydrogen Peroxide

It is well known that Hydrogen peroxide is lethal to microorganisms, including heat-resistant spores. Many manufacturers are using a combination of hydrogen peroxide and heat for the sterilization of the surface of the container material. Sterilizing performance increases with both peroxide concentration and temperature. Some aseptic filling systems use a bath of hot peroxide to sterilize the container or the container material. However, the majority of the systems apply the peroxide solution (usually at 30-35% concentration) to the surface of the container material by dipping or by a finely dispersed spray. The surface is then subjected to heat, either from radiant heating elements or from hot air jets. The peroxide solution on the surface is therefore heated and evaporated, to sterilize the surface at the same time and remove the peroxide solution to prevent it contaminating the product after filling. Hydrogen peroxide is a poison, and in some countries there are strict limits to the concentrations which may remain in the filled container, and which are allowed in the atmosphere surrounding aseptic filler in operation and which could be inhaled by operators.

24.2.4 Ultraviolet (UV) Irradiation

The optimum wavelength for UV radiation to be effective is about 250 nm. The effectiveness falls rapidly away at shorter or longer wavelengths than the above. The effect seems to arise from direct absorption of the radiation by DNA of the bacterial cell. However, UV irradiation is not as effective as Hydrogen Peroxide.

24.3 TYPES OF ASEPTIC FILLING SYSTEM

The principal controlling factor in design of aseptic filling system is the type of container which is to be filled, with subsidiary factors being container material and whether the container is preformed one or whether it is formed during the aseptic filing process.

24.3.1 Cans

Though they are the earliest aseptic fillers to be used, presently they are relatively expensive, with cheaper alternatives being available. It is especially so, for a low-cost product such as milk. They are also bulky to transport and store before use.

The cans may be of tinplate or drawn aluminum, with the solder being of higher melting point than normal to withstand the can sterilization temperatures. The cans are sterilized in the tunnel at atmospheric pressure by steam at 200 to 220 °C, super heated with gas flames. The sterilizing time is about 40 seconds. The can lids are sterilized, by superheated steam, in a separate unit.When the cans have passed through the sterilizing tunnel, they continue through the filling chamber where they are filled, often using a simple in-line filler of the slit or multi-port type. The filling quantity is determined by the product flow rate and speed of travel of the can under the filler.

24.3.2 Cartons

These are commonly used for aseptic filling systems for milk, cream, soya-based milks and fruit juices. The filling systems are mostly in which the carton is formed within the filler from a continuous reel of material, though cartons are also supplied as preformed blanks, folded flat, and assembled into cartons in the filler. The carton material is a laminate of paperboard coated internally and externally with polyethylene, which makes the carton impermeable to liquids and allows thermal sealing of both the internal and external surfaces. An oxygen barrier is provided by a thin aluminum foil incorporated in the laminate. The structure of paperboard laminate is shown in 24.1:

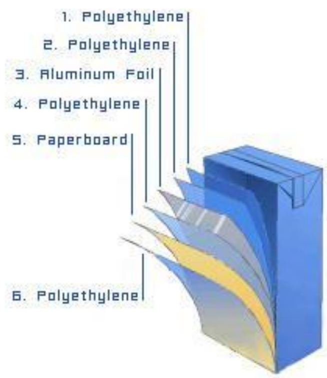


Fig.24.1 Cartons (Source: Tetrapak manual)

In the fillers, the container material moves continuously downward in a strip, and is formed by shaping rolls into a cylinder. An overlapping longitudinal seal is formed by heat sealing. An additional thin polythene strip is heat bonded along the inside of the longitudinal seam at the same time. As the continuous cylinder moves downwards, a series of transverse heat seals are made by jaws which move down at the same speed as the cylinder. These seals have the effect of closing the bottom of the cylinder, so that it can be filled with product. This is done through a filling tube from above, and a float-operated filling valve at the outlet of the tube maintains the liquid level above the sealing level (as shown in diagrams 24.2).

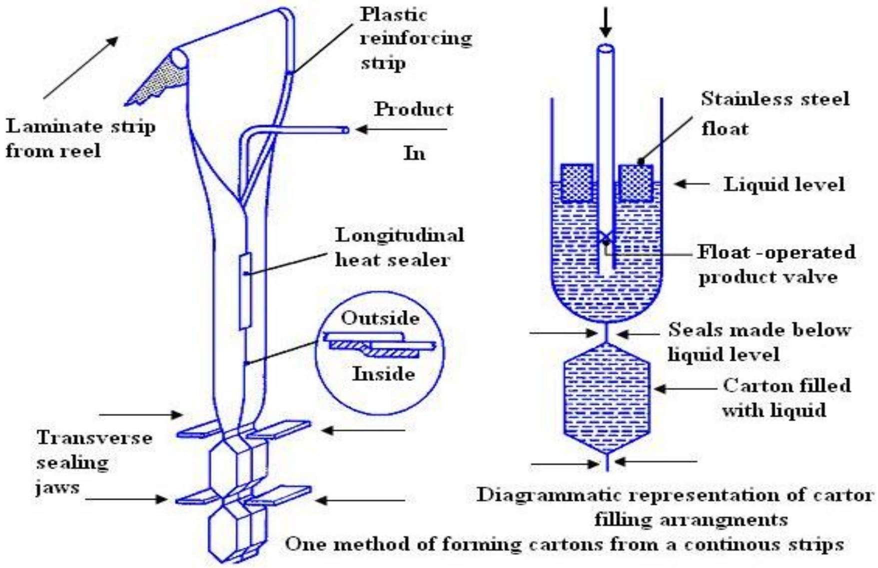


Fig.24.2 Forming cartons from continuous strips

Different forms of seals were evolved, the earlier ones giving shape of tetrahedral, while the later ones are molding into rectangular blocks.

In some of the designs a headspace is provided in the carton by arranging a float-controlled filling valve to give a product level below the top transverse seal. The filled volume is then determined by the carton dimensions and the position of the valve. The cartons are sterilized with hydrogen peroxide and heat, before they are filled as above.

Depending upon the application of Hydrogen Peroxide, and stage at which it is exposed to sterile air, it is done in two alternative methods, as shown fig. 24.3:

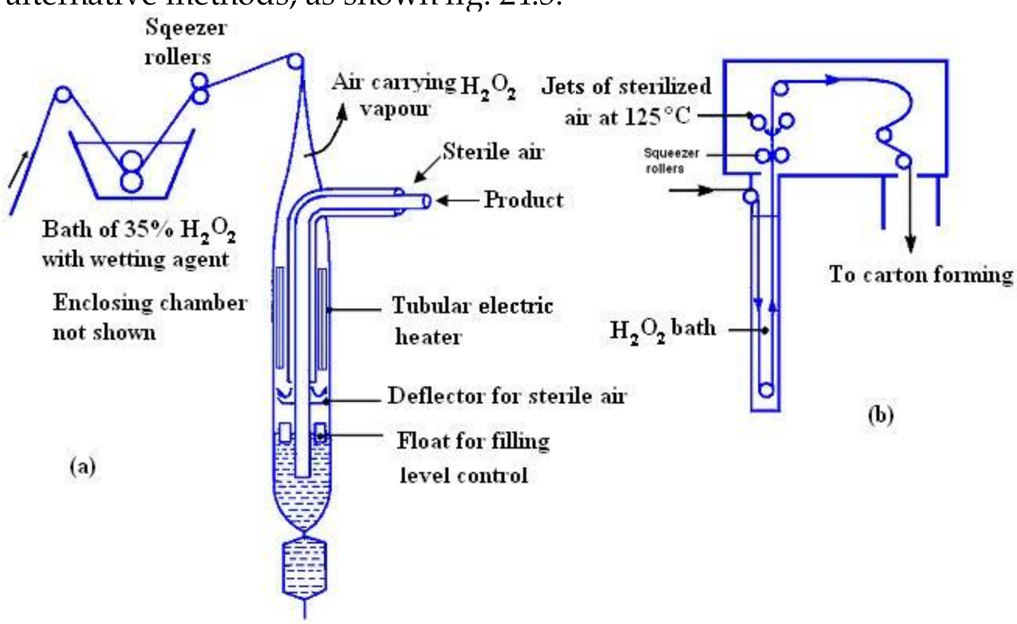


Fig.24.3 Alternative methods of sterilization of carton material from a reel

Lesson-25

Care and Maintenance of Sterilizers

25.1 INTRODUCTION

The sterilizers can be classified as Batch and continuous types, and their maintenance aspects are mentioned below accordingly.

