Engineering and Safety Aspects in the Production and Storage of Frozen Fishery Products

P.N.Joshi
Central Institute of Fisheries Technology,
Cochin 682 029

Fish is a highly perishable product under ambient temperature conditions and hence it is very essential to prevent its spoilage till it reaches the consumers. Even though several methods of preservation have been employed such as dehydration, canning, freezing etc. the freezing preservation of fish has become more popular owing to the reason that the frozen product is subject to the least deterioration of quality compared to the products preserved by all other methods. The very important aspect in freezing fish is the rapidity at which fish is frozen. In other words, the rate of freezing has a profound influence on the quality of the product.

In order to freeze the fishery products several types of freezers are used. In all these freezers the principle of refrigeration is used to cool the product from the ambient temperature conditions to the frozen state. "Refrigeration is the technique of producing cold and keeping temperature below those of the immediate surroundings."

Vapour compression refrigeration system

This is the usual system adopted in all the refrigeration applications except in cryogenic method. Refrigeration is accomplished by the evaporation of a liquid refrigerant thereby extracting heat from the medium to be cooled.

All the principal parts, and path of the refrigerant flow are shown in the diagram. The pressure is maintained at different levels in two parts of the system by the expansion valve (high side float valve). The function of the expansion valve is to allow the liquid-refrigerant under high pressure to pass at a controlled rate into the low pressure part of the system. Some of the liquid evaporates while passing through the expansion valve, but greater portion is vaporized in the evaporator at low pressure (low temperature). The liquid refrigerant absorbs its latent heat of vaporization from the air, water or other material, which is being cooled. The function of the compressor is to increase the

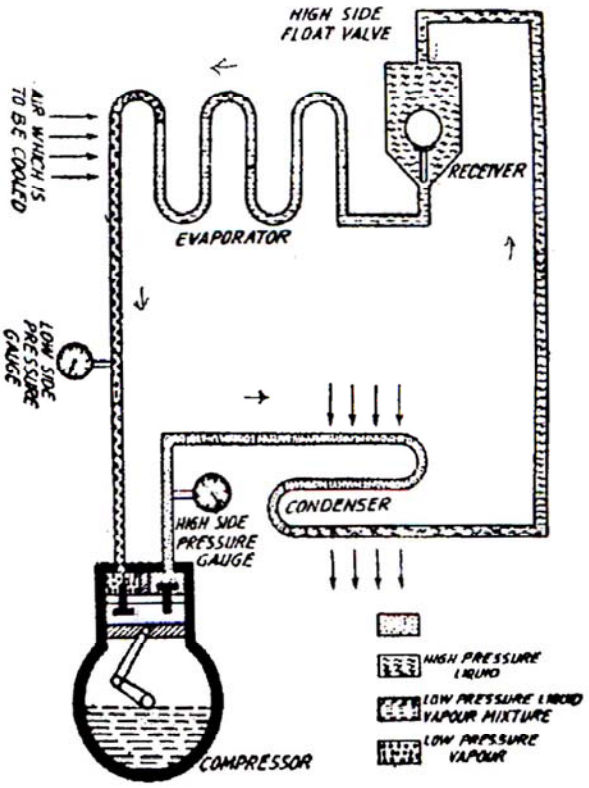

Fig 1. Vapour-compression Refrigeration System

pressure and temperature of the refrigerant above atmospheric, which will be ready to dissipate its latent heat in the condenser. In passing through the condenser, the refrigerant gives up the heat, which is absorbed in the evaporator plus the heat equivalent of the work done upon it by the compressor. This heat is transferred to the air or water, which is used as cooling medium in the condenser.

There are several ways in which fish can be frozen, but all require specialised equipment to effect the necessary rapid drop in temperature and reduce the core temperature sufficiently to ensure that the product can be safely placed into the cold storage. The different types of freezer in common use are as follows

Heat transfer can be rapid even with moderate circulation because there is good contact with the product. The principle that dissolved substances depress the freezing point of water makes brine an effective medium for freezing foods. The salt solution has lower freezing point than pure water and brine can be made cold enough to freeze foods which are immersed in it. The freezing point of brine is determined by the concentration of the salt.

