UNIT 6 COOLING SYSTEMS FOR MILK AND MILK PRODUCTS

Structure

6.0 OBJECTIVES

After reading this unit, we should be able to:

- apply the use of refrigeration in dairy industry
- specify the various purposes of refrigeration of milk & milk products
- know about different types of refrigeration equipment used in dairy industry.

6.1 INTRODUCTION

In the last unit we have acquired the basic knowledge about producing refrigeration and the general construction and working of a refrigerating machine and various types of its components. In this unit, we will concentrate on the use of refrigeration in dairy industry. Now the possible question which may arise in our mind is that why the refrigeration or cooling is required for milk or milk products? When and where the refrigeration is applied on dairy products? How much and how long the cooling is required? And finally how the required refrigeration is achieved efficiently or what are the actual methods and actual design of equipment used in the refrigeration of dairy products? We will try to find answers to all such type of questions, so that we may become familiar with type of cooling methods used for milk and milk products at various stages of production, processing and consumption.

First question is that why refrigeration/ cooling is required for milk and milk products. We know that cooling of milk is done to retard the bacterial growth and prevent it from spoiling. Because as soon as the milk is produced bacterial growth starts in it. If it is allowed to remain at normal temperature as 15^oC to 35^oC for a long time, bacterial growth will continue. Now all the milk produced at dairy farms cannot be used at once and it needs to be distributed to different places, needs to be transported to small or large dairy industries for processing and making of milk products. Thus after production milk is required to be chilled upto 4^oC or less until, it is distributed and consumed or processed to check the bacterial growth, avoid the spoilage and preserve the quality as it is produced. Even after processing and packaging, the milk and milk products are required to be chilled, i.e. to be kept at a low temperature until these are consumed.

Now we know that refrigeration is very much essential for preservation of milk and milk products by storing at a low temperature between the production and consumption stages. So, one application or use of refrigeration is to increase the storage life of milk and milk products. The other application is that refrigeration may also be required in carrying out some operations on milk like milk pasteurization, butter making, ice-cream manufacturing, freezing/ hardening, etc. Milk cannot be pasteurized without cooling after keeping at a higher temperature, butter cannot be formed without churning the cream at lower temperature and ice cream cannot be manufactured without cooling and freezing and hardening it. So, in the nutshell we can say that refrigeration is an integral part of dairy industry and is needed mainly for:

- Milk chilling at production farm
- Storage of milk and milk products before consumption
- Processing and manufacturing of milk and milk products like ice-cream

One more aspect to the use of a refrigeration unit in dairy industry is that it can be used either directly or indirectly. In the direct cooling we install the evaporating coil of refrigeration unit at the place where cooling is required for milk and milk products. But in the indirect cooling, an ice bank i.e. a chilled water tank/ice bank is installed separately. In this ice-bank tank the evaporating coils of the refrigeration unit are fitted and around it water is filled. When refrigeration unit operates, the evaporating coil absorbs heat of water and make it chilled water. Then this chilled water is supplied to the cooling equipment and it cools the milk or milk products.

6.2 FARM MILK COOLERS

Milk chilling means cooling the milk below 4°C at production and collection centers so that to preserve the quality as produced until it is transported and distributed. The equipment used for initial chilling/ cooling of milk depends on variety of variable factors such as quantity of milk, availability of chilling facilities etc. In general the milk chilling at production farm or collection centre can be done in two ways i.e.

1. Can cooling
2. Bulk milk cooling

These methods are described in detail as follows:

i. Can Cooling

In this method, the milk is stored in cans after milking at production centre. The milk remains in cans until it is used or processed. These cans are cooled by any of the cooling methods as described below:

a) Use of ice-chambered non-insulated cans

The cans are of special type in which the milk is filled in the inside chamber and ice cubes are filled in the outside chamber. The temperature of ice is 0°C, less than that of milk. So, it absorbs heat of milk through the wall of inside chamber and cools it. While cooling the milk the ice melts and changes into water. As the cans are non-insulated to the atmosphere, the cooling loss to the atmosphere is high. The method requires supply of ice and large space for storage of cans. This method is not so commonly used because wastage of ice is more.

b) Immersion of milk cans in chilled water insulated tank

In this method, there is an insulated metallic tank as shown in fig.6.1. Insulated means, any type of insulating material is applied on the outside surface of tank. The insulated material reduces to a large extent the transfer of heat from surrounding to the cold tank and thus reduces considerable cooling loss to the atmosphere.

The tank is filled with chilled water and the cans are placed in water such that the water level remains at the neck of cans. The chilled water will chill the milk by absorbing heat of milk in cans through the wall of can. The chilled water can be available naturally in cold regions or the chilled water may be formed by putting ice blocks in water. Ice blocks can be purchased from market. Here the rate of cooling is slow. But the method avoids the use of separate refrigeration machine/equipment.

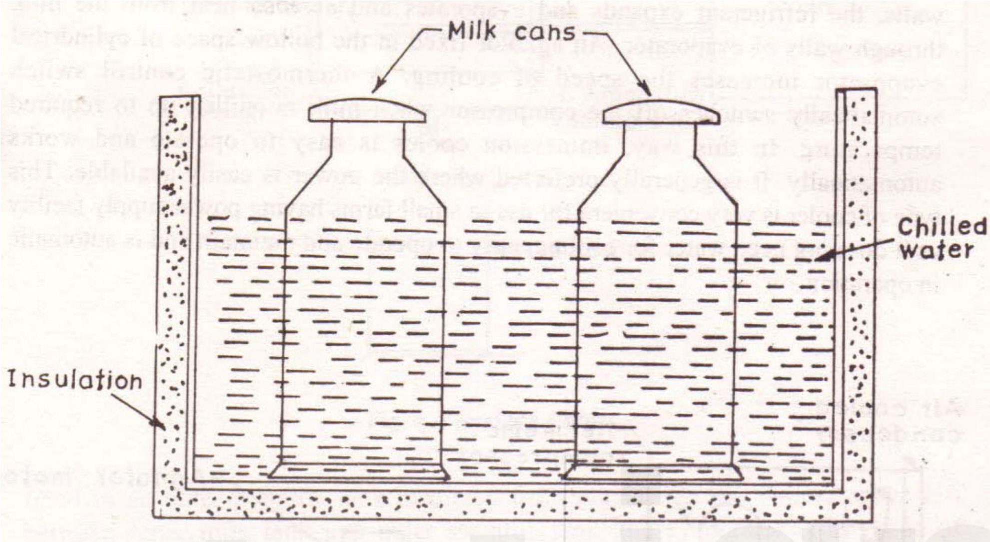

Fig. 6.1 Immersion of Cans in Chilled Water Insulated Tank

c) Immersion of milk cans in a chilled water insulated tank with separate refrigeration unit

This method is generally used in large dairy farms where quantity of milk produced is large. In this method, there is an insulated tank, which is filled with water as shown in fig.6.2. At the top of tank a small refrigeration unit is placed consisting of a hermetic compressor and an air-cooled condenser. The evaporator coil connected to the condenser via a capillary tube is dipped in water in the tank. The milk cans are placed in the water within tank.

When refrigeration unit runs, the evaporating coil cools the water. An agitator fitted in the tank circulates the chilled water around the cans. The agitator increases the heat transfer and decreases the chilling time. In this way, the milk placed in the cans is chilled. This is a very efficient method. But it is also costly due to power consumption by the refrigeration unit.