25.1.1 Batch sterilizers

The components that are liable to be damaged over the use and need replacement or recalibration are a) Main door gaskets b) Steam supply valves c) Steam trap d) Water spray nozzles e) Pressure gauges f) Pressure safety valves.

The gaskets are usually of asbestos tape or rope and will get damaged over the period. The correct dimensions of the gasket are important, as well as seating in the groove provided to the closing door. The hinges of the door will need lubrication, to facilitate smooth opening and closing. So are the bolts and levers that ensure tightness of the closure of door. If the sterilizers are of rotating type, then lubrication of the support systems is essential.

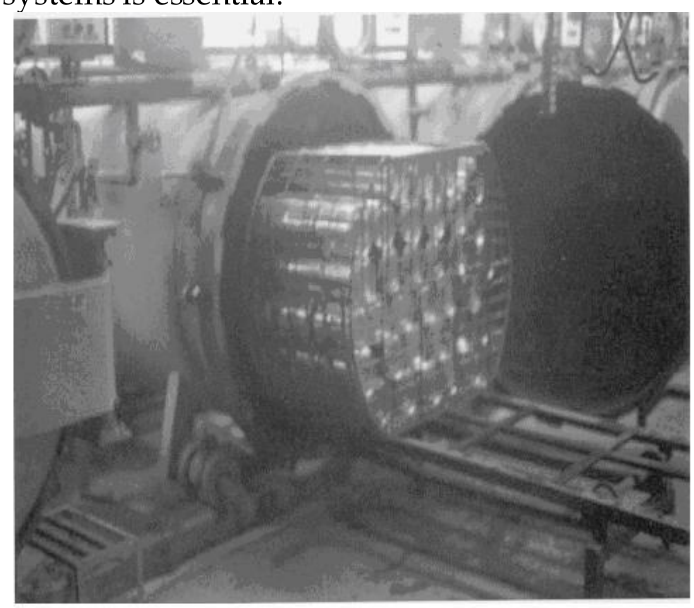


Fig.25.1 Batch sterilizers

Steam supply valves should be leak proof, and if necessary the gland packing has to be replaced. They should be replaced whenever leakage is noticed, to avoid loss of steam and increased cost of operation, and accidents to the operators. The proper operation of steam trap is to be checked from time to time, and there should not be damage due to corrosion or scale formation.Steam pressure gauges must be tested for accuracy, as well as the steam safety valve. Steam safety valves also are susceptible to corrosion and not opening at the required set point. It has to be checked whether any local laws are to be satisfied in their installation or operation. Water spray nozzles should be checked for scale formation and choking.

As the sterilizer operates at high temperature, the insulation and its maintenance are also important. Proper protection and cladding of the insulation whether glass wool or mineral wool is to be taken care of.

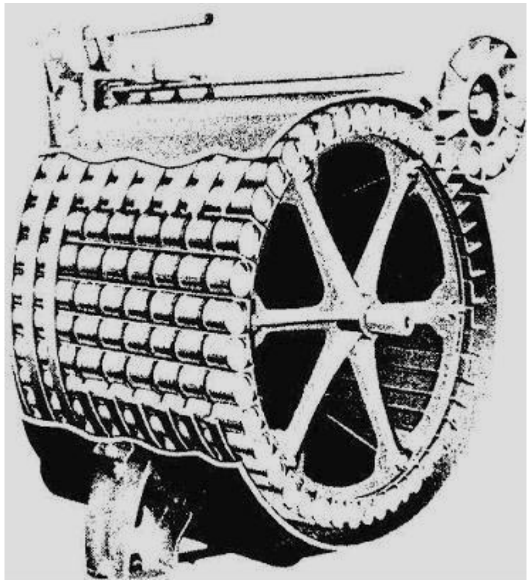


Fig.25.2 Continuous can sterilizer

5.1.2 Continuous sterilizers

In the continuous type of retort systems, the pressure sealing system has to be checked for leakages, and replace the gaskets if necessary. Lubrication of all rotating parts is necessary.

25.2 UHT PLANT OPERATIONAL CARE AND MAINTENANCE

1. Raw milk quality should be properly tested, and only milk of highest quality must be accepted for UHT processing. The factors of importance are microbiological, flavor related, and adulteration.
2. As much as possible, electrical failure should be avoided, and if in doubt, the plant should be started and operated on standby electrical generator itself.
3. All the precautions for the plant hygiene and personnel hygiene must be observed, in the lines of latest standards of hygiene.
4. Test must be carried out periodically for the plant hygiene, and corrective measures should be immediately initiated.
5. Care must be taken to maintain operative temperatures and pressures inside the heat exchangers, so that there is no formation of vapours and subsequent formation of scale. About 3-4 bar pressure is normal. If 6-8 bars are approached, then stop the plant.
6. Special gaskets will be needed. Nitrile rubber-138 °C; Ethylene Propylene Diene Methylene 155 to 160 °C is for UHT plants. Right type of fixing material has to be chosen. Also mechanical methods are used for holding the gasket in place.
7. New methods of cleaning and solutions are being used for complete and effective cleaning of deposits especially in heating section. The UHT plant should be provided with CIP line for automatic cleaning operations synchronized with the automation of the UHT plant itself.

Lesson-26

Solving Numerical

26.1 THERMAL PROCESS CALCULATION

26.1.1 Commercial Sterility

It is defined as a condition in which microorganisms which cause illness, and those capable of growing in food under normal non refrigerated storage and distribution, are eliminated.

26.1.2 Microbial Inactivation Rates at Constant Temperature

Rate of microbial inactivation: When a suspension of microorganisms is heated at constant temperature, the decrease in the number of viable organisms follow a first order reaction.

Let N = number of viable organisms.

$$\frac{dN}{dt} \propto N \text{ (or) } \frac{dN}{dt} - KN \text{ \_\_\_\_\_\_\_\_\_\_ } (1)$$

Where ‘K’ is the first order rate constant for microbial inactivation. Integrating equation and using the initial condition, N = No, at t = 0 temperature.