In immersion freezing, the brine is maintained at -21°C by using the vapour compression refrigeration system in an insulated stainless steel tank keeping the stainless steel evaporator plate at the bottom of the tank. (Fig. 2). Two mixing

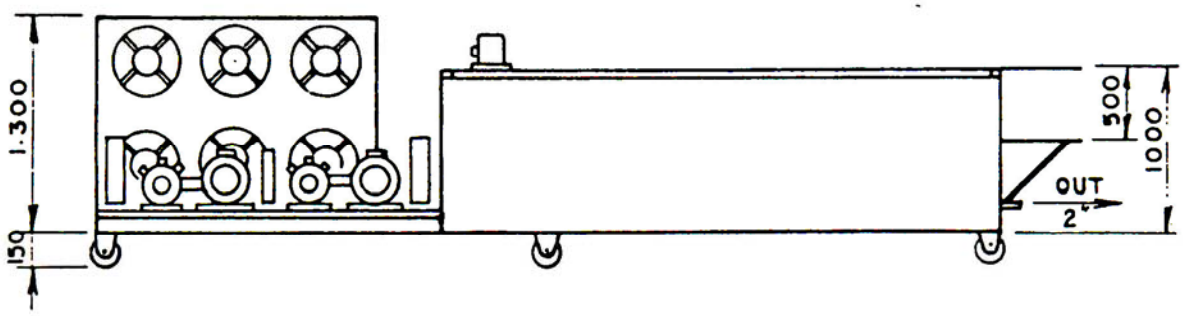

Fig. 2. Brine immersion freezer

Immersion freezers

Immersion freezers and spray freezers operate by maintaining direct contact between a very cold liquid, or gas from that liquid, and the fish.

Brine Immersion freezer

Freezing by immersion of the fish in a cold liquid is used because of its inherent simplicity and high output. In comparison with air, liquids have much higher thermal capacities and thermal conductivity.

motors have been provided to circulate the brine around the evaporator plate and stainless steel basket filled with the product to be frozen, kept in the circulating brine. With brine at -21°C it is possible to attain the core temperature of the frozen product to -20°C as the brine is a liquid medium with inherent higher thermal capacity and conductivity

Contact freezers

Contact freezing is usually accomplished in plate freezers and involves placing the product on metal plates through which a refrigerant in circulated. The two main types of plate freezers are horizontal plate freezers and vertical plate freezers.

Horizontal plate freezer

In the horizontal type which is quite common, freezing is accomplished by refrigerant flowing through connected passage ways in the horizontal movable plates stacked in an insulated cabinet. The space between the plates is adjustable, usually by means of a hydraulic or pneumatic ram which moves the plates up and down with one fixed plate at the bottom. There are flexible connections from the refrigerant pipes to the plates. Loading, by inserting the produce to be frozen between the plates and unloading, are done with the plates set at the open position. Both top and bottom sides of the product are brought into contact with the plates before freezing and some compression may be exerted in order to reduce the freezing time. The plate freezer is particularly suitable where the product is to be frozen in trays or in packs of regular rectangular shape with thickness up to 60 mm. Fig. 3 shows the diagrammatic view of a horizontal plate freezer.

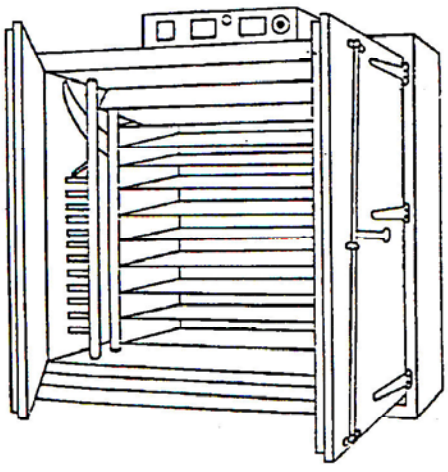

Fig 3. Horizontal plate freezer

Vertical plate freezer

The principle here is the same as Horizontal plate freezer. The freezer consists of a series of vertical plates with spaces in between them. This type of freezer was developed primarily for freezing of whole fish at sea on distant water vessels.

Air blast freezers

Air blast freezers are those in which a stream of cold air absorbs heat energy from the product as it passes over them, thereby reducing their temperature. In this type of freezer air at temperature of -40°C is forced around the product at speeds ranging from 5 to 7 m/s. These freezers are generally constructed in the form of rooms or tunnels. They are used for freezing fishery products such as shrimp, fish fillets, breaded precooked products packed in packages and small whole fishes. Fig.4 shows the details of a typical air blast freezer. The main disadvantages of air blast freezers are that freezing time tend to be longer and it occupies more space and require more power than other types mainly because of the relative poor heat transfer properties of air. Freezing time varies from 6 to 8 hours depending upon the thickness of the product. In some cases where distortion of fish frozen in the plate freezer is considered to be disadvantage, the air blast freezer may be preferred particularly for whole fish which are to be frozen singly as IQF product.