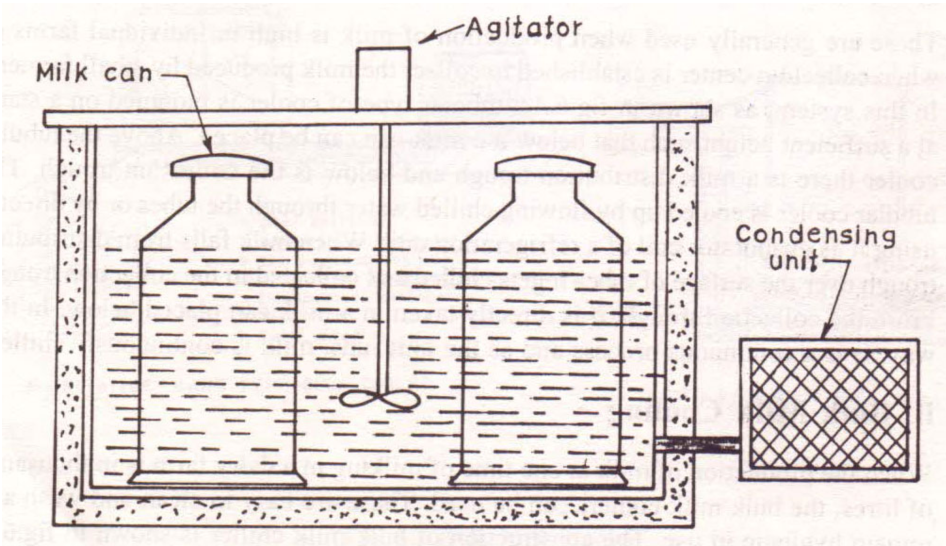

Fig 6.2 Immersion of Cans in Chilled Water Tank with Separate Condensing Unit

d) Immersion cooler with a refrigerating unit

It is the most compact, fast and effective method of milk can cooling. In this method, there is a small capacity hermetic compressor and air-cooled condensing unit (figure 6.3). The condenser is connected to a specially designed evaporator through a capillary tube. The evaporator is a double wall hollow cylinder, which can be directly dipped in the milk can. Inside the cylindrical jacket between the two walls, the refrigerant expands and evaporates and absorbs heat from the milk through walls of evaporator. An agitator fixed in the hollow space of cylindrical evaporator increases the speed of cooling. A thermostatic control switch automatically switches off the compressor when milk is chilled up to required temperature. In this way, immersion cooler is easy to operate and works automatically. It is generally preferred where the power is easily available. This type of cooler is very convenient for use in small farms having power supply facility as it does not need water for cooling, easy to operate and maintain and is automatic in operation.

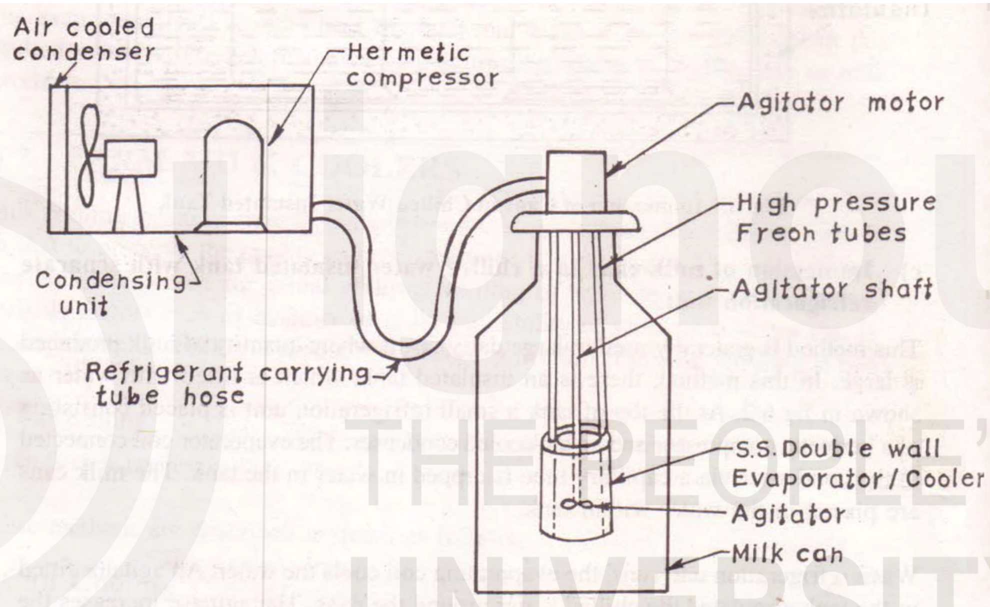

Fig 6.3 Immersion Cooler

e) Surface Coolers

These are generally used when production of milk is high in individual farms or when collection center is established to collect the milk produced by small farmers. In this system, as shown in fig.6.4 a tubular type of cooler is mounted on a stand at a sufficient height such that below it a milk-can can be placed. Above the tubular cooler there is a milk distribution trough and below is the collection trough. The tubular cooler is cooled up by flowing chilled water through the tubes or by directly using it as evaporator coil of a refrigeration unit. When milk falls from distribution trough over the surface of tubes it gets chilled and collected in the collection trough. From the collection trough, it is directly taken in a milk can placed below. In this way, it is a continuous process and as the unit runs, milk is continuously chilled.

ii. Bulk Milk Cooling

When the production of milk at one time of milking in a dairy farm is in thousands of litres, the bulk milk coolers can be used. These are easy to clean and wash and remain hygienic in use. The construction of bulk milk chiller is shown in fig.6.5. There is a huge size bulk milk tank fabricated of alloy steel. This tank is permanently

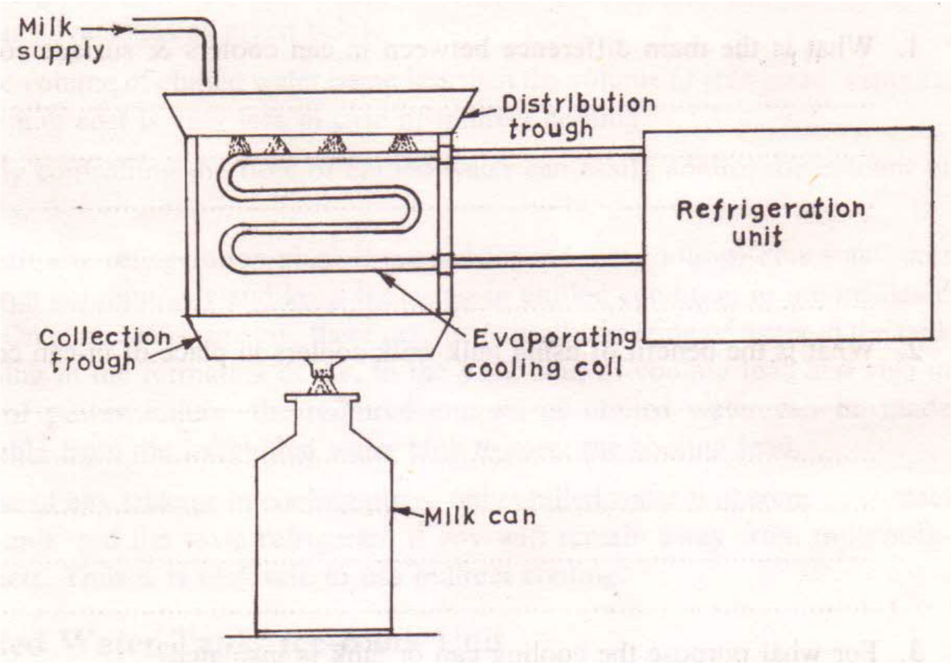

Fig. 6.4 Surface Cooler

fixed in an outer metallic tank insulated from outside. In the bottom space left between inner milk tank and outer metallic tank, the evaporator coils made of copper are placed. A thermostatic expansion valve is generally used with the evaporating coils. The compressor and condensing unit is placed nearby at a suitable place. Water is filled in all the space left between milk tank and outer tank. When the compressor runs, the refrigerant flowing through evaporating coil evaporates and absorbs heat from the surrounding water. Thus the water gets chilled and even some ice formation takes place around the coil. This chilled water is spread over the outer surface of milk tank top by chilled water pump for better heat transfer. In this way, the chilled water circulates around the inner milk tank and cools the milk filled in. At the top of milk tank, an agitator motor is fixed which rotates the agitator in milk through an elongated steel shaft. The agitator is also made of steel. When agitator rotates, it circulates the milk along the inner surface of tank and increase heat transfer. The refrigeration unit works automatically and stops when there is sufficient quantity of ice and chilled water outside the milk tank. Due to ice, cooling of milk continues even when refrigeration unit i.e. compressor is not running.