Integrating the above

$$ln[N]_{N_0}^{N} - -Kt$$

$$\ln\left[\frac{N}{N_0}\right] - -Kt$$

The above equation suggests a linear semi logarithmic plot of N against‘t’. The equation can also be expressed in common logarithms.

$$2.303 \log\left(\frac{N}{N_0}\right) = -Kt \quad \text{or} \quad \log\left(\frac{N}{N_0}\right) = \frac{-Kt}{2.303} \quad \text{or} \quad \log\left(\frac{N}{N_0}\right) = -\frac{t}{D}$$

$$\log\left(\frac{N}{N_0}\right) = -\frac{t}{D} \text{ \_\_\_\_\_\_\_\_\_\_ } (3) \qquad D = \frac{2.303}{K}$$

Where ‘D’ is the decimal reduction time, or the time required to reduce the viable population by a factor of 10.

Thus, the decimal reduction time and the first-order Kinetic rate constant can be easily converted for use in equations requiring the appropriate form of the kinetic parameter.

26.1.3 Shape of Microbial Inactivation Curves

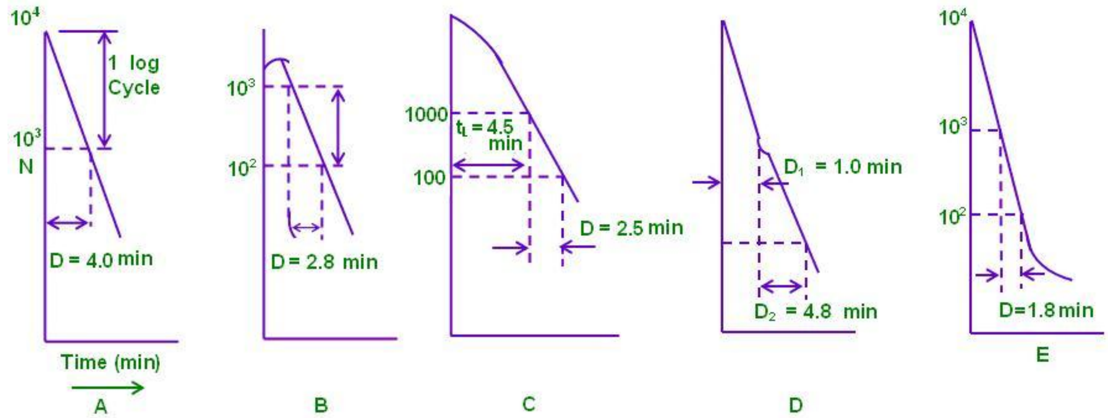


Fig.26.1 Microbial inactivation curves

Microbial Inactivation process is a logarithmic function with time according to equation (3). However, although the most common inactivation curve is the linear semi logarithmic plot, several other shapes are encountered in practice.

Figure 'B' shows an initial rise in numbers followed by first order inactivation. This has been observed with very heat-resistant spores, and may be attributed to heat activation of some spores which otherwise would not germinate and form colonies before the heat treatment reached the severity needed to kill the organism.

Fig 'C' shows an inactivation curve which exhibits an initial log or induction period. Very little change in numbers occurs during the log phase. The curve represented can be expressed as:

$$\log \frac{N_0}{N} = 1 + \left(\frac{t - t_L}{D}\right) ; t > t_L \quad \text{———} (4)$$

Where,

t_L= the log time, defined as the time required to inactivate the first 90% of the population.

In most cases, the curved sections of the inactivation curve do not extended beyond the first log cycle of inactivation. Therefore defining t_L as in equations (4) above, eliminates the arbitrary selections of the log time from the point of tangency of the curved-line and the straight-line position of the inactivation curve. In general, t_L approaches D as No becomes smaller and the temperature increases. When t_L=D, the first-order inactivation rate starts from the initiation of heating and equation (4) reduce to equation (3) equation (4) is not often used in thermal powers calculations unless the dependence of t_L on N_0 and T are qualified. Microbial inactivation during thermal processing is after evaluated using equations (3).

Figure 'D' represents the inactivation of each species is assured to be independent of the inactivation of others.

From equations (3), the number of species A and B having decimal reductions times of D_A and D_B at any time is:

$$N_A = N_{A0}\ (10)^{-\left(\frac{t}{D_A}\right)}\ ;\quad N_B = N_{B0}\ (10)^{-\left(\frac{t}{D_B}\right)}$$

$$N = N_{A0}\ (10)^{-\left(\frac{t}{D_A}\right)} + N_{B0}\ (10)^{-\left(\frac{t}{D_B}\right)}$$

If $D_A < D_B$, the second term is relatively constant at small values of t and the first term dominates, as represented by the first line segment in fig 'D'. At large value of t, the first term approaches zero and microbial numbers will be represented by the second line segment in fig (3).

The heating time required obtain a specified probability of spoilage from a mixed species with known 'D' values is the largest heating time calculated using equations (3) for any the species.

Figure 'E' shows an inactivation curve which exhibits tailing. Tailing is often associated with very high N_0 values and with organism which have a tendency to chump. In the case of lag in the inactivation curve, the effect of tailing is not considered in the thermal process calculation unless the curve is reproducible and the effects of initial number and temperature can be quantified.

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Lesson-27

Filling Operation: Principles and Working of Different Types of Bottle Fillers and Capping Machine

27.1 INTRODUCTION

After the process system, the filler is the heart of any milk handling line in a dairy plant. Whether it is simple 6-head rotary filler, or a high-speed multilane linear machine with a hepafiltration chamber, the filler is the center of line activity.

The landscape of the filler business has changed dramatically in recent years, as more and more beverages (including single serve milk) are being sold in plastic. Packaging materials and package sizes have changed, and many manufacturers are now offering different lines of equipment for use with more than one kind of packaging. Machines are faster and achieve higher levels of hygiene for longer shelf life and ambient storage.

Companies have included blow molded plastic in their lines of packaging and equipment. Some companies have got linear aseptic filler for HDPE bottles in commercial use for low acid food and beverages. Companies can now commercially fill low acid products into HDPE plastic containers and distribute them without refrigeration.

The latest filling machines have features like 64-valves with 32 pocket star wheels and designed to fill plastic and glass bottles with a maximum diameter of 3.0' (76 mm) at speeds up to 800 bpm. Other models are available for larger containers. Special features include demountable valve flanges, electronic level control system, filler driven in-feed conveyor, automated lubrication system, automated cleaning and sanitizing system, and digital control system with touch screen operator interface.

Modern machines can have multi-lane inline equipment and can fill in both Ultra-Clean and Aseptic processes. The machine can receive product/s from one of many different UHT processors. Because it is multi-lane, it may be used to fill more than one type or flavor of product simultaneously. Production rates will vary, depending on the number of lanes, the size of the container and the viscosity of the product. Fill time is the major limit on cycle time, but the bottles can be filled in multiple stages to shorten the cycle time.