Tunnel freezer

It consist of insulated tunnel into which the material to be frozen arranged on trolleys is pushed in and air at a temperature of -40°C is blown into it. There should be air gap between product layers for efficient freezing. In Tunnel freezers the fish to be frozen moves either in trolleys or singly if the fish is large. Loaded trolleys are pushed into the freezers at one end and when the product is fully frozen, they are removed from the other end.

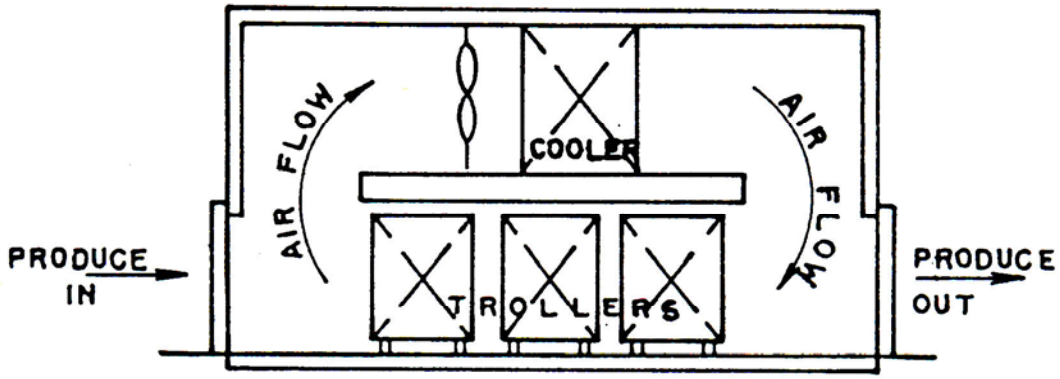

Fig. 4. Air blast freezer

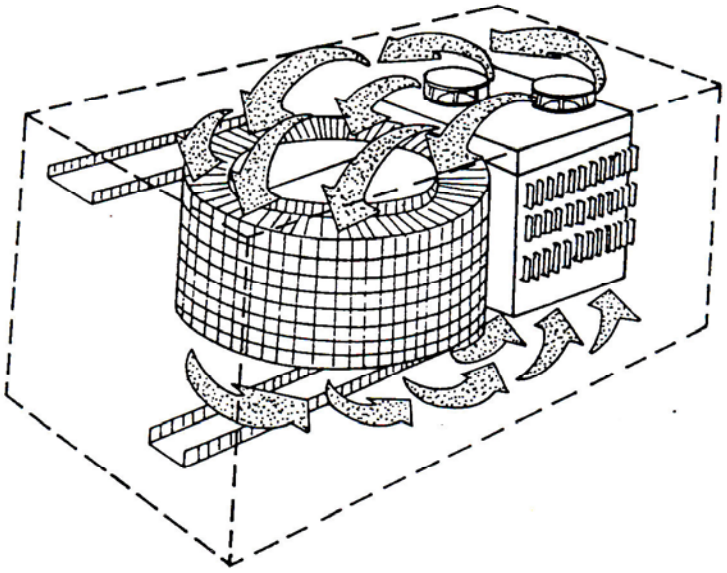

Fig. 5. Spiral freezer

Belt freezer

Belt freezers use a belt generally made up of stainless steel wire mesh and it moves inside the chamber and the fish to be frozen is kept on the belt. In modern belt freezers air flown is vertical and air is forced through the product layers.

Fluidised bed freezer

It is a version of the continuous belt freezers, which can be used for freezing small uniform products. A blast of cold air passing through the mesh belt from below the product. Here the product is partially supported on the rising column of cold air.

Spiral freezer

In spiral type freezers the air flow is from top to bottom or across the spiral and the air is cooled by the vapour compression refrigeration system. A diagrammatic representation of the spiral freezer is shown in Fig. 5.

Individual quick freezers (IQF)

Quick freezing of fish generally defined as lowering the temperature from -1°C to -5°C in 2 hours or less, and further reducing the temperature at the end of freezing period to the recommended storage temperature of -20°C. In the IQF system, the air is cooled by the conventional vapour compression refrigeration method. The air flow through the conveyor is from top to bottom in some cases, from bottom to top in some others. The refrigerant used is Ammonia in majority of the units. In some units Freon-22 or other eco friendly gases are used.