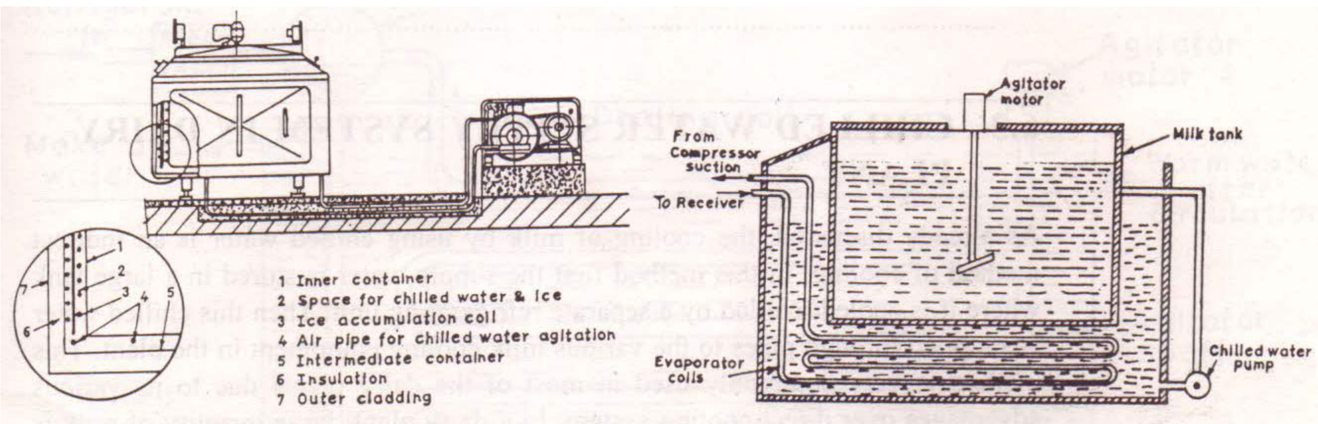

Fig. 6.5 Bulk Milk Cooler

Check Your Progress 1

1. What is the main difference between in-can coolers & surface coolers?

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2. What is the benefit of using bulk-milk coolers in place of in-can cooling?

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3. For what purpose the cooling can or tank is insulated?

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4. For what purpose the agitator is used in bulk milk cooler?

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5. Why water is used as a cooling medium in farm milk coolers?

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6.3 CHILLED WATER SUPPLY SYSTEM IN DAIRY PLANT

As already discussed, the cooling of milk by using chilled water is an indirect method of cooling. In this method first the supply water is stored in a large tank where it is cooled/ chilled by a separate refrigerating unit. Then this chilled water is supplied through pipes to the various milk cooling equipment in the plant. This method is very commonly used in most of the dairy plants due to its various advantages over direct cooling system. In a dairy plant, large quantity of milk is handled/processed. The milk is collected from the milk supply tankers at a particular time. All this milk cannot be processed at a time and needs to be kept in chilled condition to preserve its quality. Moreover, the cooling of milk/milk-products may be required in some other processes also. Thus, the cooling requirement is not continuous or steady. And any time any amount of cooling may be required. For this type of requirement, it is generally not feasible to install refrigeration unit at each cooling point. On the other hand, the indirect cooling suits very much due to its various advantages as given below:

1. As the volume of chilled water being less than the volume of refrigerant vapours, the piping cost is very less in case of indirect cooling.
2. Simply controlling the flow of chilled water can easily control the amount of cooling.
3. A small size refrigeration plant is needed for indirect cooling. This small unit may run continuously and keep the water in chilled condition in the insulated tank. On continuous running, there may be partially freezing of water in the tank resulting in the formation of ice. In the peak hour of cooling load and also in case of power failure, the required amount of chilled water can be made available from the ice/chilled water tank to meet the cooling load.
4. In case of any leakage in cooling pipes, only chilled water will come in contact with milk and the toxic refrigerant if any will remain away from milk/milk-products. Thus it is also safe to use indirect cooling.

i. Chilled Water Tank/ Ice-Bank Unit

The chilled water tank is also called ice-bank unit because when there is no supply of chilled water to dairy plant and refrigeration unit is continuously cooling the water, ice-formation will take place. This ice works as a bank of chilled water, which can be supplied during the peak of cooling requirement. As shown in figure 6.6 it is a metallic tank whose outside surfaces are insulated with glass wool and brick wall. The tank contains a network of cooling coils through which the refrigerant flows. The cooling coil/evaporator coil is of flooded type and remain filled with refrigerant liquid generally ammonia. The liquid ammonia from the receiver of refrigeration plant enters the coil through a low side float valve. The low side float valve reduces the pressure and temperature of liquid ammonia and maintains a constant level of it in the cooling coil. The liquid ammonia absorbs heat and cools the water outside the pipe in the tank. On absorbing heat the liquid ammonia evaporates and its vapours lift up and accumulates in the accumulator above the coils. From the accumulator, these vapours are sucked by compressor through an insulated pipe and again compressed and sent to condenser. A float valve keeps the water level constant in the tank. An agitator installed on one end of tank keeps the

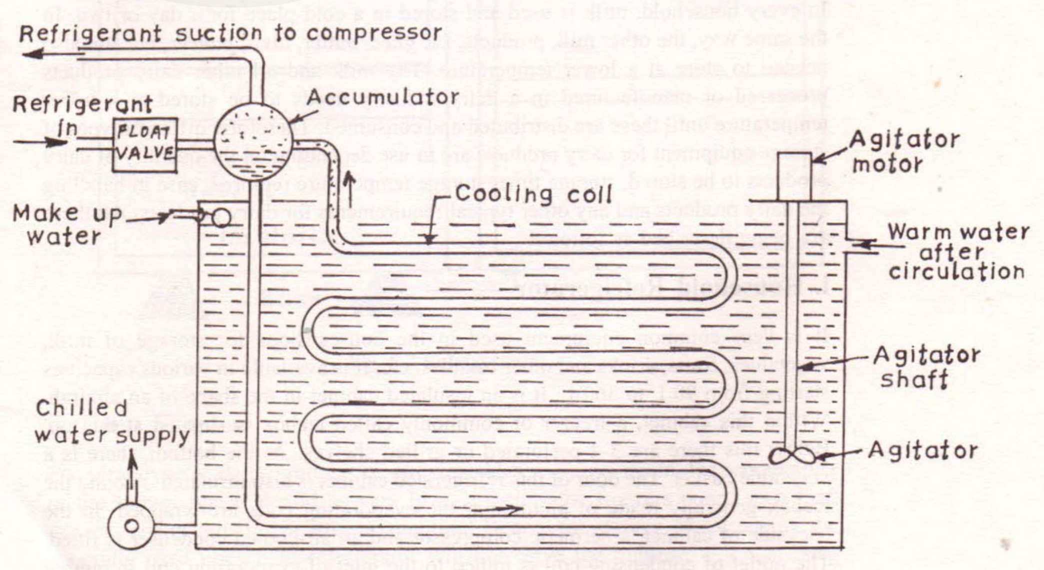

Fig. 6.6 Chilled Water Supply System/Ice-Bank Unit

water flowing over cooling coil for better heat transfer. Outside the tank on one side, the cooling water pumps are installed which take water from the bottom of tank through their suction pipes and supply it to the dairy plant through the network of chilled water pipes. After fulfilling the cooling requirement, the chilled water becomes normal water and is again supplied to the chilled water tank from the top near the agitator.