27.2 VACUUM FILLING OF BOTTLES

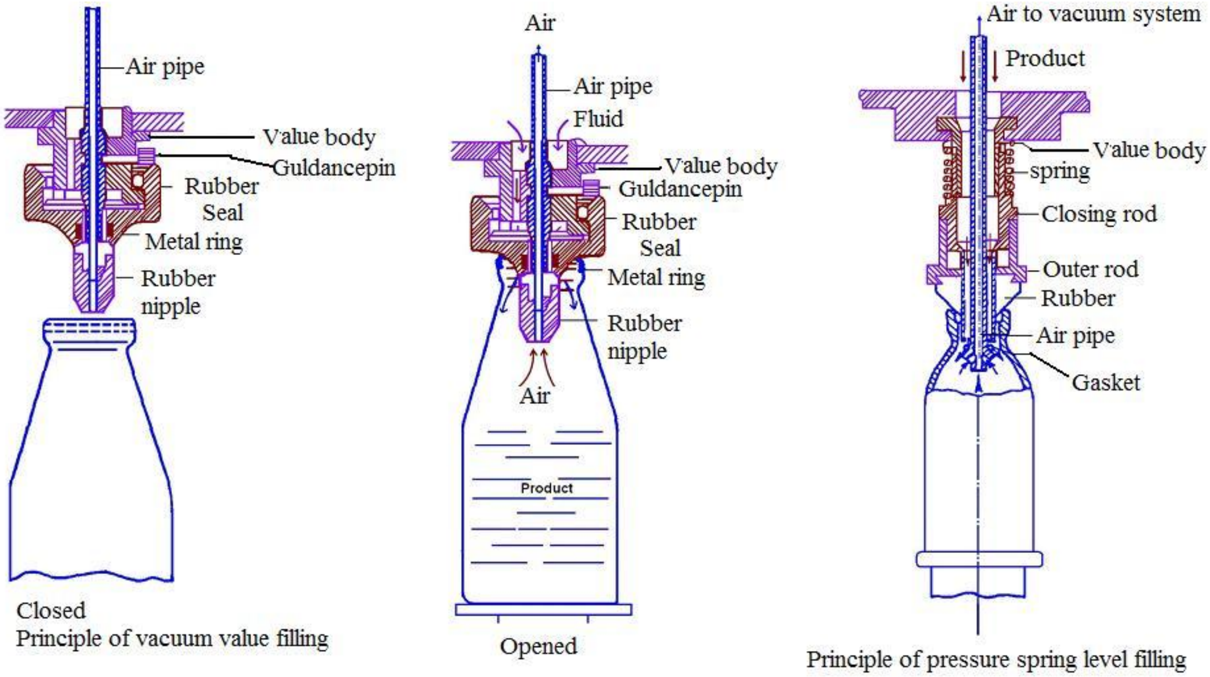

Fig. 27.1 Vacuum filling of bottles

The bottles after bottle washing machine are fed to the bottle filler by conveyor. The bottles are made to feed on to individually by a star wheel on to a Platform. The platform will rise and fall making it to meet the filler valve positioned above. The mouth of the bottle is pushed against the rubber seal of the filling device thus making it air tight. The air in the bottle is removed due to the vacuum which exists in the upper part of the filling vessel, which will also be rotating along with the platform of bottles. Simultaneously, the opening between the rubber seal and filling tube is released by the raise of the bottle against the rubber seal, and milk enters the bottle, due to low pressure existing in bottle. Once the milk has risen to the level of the hole of the filling tube, no more air can be removed from the bottle, and the filling operation is terminated.

This type of filling has the advantages of rapid filling, reduced milk losses. If the mouth of the bottle is damaged, it cannot properly raise the rubber seal, and milk will not be filled in that bottle. This automatically reduces the product loss. The vacuum system also ensures foam free filling.

27.3 CAPPING MACHINE

The capping machine is synchronized with the filling machine. The Al foil, which is usually the capping material, has to pass through a plain or embossed on the die and a punch which is reciprocated o the die. The foil is self lubricated which otherwise will not cut the edges smooth. The foil thickness ranges from 0.04 to 0.05µm. The dia is 38mm and one kg Al foil may give about 3000 caps and a roll of foil may weigh 5 or 6 kg. Plain, coloured or lacquered foils are used.

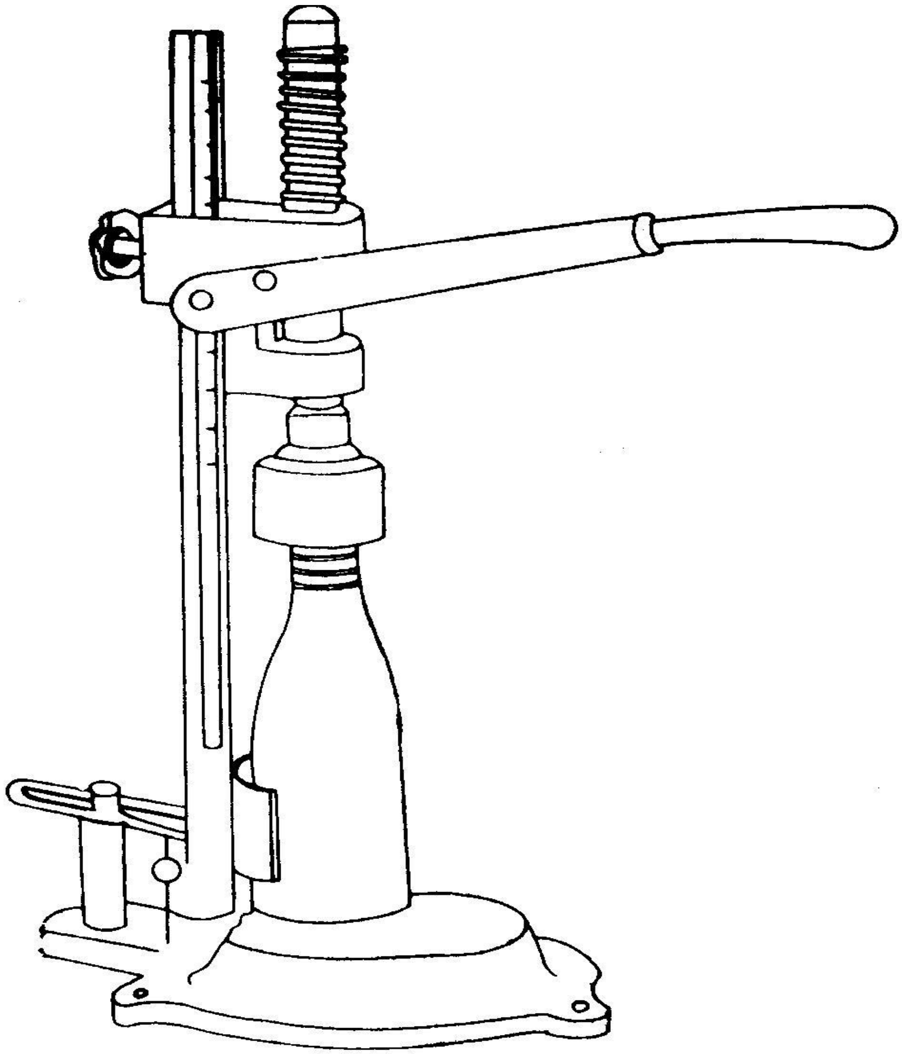

Fig.27.1 Capping machine
(Source: C.P Ananthakrishnan (1987)

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Lesson-28

Pouch Filling Machine: Form-Fill-Seal Types

28.1 INTRODUCTION

The Form Fill Seal machines are a genre of filling equipment that can fill in a flexible packing material. The product should be free flowing type, either liquid or even granular. The equipment may be controlled electro-pneumatic or mechanically or a combination of them. Of late, the mechanical types are being preferred over the electro-pneumatic types for their simple operations as well as low energy consumption.

The process involves certain steps, which will take place cyclically in auto operation.

There is option for variation in size and quantity of the product packed. To a large extent, the market milk is now being sold by packing in these machines.

The following are the operations that go cyclically.

1. Forming of tube of packing material from film in rolled state
2. Simultaneous operation of filling and sealing
3. Movement of film to form next package
4. Simultaneous separation of filled and sealed packet while filling of next packet.