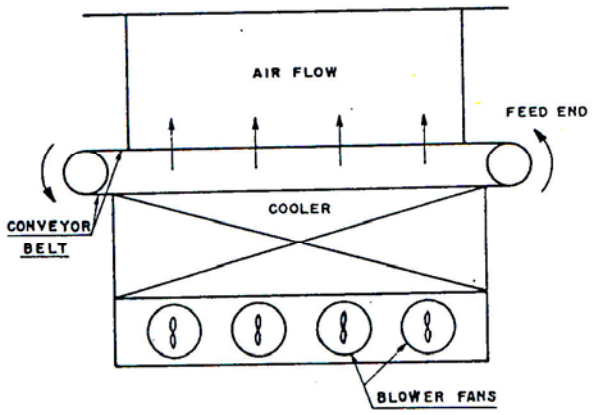

Fig. 6. I .Q. F. machine (Fluidised bed freezer)

The conventional method of freezing fishery products is by freezing in the block form mainly in the plate freezers. Such blocks were thawed and refrozen as IQF for retail markets of the importing countries. The reprocessing affects the quality of the product and increase in the drip loss. Direct IQF production by the exporting country avoids the above drawbacks and the suppliers can get a higher price for their products. Government of India had encouraged the production of IQF products by giving subsidy to the IQF plants as well as providing C.C.S. on the IQF products exported.

Cryogenic freezer

The principle Involved here is to freeze the material with liquefied gases at extremely low temperatures, such as Liquid Nitrogen (-196°C), liquid air (-194.2°C) and liquid carbon dioxide (-71°C). The liquid is carefully sprayed in required quantities on the material passing on a conveyor belt. Utmost care is required in adjusting the quantity of liquid sprayed, as even slight excess may cause freezer-burn on the material due to extremely low temperatures.

Liquid nitrogen IQF unit consists of an insulated tunnel with stainless steel conveyor just like an ordinary air blast freezer but without any evaporating coil. The freezer unit (Fig.7) incorporates three zones viz precooling zone, spray or freezing zone and temperature equilibrium zone. The precooling zone occupies approximately one half of the overall length of the system and is equipped with four turbulance fans. These fans impart a high velocity to the cold gaseous nitrogen moving it counter current to the incoming food products and extract the greatest amount of refrigerant energy (about 50%) from the vapours. An exhaust blower is connected at the feed end of the freezer to remove nitrogen vapours that have been expanded in the freezing process.

In the spray zone, the food products are exposed to finely divided droplets of liquid nitrogen which vaporise on contact with the food products, causing a lightning fast reduction in temperature and thereby freezing the products. A series of nozzles mounted on a spray header or manifold distributes high velocity droplets of liquid nitrogen through out the zone.

The temperature equilibrium zone is isolated by curtains and is equipped with a counter rotating circulation fan. In this zone, the surface and core temperature of the product approach equilibrium prior to discharge from the freezing system.

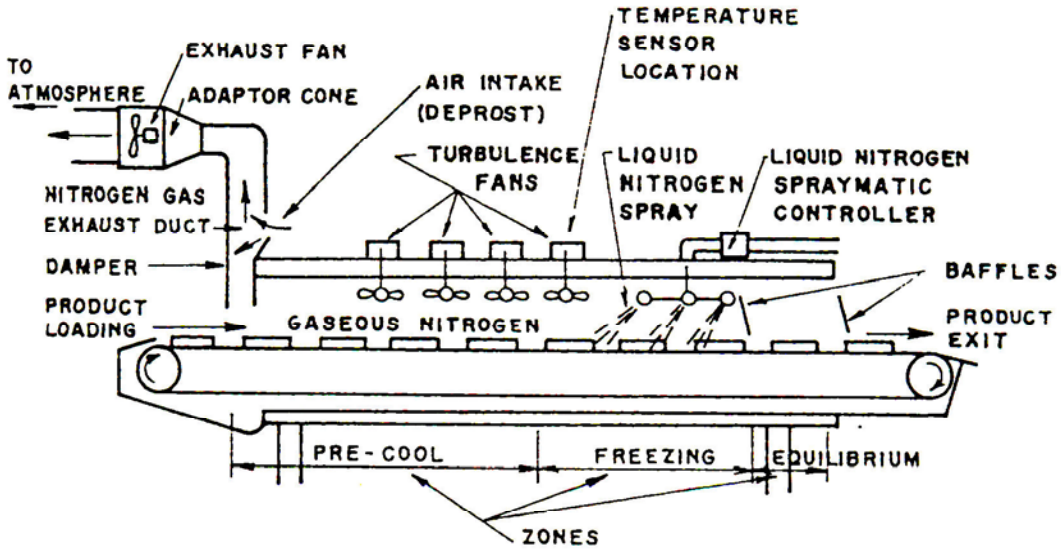

Fig. 7. I.Q.F. machine using liquid nitrogen

In the case of liquid nitrogen system the core temperature can be brought down to lower than -20°C in much shorter time compared to air blast system or brine system. Hence the freezing time is much shorter compared to other systems with improved quality of the product. However, the cost of liquid nitrogen at present is very high and liquid nitrogen consumption also comes to about 1.2 to 1.5 kg. per kg. of product frozen. Hence this system cannot be economical unless liquid nitrogen is made available at a reasonably low price.