Check Your Progress 2

1. Why the chilled water tank is also called ice-bank unit?

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2. Which type of evaporating coil is used in chilled water tank?

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3. What are the benefits of using chilled water plant/ice-bank unit in a dairy plant?

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6.4 REFRIGERATED STORAGE FOR MILK AND MILK PRODUCTS

In every household, milk is used and stored in a cold place for a day or two. In the same way, the other milk products, *i.e. ghee,* butter, *lassi*, *paneer*, etc. are also needed to store at a lower temperature. The milk and all other dairy products processed or manufactured in a dairy industry needs to be stored at a lower temperature until these are distributed and consumed. Therefore, different types of storage equipment for dairy products are in use depending on the quantity of dairy products to be stored, storage time, storage temperature required, ease in handling the dairy products and any other typical requirements for dairy products. All these are being described as follows:

i. Household Refrigerator

It is very common equipment used in the houses/shops for storage of milk, vegetables, fruits, drinks and other eatables, etc. It is available in various capacities starting from 90 L to 360 L. It is an insulated cabinet in the shape of an almirah. Within this cabinet, a freezer or commonly called icebox is situated at the top. Below this there are 3-4 perforated or grilled shelves. At the bottom, there is a vegetable basket. The door of this refrigerated cabinet is also insulated. Around the icebox generally made of aluminum, the evaporating coils are wrapped. In the backside of cabinet, a hermetic compressor and an air-cooled condenser is fitted. The outlet of condensing coil is joined to the inlet of evaporating coil through a capillary tube crossing the back wall of cabinet. The evaporating coil is dry expansion type. When compressor is started, the refrigerant liquid within the evaporating coil flows and evaporates. While evaporating it absorbs heat and cools the icebox and surrounding air. The cold air around the coil is heavier than the warm air at the bottom. So, by natural convection, the cold air settles down and warm air lifts up. The circulating cold air current cools all the items placed on shelves. The temperature of cooling coil is low enough such that within the icebox temperature is less than 0°C. So, the water placed in ice trays convert to ice, which can be used for various purpose in the house. The temperature in the cabinet outside the icebox is generally from 0°C to 4°C. Within the cabinet wall a thermostatic control is given which can be adjusted for slow or fast cooling. Due to thermostatic control when the required temperature inside the refrigerator cabinet is achieved, the compressor automatically stops. When this temperature again rises above a certain level, the thermostatic control again starts the compressor. In this way, once the thermostatic control knob is adjusted, the required low temperature is maintained in the refrigerator cabinet.

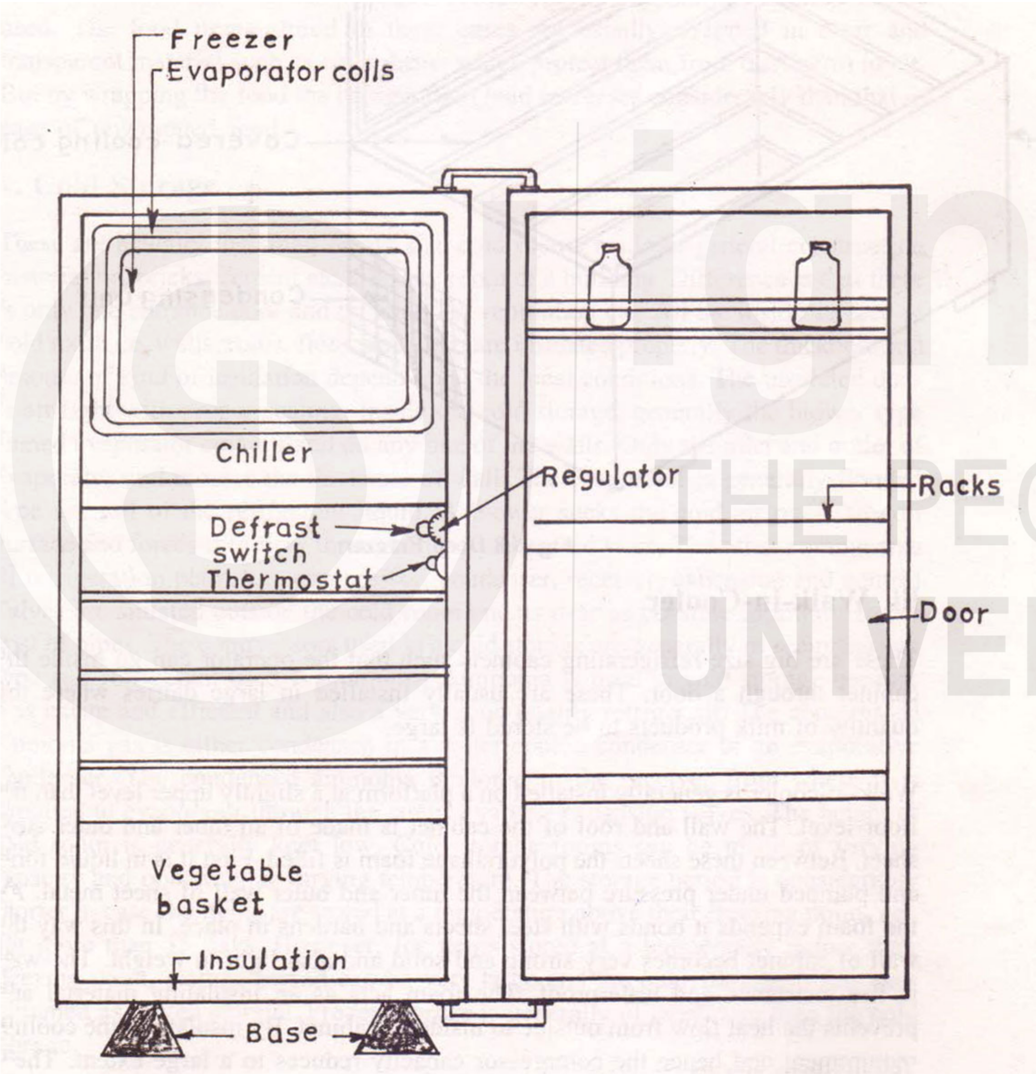

Fig. 6.7 Refrigerator

ii. Deep Freezer

For some type of dairy products or other eatables, e.g., ice-cream, the temperature of the storage space should be very low i.e. below the freezers point, such that, the ice- cream remains in frozen condition. Hence, for storage of ice cream, the generally used household refrigerator will not serve the purpose. For that deep freezers are used. It has a box shape insulated cabinet with an insulated door at the top. The inside wall is made of thin plastic sheet behind which the evaporating coils are fixed all round. As on the outer side of evaporating coil there is an insulating layer, all the cooling effect of coils comes inside the cabinet through the thin sheet. Outside the refrigerated cabinet, there is a hermetic compressor with air fan cooled condensing unit. The length of capillary used is more in case of deep freezer due to which the temperature of evaporating coil is very low generally -20°C. Deep freezers are generally used at ice-cream shops and parlours.