28.2 SEQUENCE OF OPERATION

With reference to the fig 28.1, the film roll is loaded at the backside of the filling machine on a sliding platform. The film edge is passed over end of roll contact lever, dancer roller, UV tube and brought to the front side over to forming plates. The function of UV tube is to stelriize the film. The forming plates roll the flat film in to a tube with a certain band of overlap. Within the tube is the fluid filling pipe enveloped. The tube then passes over to vertical seal jaws that are engaged and disengaged with the help of an air operated piston, or in some machines by mechanical means. In between the jaws, the overlapped part of the film tube passes. The set of jaws have one stationary and one moving jaw. The moving jaw has a Ni-chrome rod, supplied with variable voltage such that the heat is generated when the current passes intermittently. During the period when the current does not pass, when the jaws are disengaged, the cooling water being circulated in the moving jaw cools it and prevents continuous over heating of the sealing rod. The film is supported by Teflon cloth and rubber cushion, as well as protected by Teflon cloth from sealing rod. This arrangement prevents electricity passing on to the film and other parts, while allowing only the heat to pass on to the film and partly melting and fusing the vertical joint.

Lower down the film tube, there is a pair of nip rollers giving a holding and pulling down action, when the jaws are disengaged, making the film to move to seal the next portion of vertical overlap.

Further lower down the film tube is engaged by horizontal jaws, at a sufficiently below the lower edge of fluid filling pipe. This arrangement allows the formation of lower seal of the packet, while the fluid is being filled to a known quantity. The quantity of flow is controlled by a valve operated by a rod. The rod is lifted by a solenoid coil positioned at the top of machine, just at the feeding line from the over head tank carrying the fluid to be filled. While filling is taking place, a pair of flat blades operated by spring keeps the film perfectly flat at horizontal edge so that there are no folds and horizontal seal is perfect.

When the filling of fluid and the horizontal sealing is complete, the horizontal jaws (as well as vertical jaws) get disengaged, and the nip rollers start rolling to bring the next length of film tube to be filled for next packet. While the second packet is being filled, the first packet already filled will be getting the horizontal seal of top portion of the filled packet. When the next time the jaws open, the first packet drops down by its own weight because of weakened connection to the rest of the tube.

The above cycle of operation is repeated when the controls are in automatic operation, while single action takes place when in manual operation during initial adjustment of time and temperature combination for obtaining proper seal.

28.2.1 Controls

The Form Fill Seal Machine has various controls for the following operations.

1. Adjusting the temperature of sealing rod by controlling the electric supply, to match to the thickness of the film to be sealed.
2. Adjusting the timing for the jaws to be engaged and simultaneously filling operations to take place, with a known quantity of fluid.
3. Adjusting the quantity of fluid to be filled when jaws are engaged
4. Adjusting the timing for the jaws to be disengaged and allow time for movement of film to the required length of package.

The other useful instrumentation are the end of film indicator (gives audio signal), so that the new film roll can be changed easily, fine adjustments for the quantity of fluid filled in few grams range, fine adjustment of timings, etc. There is a provision to print the batch number and date of filling on the packet.

The equipment will require water for cooling the jaws at a fixed flow rate and of low temperature. Also, compressed air is required which is at a particular pressure and free of condensed moisture.

The filling machine comes in both Single header and double header types. The double header undertakes similar operations simultaneously as that of a single header.

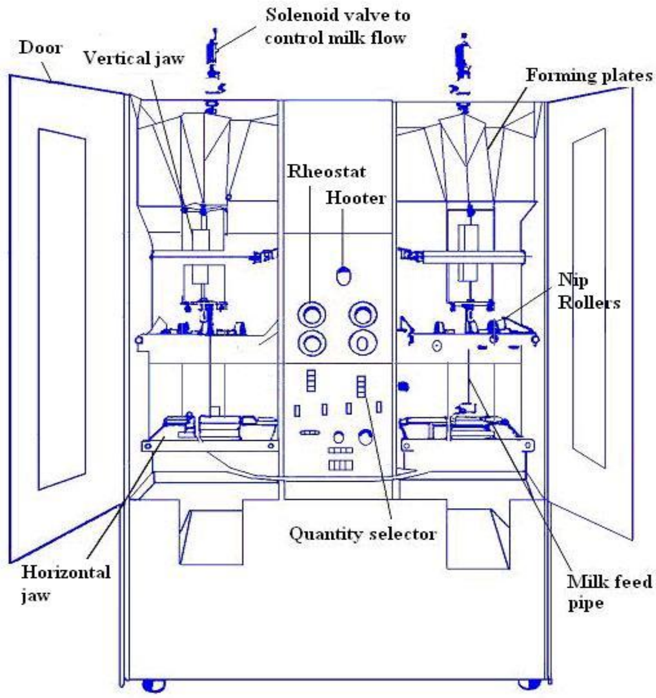

Fig.28.1 Form-Fill-seal machine

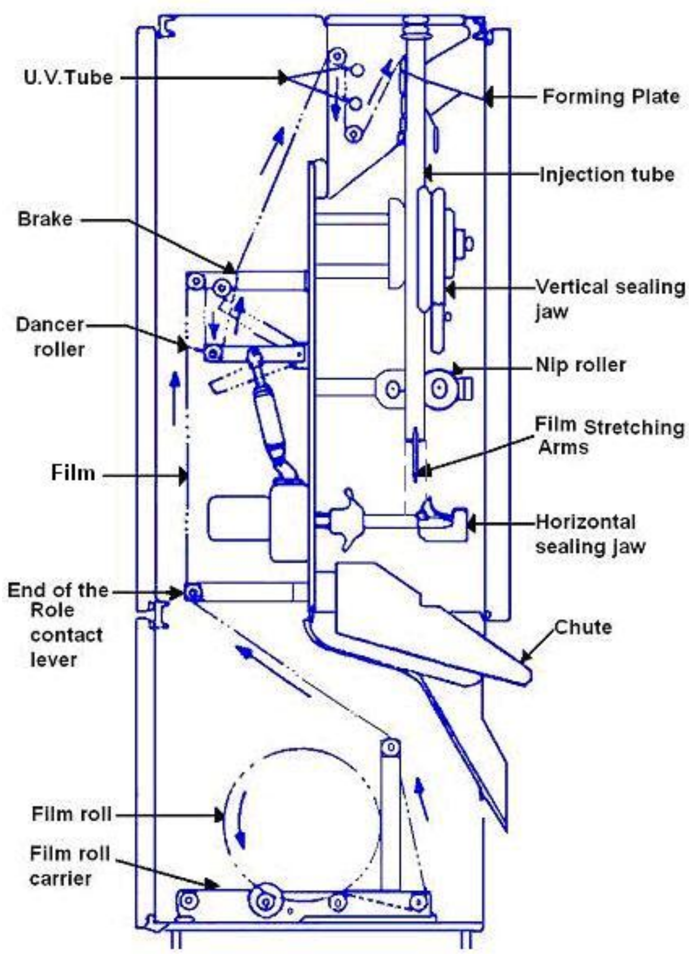

Fig.28.2 Film feed circuit

Lesson-29

Aseptic Filling by Bulk Handling System, Care and Maintenance

29.1 INTRODUCTION

With increasing consumption of long life foods like milk, fruit juices and other liquid foods, as well as certain pharmaceutical applications, the bulk handling of foods aseptically is taking prominence.

The above operation is possible with improvement in packing material and related technologies. The large size packages that can withstand mechanical damage and ability to have perfect seal are being manufactured. The packing containers are heat sealable like the milk pouch film sealing. There is also both one way as well as returnable containers being manufactured.