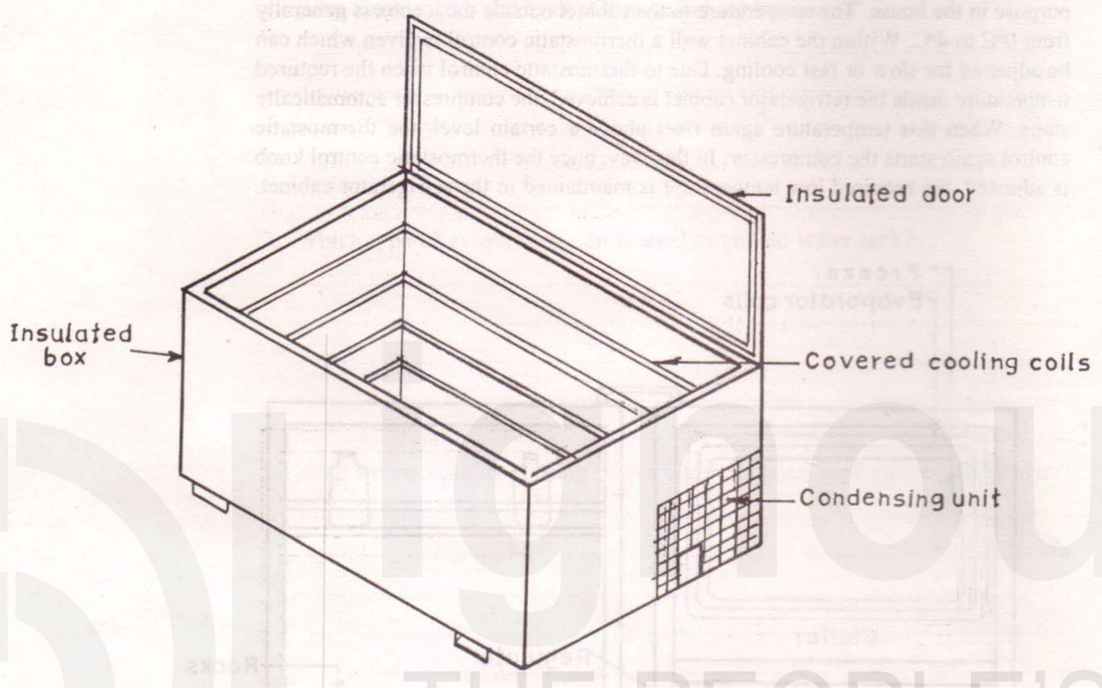

Fig. 6.8 Deep Freezer

iii. Walk-in-Cooler

These are big size refrigerating cabinets such that the operator can go inside the cabinet through a door. These are usually installed in large dairies where the quantity of milk products to be stored is large.

Walk-in-cooler is generally installed on a platform at a slightly upper level than the floor level. The wall and roof of the cabinet is made of an inner and outer steel sheet. Between these sheets the polyurethane foam is filled. First it is in liquid form and pumped under pressure between the inner and outer wall of sheet metal. As the foam expands it bonds with steel sheets and hardens in place. In this way the wall of cabinet becomes very strong and solid and also light in weight. The wall is fire resistance and waterproof. The foam acts as an insulating material and prevents the heat flow from outside to inside of cabinet. By insulating, the cooling requirement and hence the compressor capacity reduces to a large extent. There is a locking arrangement on the door and it can be opened from both sides. Inside the cabinet, the lights are also provided. The compressor and air-cooled condensing unit are installed in a separate cabinet outside the refrigerated cabinet. The dry expansion type and finned evaporating coil is situated in an enclosed box fitted at one of the wall inside the cooler. In front of the coil a cooling fan is provided. When compressor runs the temperature of evaporating unit falls down. Simultaneously the cooling fan/blower runs which sucks the air flowing over the evaporating coil and circulate this cold are in the whole space of cabinet. In this way inside air gets cooled which further cools the dairy products stored in the cabinet. The open racks may be used for keeping the products in cabinet. At some appropriate point inside the cabinet the probe of a temperature controller is fixed. As the desired temperature reach in the cabinet, temperature controller senses it, and switch off the compressor automatically. The walk in cooler is very easy to use and repair. It may be available in various sizes depending on requirement.

iv. Display Case

It is a highly useful item from business point of view. Most of the food shops, restaurants, ice-cream parlours, sweet shops or any other such type of business place have one or more refrigerated display cases which are made in various sizes and shapes. A display case serves two purposes, one it preserves the foodstuffs until these are sold and other it displays the foodstuffs in an appealing way. A cold air blanket preserves the foods displayed in this type of cases. The compressor and air-cooled condensing unit are generally installed in the bottom of case at a hidden place. The evaporating coil may pass through the shelf or surrounding wall or in the roof depending on various designs. A blower type-evaporating coil may also be used. The food items stored in these cases are usually wrapped in clear and transparent material such as cellophane, which protect them from dust/germ in air. But by wrapping the food the refrigeration load increases considerably than that in case of unwrapped food.

v. Cold Storage

These are actually the small or big size cold rooms made of general construction material i.e. bricks/ cement etc. like any room of a building. Difference is that there is only one entrance door and no window/ ventilation etc. All the inside surface of cold room i.e. walls, roofs, floor, door, etc. are insulated properly. The thickness and amount of kind of insulation depend upon the local conditions. The insulated door is air tight with proper sealing. Inside the cold storage, generally the blower type finned evaporator coil is fixed on any one of the walls. Only the inlet and outlet of evaporator coil crosses the thickness of wall. The evaporator is generally flooded type i.e. full of the refrigerant liquid. A blower sucks the cold air over the coil surface and forces it to flow through the space in cold store. The other components of refrigeration plant, i.e., compressor, condenser, receiver, expansion and control valves are situated outside the cold room and as near as possible to minimize the cost of pipes. The compressors used in a cold storage are generally of reciprocating type and refrigerant used is ammonia. Ammonia is used in cold storage because it is cheap and efficient and also a very good quality refrigerant. The compressed ammonia gas is either condensed in a water-cooled condenser or an evaporative condenser. The condensed ammonia is stored in the receiver from where it is supplied to evaporator through the control valves/ expansion valves. The height of cold room is generally kept low. Cold storage rooms can be made of varying capacity and operating at varying temperature. The storage period is considerably shorter in case the items are stored at a temperature above their freezing point, i.e., not more than 15 days. However, for items stored at a temperature below their freezing point, storage period can be very large and the cold storage in this case is named as frozen storage. Frozen storage is generally of small size than the cold storage.

Check Your Progress 3

1. What is the difference between a household refrigerator and deep freeze?

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2. In which type of application a walk-in-cooler is used?

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3. What is the purpose of using blower type evaporating coil in a cold storage?

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6.5 ICE-CREAM FREEZERS

Ice cream is a well-liked dairy product. It is always consumed in frozen condition. The freezing temperature of an ice-cream mix is very low due to the ingredients like milk sugar, salts and cane sugar, etc. Therefore it is required to be cooled to a very low temperature for freezing. Thus, manufacturing of ice cream is not possible without the refrigeration/ cooling application. An ice-cream freezer has the following functions during manufacturing of ice cream.

1. First, It must cool the mixture of ice-cream ingredients to the proper low temperature for handling in packages/containers. Thereafter, it must cool the packaged ice cream to a low enough (such a low) temperature so that the ice cream hardens properly with smooth consistency and uniform ice-crystals.
2. Alongwith cooling, it must mix a predetermined amount of air uniformly into this ice cream in such a manner that it gives the ice cream the proper swell or overrun.
3. If required, It must perform the mixing of fruits and flavour into ice cream while it is being frozen.

Here we will discuss only the first major function of ice-cream freezing equipment, i.e., cooling and freezing of ice-cream mix. The extraction of heat from ice-cream mix takes place in three different steps. First is the extraction of sensible heat of liquid mix so that its temperature lowers down to the freezing temperature. Second step is extraction of latent heat of liquid mix at freezing point so that it becomes semi-frozen slush. And third is the extraction of sensible heat of this slush so that its temperature further lowers down below the freezing temperature and it become hard ice cream. Depending on the amount of ice cream to be manufactured and so the amount of heat extraction, the freezing equipment is designed. Freezers of the commercial type may be classified as batch or continuous, depending upon whether the ice cream is made in batches or is ejected in a continuous stream. Depending on the type of cooling/ method of refrigeration, these are also classified as brine type or direct expansion type. In the brine type, the brine is cooled to a required low temperature by a conventional refrigeration plant and is supplied to the ice-cream freezer for extracting heat of ice-cream mix. This is the indirect method of cooling. Brine is simply a solution of salt in water and can be cooled to quite low temperature less than $0^{o}C$ without freezing. So, brine is used in place of water in case of ice-cream manufacturing application. In the direct type, the refrigerant is directly expanded in the suitably designed ice-cream freezer where it evaporates and extracts heat from ice-cream mix. The various types of ice-cream freezer/ equipment are explained here.

i. Batch Freezer

It consists of a double wall cylindrical drum of varying capacity. The inside wall of freezing cylinder is made of steel or copper with a stainless steel liner. The outer wall is insulated with cork and covered with airtight metal housing. The narrow space between the inside and outside wall is called jacket through which either chilled brine or refrigerant flows. Due to narrow passage in jacket, the brine will flow with high speed and provide good heat transfer. At a time one batch of ice-cream mix is put in the drum and cooled by the flow of brine or expansion of refrigerant in the jacket. Inside the cylinder a dasher is fitted which rotates by a direct motor drive. The dasher has scrappers, which scrap the frozen ice cream from the refrigerated inside surface of cylinder. A beater is also provided for whipping/ mixing of air into the ice cream so that it becomes fluffy.

Alongwith the freezing cylinder, certain other accessories are also used in batch freezers. The batch-measuring device measures the charge of mix. The draw-rate indicates the stiffness of the ice cream by means of load on the dasher motor.

The ice-cream mix is required to be cooled to a certain temperature depending on the level of stiffness required. Therefore, some means of controlling the cooling and stopping during the whipping and unloading period must be provided.

ii. Refrigeration Control

In case of brine cooling, control is very much easy by simply controlling the flow rate of brine through the cylinder with the help of a valve. But in case of direct expansion of refrigerant usually ammonia, two principal types of controls are used as shown in figure 6.9. These are York-type refrigerating system and the creamery - package type refrigeration system. Both the systems control the flow of ammonia vapors from accumulator to the suction of compressor.

a) In the York-type system, the accumulator with low side float control valve is situated at a higher level than the freezing cylinder. Due to float valve, a fix level of liquid ammonia is maintained in the accumulator. The bottom of accumulator is connected to the bottom of freezing cylinder with a pipe. In the same way, top of freezing cylinder is also connected to the top of accumulator through a pipe and control valve. When this valve is open, the liquid ammonia filling in the freezing cylinder being at a lower level takes heat from the ice-cream mix and produce cooling. On absorbing heat liquid ammonia converts into vapours, which lift through control valve, and accumulates in the evaporator. From the accumulator, compressor sucks these vapors. When the control valve is closed, the ammonia vapours formed in the jacket of freezing cylinder cannot lift up to the accumulator and also cannot pass through the bottom because of lighter weight. In this way, the ammonia gas collects in the jacket and push back the liquid ammonia from jacket thus stops the cooling very quickly. Thus control valve is open when freezing is to start and closed when freezing is to be stopped during whipping.

b) In the creamery package type refrigeration system, The liquid ammonia is filled in the freezing jacket and accumulator in the same way as in York type system. But here in this case, the control valve is provided in the passage between accumulator and compressor. When the valve is opened, it allows the compressor to reduce pressure in the accumulator and hence in the freezing jacket. By reduction in pressure more and more liquid ammonia will evaporate to a low temperature and produce more cooling. When the valve is closed, it does not allow the compressor to suck ammonia vapors and thus builds up the pressure in the refrigerator jacket. Due to higher pressure, the saturation point increases and the rate of evaporation and hence cooling lowers irrespective of that the refrigeration jacket is still filled with liquid ammonia. This control method does not stop the freezing so quickly as the first method described. Hence the control valve is shut off in advance so that