29.2 BULK ASEPTIC FILLING EQUIPMENT

The Bulk fillers like individual package fillers, are located very near to the UHT plant, and the product is not stored in between. The product is filled as it comes out of UHT plant.

Standard equipment basically has an arm protruding out like a cantilever, from a support base. The arm carries a long pair of horizontal jaws for sealing, supplied with heating element. The arm also carries a valve sealing equipment that exactly matches with the nozzle of the packing bag. Once the valve is connected to the nozzle of the packing bag, it creates an air tight grip on to it. The arm is connected with vacuum line, which when activated, draws away the air from the bag to be filled. The option of circular valve or horizontal jaws depends on the type of bag that the bulk filling is done. This action is similar to the vacuum cleaner.

Once the bag is cleared of the air, the product flows through another pipe connected to the arm, and a known quantity is filled into the bag. The choice of the quantity, the time of sealing, the temperature etc is programmed. The sample packing for smaller bags can be done manually. If the bag is large, the arm has adjustment facility to lift the bag to the required height and hold it till the product is filled, so that there are no empty pockets in the bag.

The controls can be simple touch screen type and has all the machine modes and also any alarm that are required for indicating any process deviations to the operating personnel. There is a control for the sealing time, temperature, change in volume etc. The controls have both the Manual and Auto operation facility, so that filling operation goes on continuously, once the process parameters are achieved. The manual operation is usually done for sample package sealing that is required for the quality control laboratories from time to time. The touch screen controls can also be custom programmed to give the information about history of filling operations, shift basis or day basis in addition to the operation.

All product contact surfaces are of AISI 316, for maintaining proper hygiene and prevent corrosion. The CIP cleaning is done by fitting an adopter into the filling jaws. No manual strip down of equipment for cleaning is required.

The capacities of bags can be 5 lts to 1000 lts. The large bags are further supported by drums in which they are positioned while filling it. The equipment can also fill variety of containers. The filled packets are moved away from the filling arm, by roller conveyors for quick filling operations.

Fig.29.1 Bulk filler

Fig.29.2 Aseptic closure assembly

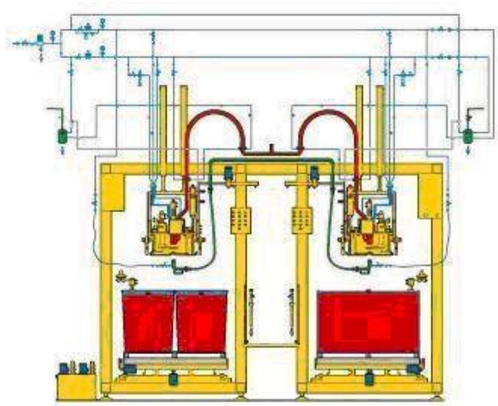

Fig.29.3 Schematic diagram of bulk filler

Fig.29.4 Package material holder cum filling tube

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Lesson-30

Mixing and Agitation

30.1 INTRODUCTION

In most of the processing operations in dairy plant, the process fluid may have to be heated or cooled. It would need some kind of agitation. Similarly, mixing various ingredients like that for ice cream mix, is also common. They form very important unit operations in the processing industry. The aim is to achieve the objective with minimum of energy input, and wear and tear.

30.2 AGITATION

It is the induced motion of a material in a specified way usually in a circulatory pattern inside some sort of container. **e.g.**Agitation of milk in a storage tank.

30.3 MIXING

It is random distribution, into and through one another, of two or more initially separate phases. **e.g..** Mixing of Ice cream ingredients before freezing.

30.4 AGITATION and MIXING OF LIQUIDS

The purpose of agitation and mixing can be many, depending on the process objective.

1. To distribute solid particles more uniformly. **e.g.** Ingredients in ice cream mix
2. Blending miscible liquids **e.g.** In Gerber test shaking different fluids before putting butyrometer in the Centrifuge
3. Dispersing gas through the liquid. **e.g.** Agitation in silos by compressed air
4. Dispersing immiscible liquids to form emulsion or suspensions of fine drops **e.g.** Butter oil in RCM
5. Assisting in heat transfer e.g. agitation in multipurpose vat for batch pasteurization

30.4.1 Agitation equipment

1. Vessel: i) Usually cylindrical, slightly round bottom to avoid pockets of stagnant liquid
   ii) Top of vessel may be closed or open
   iii) Height of liquid approximately equal to diameter of the vessel.
2. Motor with shaft of sufficient length, directly connected or through reduction gear. Shaft has an impeller and may have support

30.4.2 Types of agitators

There are different types of agitators, to suit to the varied process operations. Below are some of them. The types a) and b) are of turbine types, while the c) and d) type are propeller type.

i) Paddle	ii) Propeller	iii) Turbine
Open Straight Blade	Bladed Disk	Vertical Curved blade

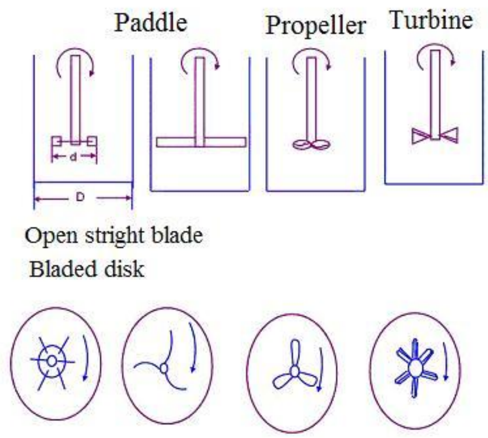

Fig. 30.1 Agitators

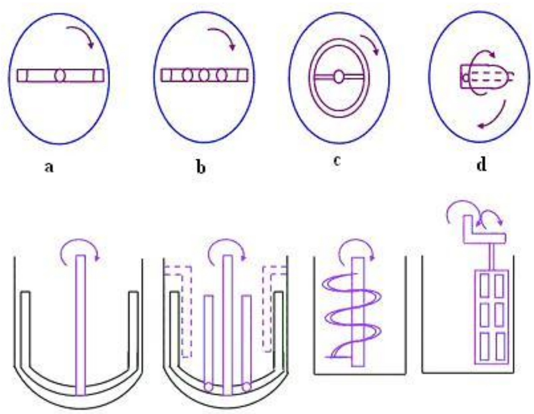

Fig.30.2 Agitator (Scraping type)

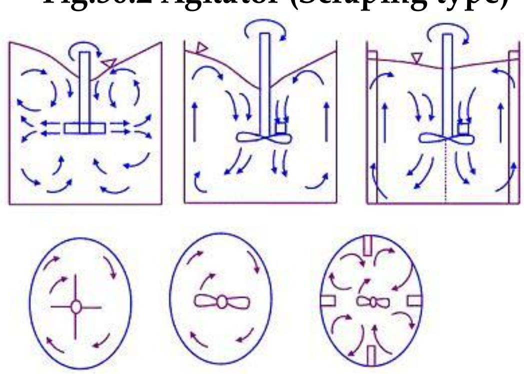

Fig.30.3 Vortex formation

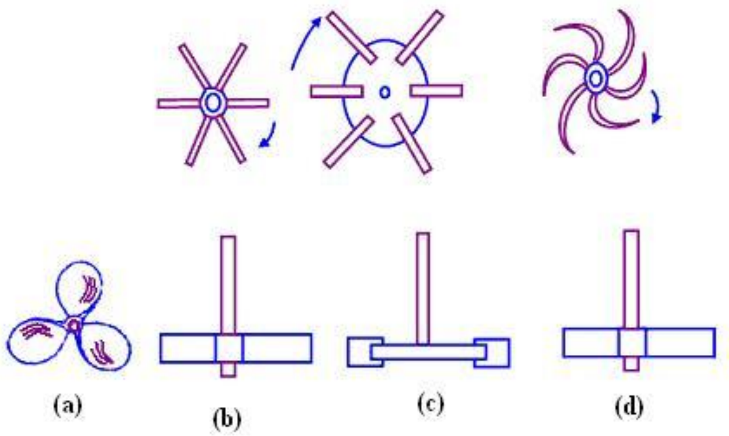

Fig.30.4 Turbine
(a). Three blade marine propeller (b). Open straight blade turbine
(c). Blade disk turbine (d). Vertical curved blade turbine