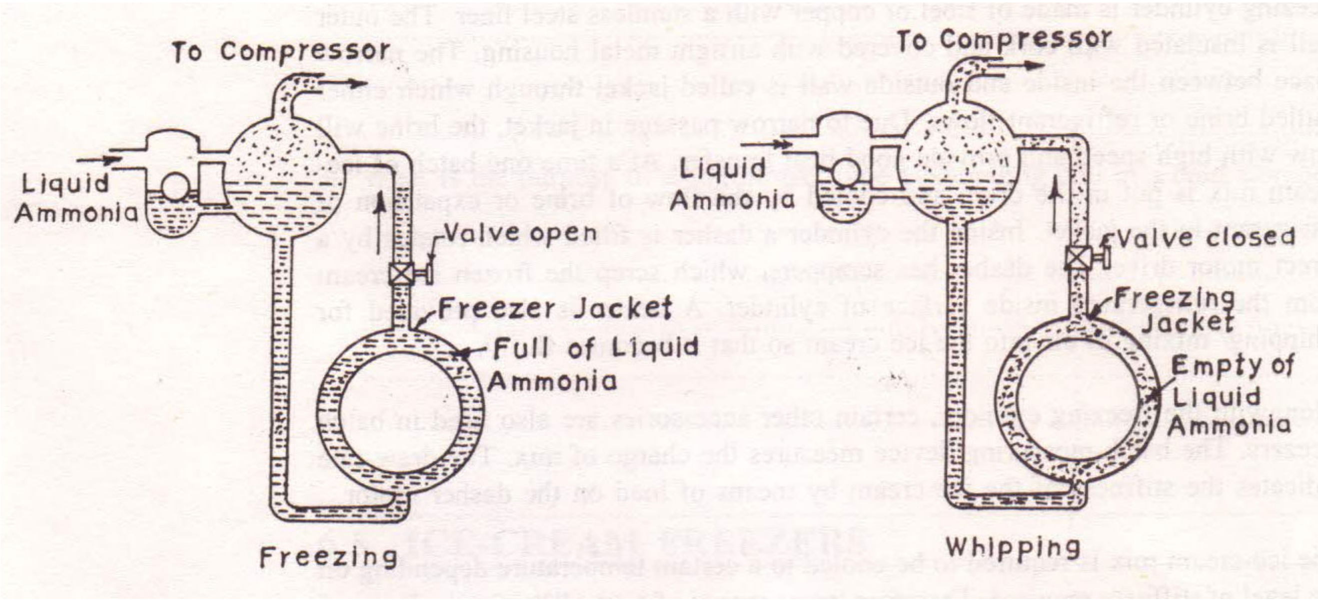

Fig. 6.9 The York-type Refrigerating System for Batch Freezer

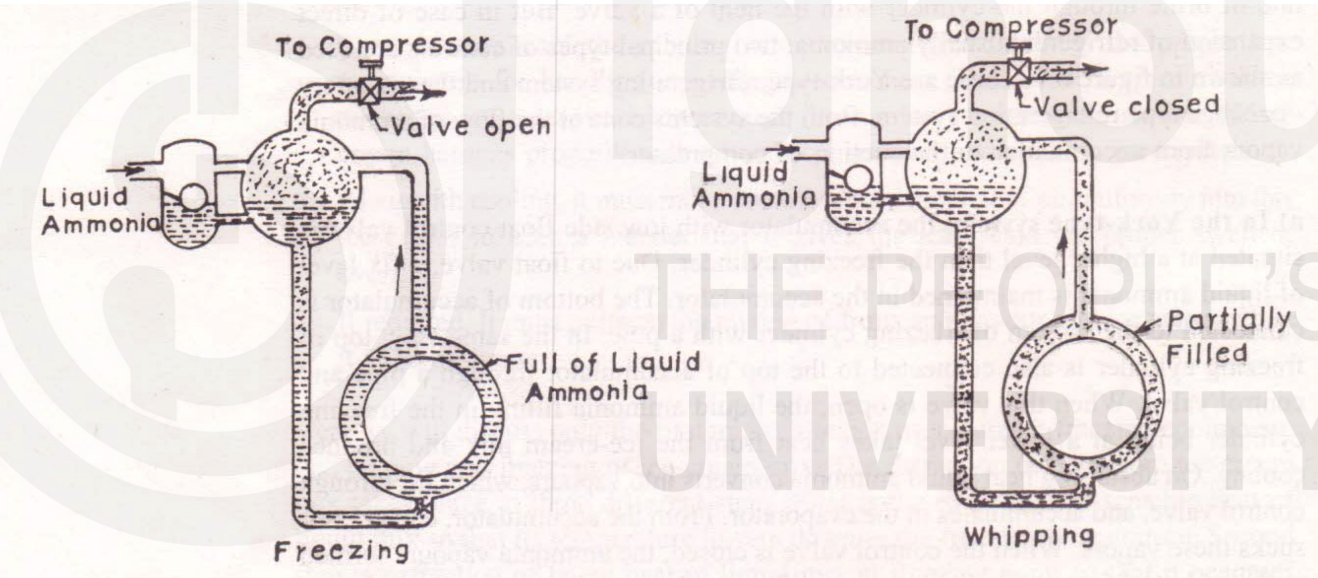

Fig. 6.10 The Creamery Package Type Refrigeration System for Batch Freezer

the cooling reduces at proper time. The cooling goes on reducing but does not stop. However it may be beneficial sometimes in the ice cream processing.

iii. Continuous Freezer

In the continuous freezer, the ice-cream mix is continuously fed or pumped under pressure from one end and we get ready ice-cream from other end continuously. In this way here ice cream flows under pressure. During flowing through the freezer, it undergoes all the processes, i.e., freezing, whipping of air, mixing of various fruits, etc. The continuous freezer is desired due to its various benefits like it saves space, labour and cost of operation. Moreover in continuous freezer, more uniform results are obtained. Due to continuous flow of ice-cream mix, heat transfer is also improved and we get positive control on the percentage of air and mix. The system of refrigeration is almost of the same type. Generally ammonia is used as the refrigerant, which is directly expanded in the jacket of freezing cylinder.

Depending on the feeding arrangement of ammonia, two types of continuous freezers are as described below:

a) Vogt Freezer using Jet type Ammonia System

The freezing cylinder alongwith ammonia refrigeration system is as shown in Fig 6.11. A jacketed tube type-freezing cylinder is situated above the accumulator. In the accumulator, the level of liquid ammonia is maintained with the help of float control valve. From the liquid ammonia feed line, liquid ammonia is fed to the jacket of freezing cylinder by the jet action through a nozzle. It expands in the jacket of freezing cylinder tube and freezes the ice cream mix flowing inside the freezing tube. The metered quantity of air mix enters from one end by the action of pump and frozen ice cream comes out from the other end continuously. After producing cooling the ammonia vapours drops back in the accumulator. From the vapour zone of accumulator, the compressor again sucks these vapours. Below the jet a spring-loaded quick shut-off valve is provided which when operated quickly stops the ammonia supply and hence cooling in freezing cylinder.

b) Creamery Package Continuous Freezer

The freezing cylinder of this freezer is like that of a batch freezer as shown in Fig 6.12. The size of freezing cylinder is large and it is connected to an accumulator fixed at a higher level, which maintain the liquid ammonia always filled in the freezing cylinder. The accumulator is connected to the compressor through a backpressure valve. However, the system of feeding the ice-cream mix is made continuous i.e. it enters from one end and exit from the other end by the force of a metering type pump. The metering type pump can also control the flow rate of mix. Air is also fed continuously along with mix through a control valve. The working of this type of freezer is automatic i.e. the ammonia is controlled automatically depending on the quantity and quality of mix and cooling required.