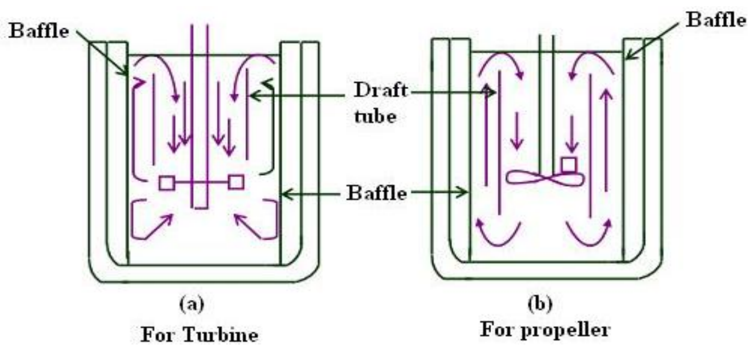

Fig.30.5 Baffle

30.4.2.1 Methods to avoid formation of vortex:

Action of agitation sometimes leads to formation of vortex, which can suck air into the fluid being agitated. Methods by which this objective is achieved are:

i) Tilted impeller shaft
ii) Mounted on side (eccentrically) of tank
iii) Baffles

* Vertical strip perpendicular to the wall of tank
* Four baffles sufficient
* For turbines type of agitators the width of baffle is < 1/12 D_t
For propeller width the same is <1/18 D_t
* Side entering, inclined or off-center propellers do not need baffles

30.5 DRAFT TUBES

Draft tubes are used when direction and velocity of flow to the suction of the impeller to be controlled. They are useful when high shear at impeller itself desired. **e.g.**: emulsions. Also they are used when solid particles tend to float on surface

30.5.1 Disadvantage

1. Draft tubes add to the fluid friction.
2. For a given power input, reduce flow rate.

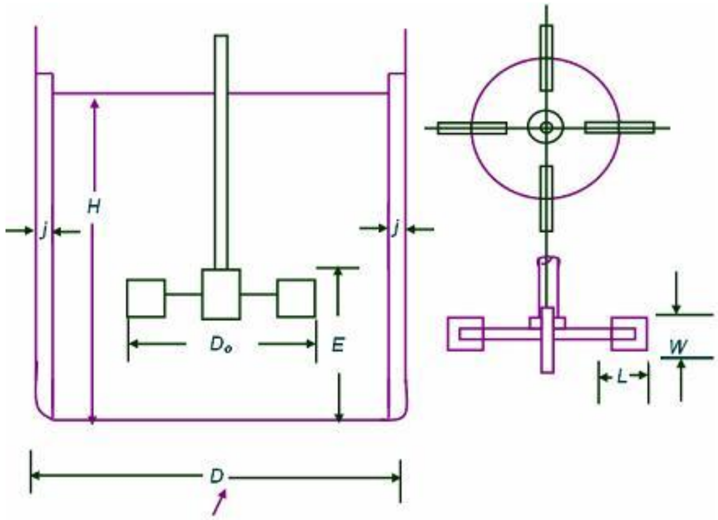

Fig.30.6 Standard turbine

30.5.2 Typical proportions

With regard to the dimensions mentioned in the above figure 30.4, the general proportions of the dimensions are given below:

$$\frac{Da}{Dt}=\frac{1}{3} \qquad \frac{H}{Dt}=1 \qquad \frac{J}{Dt}=\frac{1}{12}$$

$$\frac{E}{Dt}=\frac{1}{3} \qquad \frac{W}{Da}=1 \qquad \frac{J}{Da}=\frac{1}{4}$$

Number of baffles usually is 4. The number of impeller blades are of the range 4 to 16, but usually 6 or 8. If greater depth of the process fluid is desired, then two or more impellers are mounted on the same shaft. Bottom impeller, either of the turbine or propeller type, is mounted about one impeller diameter above the bottom of the tank.

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Lesson-31

Power Consumption of Mixer-Impeller, Selection of Mixing Equipment in Dairy Industry, Mixing Pumps

31.1. INTRODUCTION

The operation of agitation has to be effective in achieving the objective, at a minimum cost as well as in short time. With increasing cost of electricity, the energy consumption of agitation and mixing has to be carefully audited for energy savings. In the analysis electrical energy consumption, the techniques of optimization, dimensional analysis are done to minimize the cost of installation and operation.

31.2. CIRCULATION, VELOCITIES AND POWER CONSUMPTION IN AGITATED VESSELS

Volume circulated by impeller must be sufficient to sweep out the entire vessel in reasonable time. Velocity of the stream leaving the impeller must be sufficient to carry the currents to the remotest points. Turbulence in moving stream often governs the effectiveness of the operation. It is caused by large velocity gradients.

Volumetric flow rate, q is proportional to the speed and the cube diameter of impeller. Another important parameter is the Flow Number, a dimensionless number.

Flow Number, $N_{Q1} = N_{Q1} = q\, n \times (Da)^3$

Flow number is constant for each type of impeller

For standard flat–blade turbine, in a baffled vessel, $N_Q \approx 1.3$

For Flat – blade turbines, the total flow, estimated from the average circulation time for particles is

$qT = 0.92 \times n \times (Da)^3 \times (Dt / Da)$

For a Dt/ Da =3 the $q_T = 2.76\, nD_a^3$ or 2.1 times the value at the impeller (N_Q=1.3). The above equation should be used only for Dt / Da ratio between 2 and 4

31.3. POWER CONSUMPTION

When the flow in the tank is turbulent, the power requirement can be estimated from the product of the flow 'q' produced by the impeller and the kinetic energy, per unit volume of the fluid.

$Q = n \times (Da)^3 \times N_Q$

$E_K = \rho \times (V_2{}^1)^2 / 2 \cdot gc$

Where V_2^1 = Actual velocity of the particle at the impeller blade tip, which is slightly smaller than the tip speed μ^2

Power requirement, that is $n \times (Da)^3 \times N_Q = \rho\, 2 \cdot gc \times \alpha \cdot \pi \cdot n\, (Da)^2$

$= \rho \times n^3 \times (Da)^5\, (\alpha)^2 \times (\pi)^2 \times N\, q\, / 2g_c$

Where $\alpha = (V_1)^2\, (\mu)^2$

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Lesson-32
Solving Numerical

Example 1: A flat-blade turbine with six blades is installed centrally in a vertical tank. The tank is 6 ft (1.83 m) in diameter; the turbine is 2 ft (0.61m) in diameter and is positioned 2 ft (0.61m) from the bottom of the tank. The turbine blades are 5 in (127 mm) wide. The tank is filled to a depth of 6 ft (1.83 m) with a solution of 50 percent caustic soda, at 150 °F (65.6°C), which has a viscosity of 12 cP and a density of 93.5 lb/ft^3 (1498 kg/m^3). The turbine is operated at 90 r/ min. The tank is baffled. What power will be required to operate the mixer ?

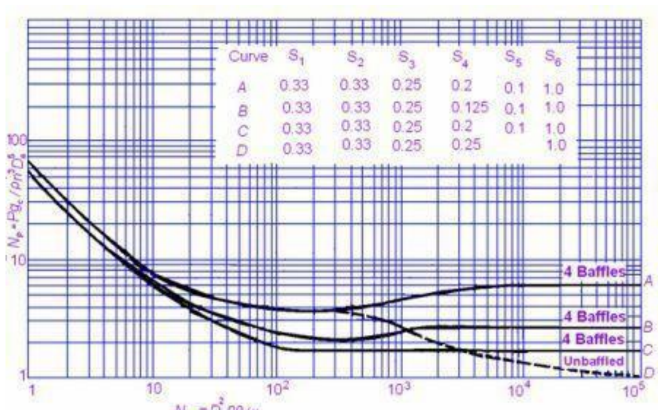


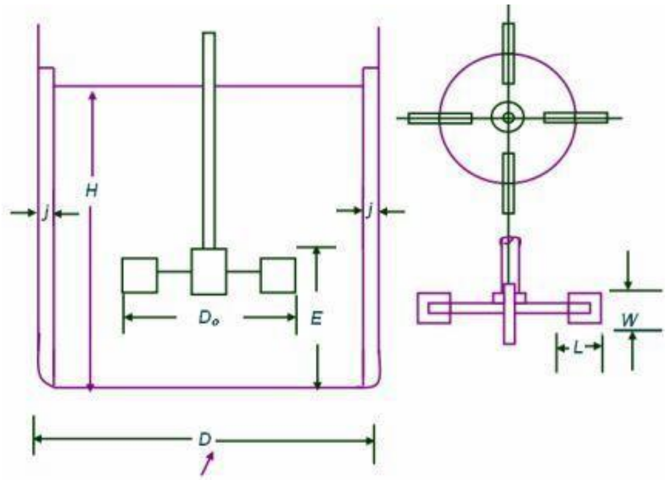
Fig. 32.1 Curve Turbine

Solution

Curve *A* in Fig1. applies under the conditions of this problem.

$S_1 = D_a / D_t$; $S_2 = E / D_t$; $S_3 = L / D_a$; $S_4 = W / D_a$; $S_5 = J / D_t$ and $S_6 = H / D_t$

The above notations are with reference to the diagram below against the dimensions noted. The notations are valid for other examples following also.



Dimension of Turbine Agitator

The Reynolds number is calculated. The quantities for substitution are, in consistent units,

$D_a = 2 \cdot ft$

$n = 90/60 = 1.5\ r/s$

$\mu = 12 \times 6.72 \times 10^{-4} = 8.06 \times 10^{-3}\ lb/ft\text{-}s$

$\rho = 93.5\ lb/ft^3$ $g = 32.17\ ft/s2$

$N_{Rc} = ((D_a)^2 n \rho)/\mu = 2\ 2 \times 1.5 \times 93.5\ 8.06 \times 10^{-3} = 69{,}600$

From curve *A* (Fig.1) , for $N_{Rc} = 69{,}600$, $N_P = 5.8$, and from Eq. $P = N_P \times (n)^3 \times (D_a)^5 \times \rho\ g\ c$

The power $P = 5.8 \times 93.5 \times (1.5)^3 \times (2)^5 / 32.17 = 1821 \cdot ft{-}lb\ f/s$ requirement is 1821/550 = 3.31 hp (2.47 kW).

Example 2: What would the power requirement be in the vessel described in example 1. If the tank were unbaffled?

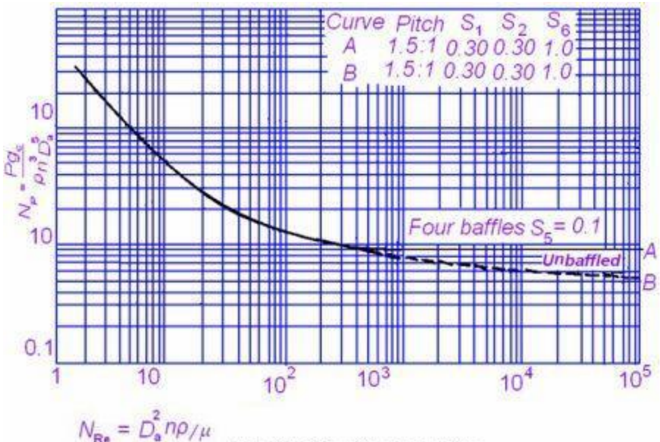


Fig.32.2 Flat-Blade Turbine

Curve *D* of fig.2 now applies. Since the dashed portion of the curve must be used, the Froude number is a factor ; its effect is calculated as follows:

N FR = n 2 × D a g = 1.5 2 ×2 32.17 =0.14

Constants a and b m= a− log 10 × N Re b in are given in the table below

Figure	Line	a	b
1	D	1.0	40.0
2	B	1.7	18.0

The constants a and b for substitution into Eq. m= a− log 10 × N Re b are

a = 1.0 and b = 40.0 from eq. m= a− log 10 × N Re b

m= 1− log 10 ×69,600 40 =−0.0960.096

The power number read from fig 1, curve *D*, for N_{RC} = 69,600, is 1.07; the corrected value of N_p is 1.07 x $0.14^{-0.096}$ = 1.29. Thus, from P= N p × n 3 × D a 5 × ρ g c Eq.

P= 1.29×93.5× 1.5 3 × 2 5 32.17 =406·ft−lb f/s

The power requirement is 406/550 = 0.74 hp (0.55 kW).

It is usually not good practice to operate an unbaffled tank under these conditions of agitation.

Example 3: The mixer of example1. is to be used to mix a rubber-latex compound having a viscosity of 1200 P and a density of 70 lb / ft^3 (1120 kg/m^3). What power will be required?

Solution

The Reynolds number is now N_{RC} = 2 2 ×1.5×70 1200×0.0672 =5.2

This is well within the range of laminar flow. $N_p = K_L N_{RC}$

Values of constants K_L and K_T in Eqs. and $N_P = K_T$ are given in the table

below for baffled tanks having four baffles at tank diameter

Type of impeller	**K_L**	**K_T**
Propeller, three blades		
Pitch 1.0[1]	41	0.32
Pitch 1.5[2]	55	0.87
Turbine		
Six-blade disk [2] (S_3 = 0.25, S_4 = 0.2)	65	5.75
Six curved blades[1] (S_4 = 0.2)	70	4.80
Six pitched blades [3] (45°,S_4 = 0.2)	-	1.63
Four pitched baldes[2] (45°,S_4 = 0.2)	44.5	1.27
Flat paddle, two baldes[1](S_4 = 0.2)	36.5	1.70
Anchor [2]	300	0.35

K_L = 65 ; from Eq. , N_P = 65 / 5.2 = 12.5, and

P= 12.5×70× 1.5 3 × 2 5 32.17 =2938·ft−lb f/s

The power required is 2938 / 550 = 5.34 hp (3.99 kW). This power requirement is independent of whether or not the tank is baffled. There is no reason for baffles in a mixer operated at low Reynolds numbers, as vortex formation does not occur under such conditions.

Note that a 10,000-fold increase in viscosity increases the power by only about 60 percent over that required by the baffled tank operating on the low-viscosity liquid.

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