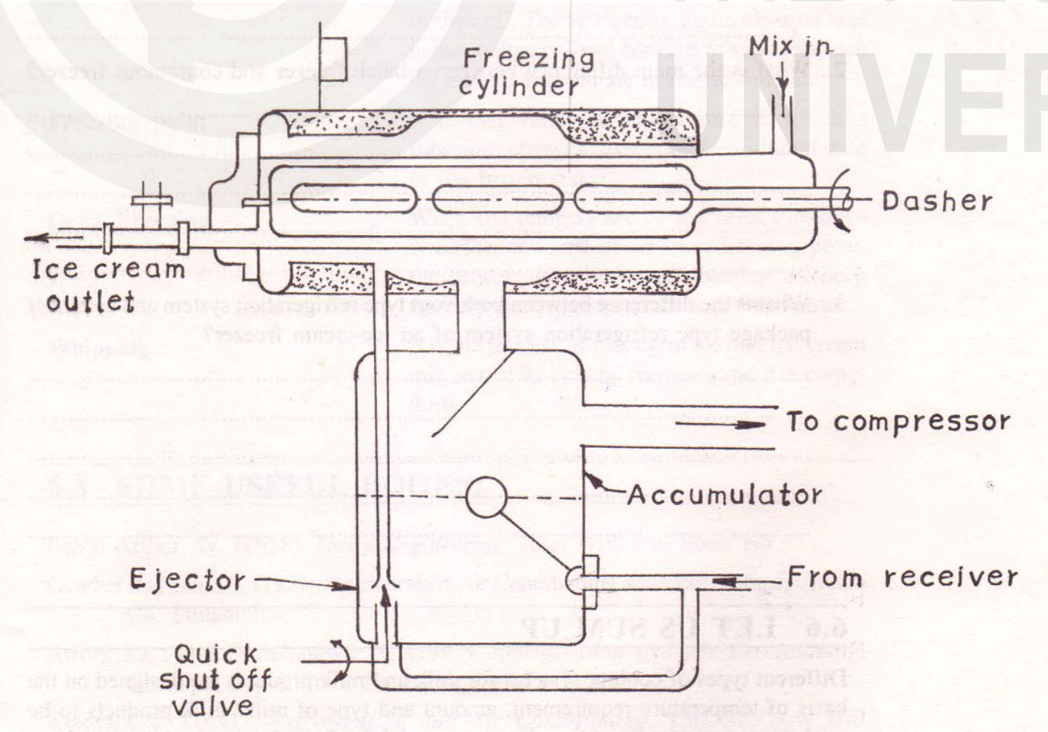

Fig 6.11 Jet Type Ammonia Circulating System in the VOGT Freezer

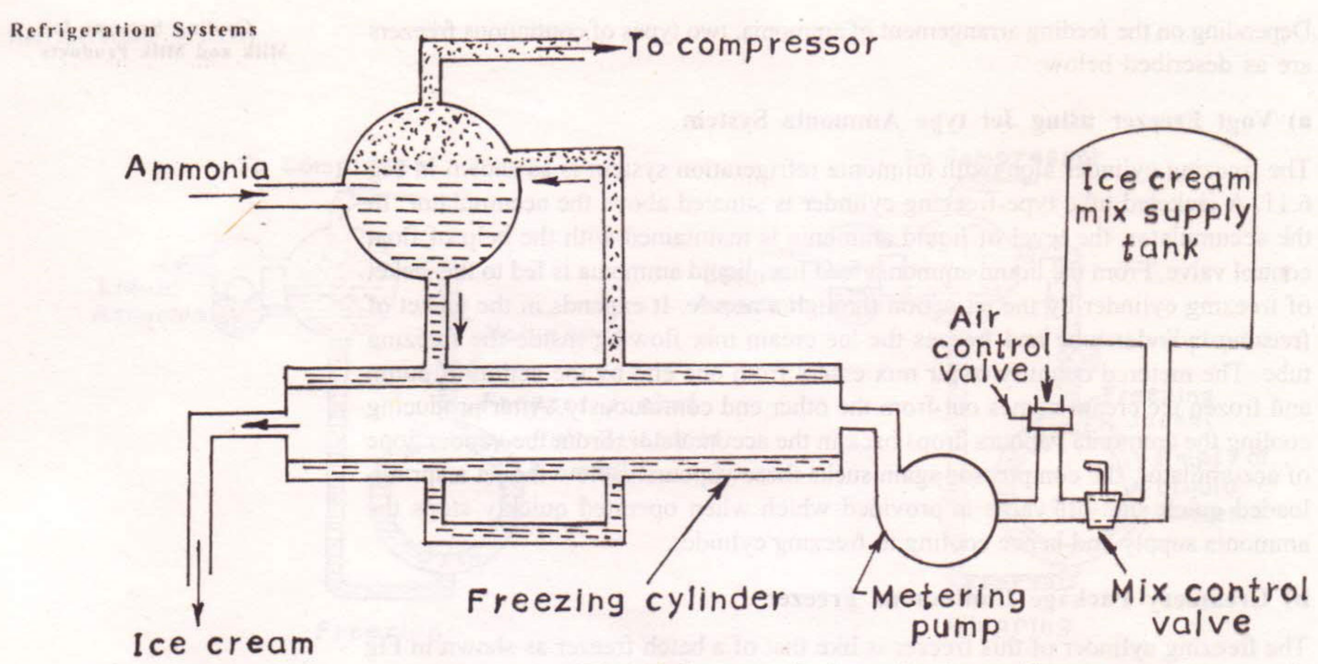

Fig 6.12 Creamery Package Continuous Freezer

Check Your Progress 4

1. What are the different steps of extraction of heat from ice-cream mix in a ice-cream freezer?

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   ....

2. What is the main difference between a batch freezer and continuous freezer?

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3. What is the difference between york/vogt type refrigeration system and creamery package type refrigeration system of an ice-cream freezer?

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   ....

6.6 LET US SUM UP

Different types of cooling systems for milk and milk products are designed on the basis of temperature requirement, amount and type of milk/ milk products to be cooled/ processed, place of application, availability of resources, etc. The cooling can be direct or indirect. Direct cooling means when the refrigerant itself is expanded in the cooling or freezing apparatus. These are also called direct expansion system. Indirect cooling means when a vapor compression refrigeration unit chills water first and this chilled water is then supplied to cooling/ freezing apparatus. The basic components of the refrigeration systems i.e. compressor, condenser, expansion valve, evaporator coil, etc. are same. Only their types and type of refrigerant vary as per different cooling requirement.

6.7 KEY WORDS

Direct cooling : In direct cooling, the refrigerant liquid is directly expanded in the evaporating coil/jacket of cooling apparatus.

Indirect cooling : In indirect cooling, first the water is cooled by evaporating coil of refrigeration system in a separate chilled water tank. Then the chilled water is circulated through cooling apparatus for cooling of milk/ milk products.

Chilled water : Water at a temperature of $0^{o}C$ to $4^{o}C$.

Condensing Unit : It is a box in which the compressor, air cooled condenser and filter/drier of a refrigeration system are separately fitted. The condensing unit can be installed at a suitable place and connected to the cooling coil and expansion valve through pipes.

Stiffness : It is the property of a material by which it resists any external force to change its shape.

Accumulator : It is simply a small tank connected to the inlet and outlet of evaporating coil/jacket. It is situated at a level above the evaporating coil. It maintains a constant level of liquid refrigerant in the coil. The refrigerant liquid absorbs heat in the cooling coil and converts to vapours which lift up and accumulate in the accumulator.

Freezing point : It is that value of temperature at which a substance changes from liquid/semi-liquid state to the frozen state.

Deep Freezing : When the temperature of a frozen substance is further lowered down from freezing point, the process is called deep freezing. In deep freezer, the frozen product becomes harder.

Whipping : It is the process of mixing of air into ice-cream mix so that its volume increases and it becomes fluffy.

6.8 SOME USEFUL BOOKS:

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Khurmi R.S. and Gupta J.K(1987). *Refrigeration and Air Conditioning*, Eurasia Publishing House (P) Limited Ram Nagar, New Delhi 110 055.

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6.9 ANSWERS TO CHECK YOUR PROGRESS

Your answer should include the following points:

Check Your Progress 1

1) i. In-can coolers are used when production of milk is less and surface coolers are used when milk production is high.

   ii. In-can cooling is a batch process where surface cooling is a continuous process.

2) i. In bulk milk coolers, handling of milk is easy, as it is through pumps where milk cans are heavy to handle.

   ii. Washing and cleaning is easier in bulk milk coolers.

   iii. Cooling of milk is more efficient and effective in bulk milk coolers.

3) i. To retard the natural heat flow from surrounding to cooling equipment.

   ii. To reduce the cost of cooling.

4) i. Heat is conducted very slowly from the cold surface to the milk and then within the milk.

   ii. Agitator moves the milk in such a way that cold milk near the surface moves to the center and warm milk from the center moves near to cold surface.

   iii. Increase the heat transfer rate from milk to the cooling surface and so reduce the cooling time.

5) i. Water is easily available.

   ii. Good carrier of heat energy

   iii. More effective than air.

Check Your Progress 2

1) i. When water is not taken continuously from the chilled water tank, it stays there and starts freezing at the surface of cooling coil.

   ii. Ice-formation at the surface of coil works as a bank of chilled water when more water is required in the plant.

2) i. Flooded type

3) i. Control on amount of cooling is easy.

   ii. To meet the peak of cooling load is easy by simply increasing the supply of chilled water from chilled cooler tank/ice-bank unit.

   iii. No risk of spoilage of foodstuffs on leakage of refrigerant.

   iv. Small size of cooling pipes is required.

Check Your Progress 3

1) i. Temperature maintained in deep freeze is lower than that maintained in household refrigeration.

   ii. Temperature in deep freeze is well below the freezing temperature of food/ dairy products stored.

2) i. Walk-in-cooler can store large quantity of milk/milk products and also compact and easy to install at any available place. It is also easy to use and repair.

3) i. The blower pulls the air over cooling coil with high speed and spread it in the whole cooling space effectively.

ii. With high speed of circulation of air, heat transfer from products to cooling coil increases.

Check Your Progress 4

1) i. Sensible heat from initial temperature to freezing temperature.

ii. Latent heat at freezing point.

iii. Sensible heat from freezing temperature to deep low temperature.

2) i. In batch freezer, ice cream is prepared in batches. Batch freezer has a fixed capacity of preparing ice cream at one time.

ii. In continuous freezer, ice cream is prepared in a continuous stream. Ice-cream mix is continuously fed on one end and final product is taken on the other end of continuous freezer.

3) i. In York type, control on cooling is made by controlling the flow of ammonia vapours from freezing cylinder to accumulator through a control valve. Cooling can be completely stopped immediately in this case.

4) i. In creamery-package type, control on cooling is made by controlling the flow of ammonia vapours to the suction of compressor. Cooling cannot be immediately stopped but however reduced in this case by closing the control valve. This slow cooling is sometime desirable in whipping process.