Frozen food storage

Frozen fishery products will have to be stored in a cold storage as soon as they are frozen. There are two types of cold storages. The first is having cooling coils as long pipes fixed on ceiling and / or on the sides of walls with natural air circulation. The second type is with comparatively compact cooling coil with forced air circulation with blower. This is more efficient as the cooled air is force circulated. The cold store is essentially an insulated chamber which is equipped with a cooling system to maintain the inside temperature at the desired level. The following features shall be present in a well designed cold store.

The insulation shall be sound and complete. The minimum insulation thickness shall be 100 mm by using RPUF(Rigid Poly Urethane Foam) and 150 mm while using EPS (Expanded Poly Styrene) insulation.

To reduce the risk of fire, the use of flammable materials in construction shall be avoided.

A complete vapour barrier shall be installed on the warm side of insulation.

By means of properly designed doors, air locks, curtains, hatches etc. exchange of cold store air and ambient air shall be discouraged.

The temperature difference between the product and the cooler shall be small. This implies a cooler with a generous surface area and modest rate of air circulation.

Fish should not be placed in the cold storage until the internal temperature approximates that of the storage room. Failure to observe this rule may result in raising the temperature of all the materials in the storage room, and spoilage may occur. During frozen storage, the fishery products may undergo undesirable changes in flavour, colour,

texture and increase in drip formation. They are dependent on the length and temperature of the storage. A high relative humidity in the cold storage room will tend to reduce the evaporation of moisture from the product. Hence it is important to design the cold store room to maintain high relative humidity at all times. The effect of temperature on the storage is very important as storage above -20°C even for a comparatively short time will result in rapid loss of quality.

The relative humidity of air in the cold store is directly affected by the temperature difference between cooling coil and room temperature. An increase in this temperature differential results in decreased relative humidity and an accelerated rate of moisture withdrawal from the frozen product.

In order to maintain the temperature one of the very important precautions to be adopted is to restrict the door openings. With frequent opening of the door hot air will enter the cold store thereby the temperature will rise rapidly. Moreover moisture also will enter the store and deposit on the evaporating coils thereby the refrigeration efficiency is also affected. It is essential to provide anteroom adjacent to the door of the cold storage. In the absence of anteroom, air curtain at the warm side of the door should be provided. It is advisable to provide automatic operating of air curtain whenever the door is opened so that entry of warm air to the store is minimised. Defrosting of the evaporator coils should be carried out regularly. otherwise too much frost will build up on the coil obstructing the air flow and the refrigeration efficiency also will affect considerably. It is advisable to provide heated gaskets for the doors to prevent moisture build up on the doors. Of course all safety measures should be taken to prevent short circuiting and fire hazard while using heating gaskets.

The storing of frozen products will have to be done properly. The practice of storing the products closely without giving clearance between them is not advisable. Similarly the products should not be stacked close to the walls to provide sufficient air movement around the product. The product should be stored on racks in such a way that sufficient air gaps are provided between individual master cartons. In no circumstance fresh fish should be loaded into the cold store for freezing purpose as the cold store is meant only for storing the product already frozen.

Most of the seafood processing plants in India are using ammonia as refrigerant for reasons of economy and availability in large quantities. The possibility of leakage of ammonia is very high in the refrigeration plant. Majority of refrigerants can burn the skin, or more importantly, eye tissue on contact at low temperatures. There is no doubt that ammonia is very toxic and that it smells unpleasant. An unpleasant smell, however, provides a good warning system. Pure ammonia does not burn, but a mixture of ammonia and air at a concentration of 15-28 % is somewhat explosive when ignited by a spark. The ignition temperature is 630°C. The refrigeration plant room should, therefore, be well ventilated.

Commonly, cold storage fires have been associated with electrical faults, hot work and ammonia leaks. Electrical hazards are high and should be countered by efficient earthing. Electrical systems and fittings in cold compartments should be of the fireproof type. Every refrigeration system must be designed so that pressure due to fire conditions can be safely relieved.

The very low temperatures prevailing in cold storage and especially deep-freeze rooms may be dangerous if a person working in them is immobilized by an accident, becomes drowsy, or is inadvertently locked in. Accordingly, any person entering such rooms should wear protective clothing appropriate to the temperatures prevailing there. Care should also be taken to ensure that any

person working in a cold-storage room could always come out easily by providing doors, which can be opened from the inside as well as from the outside.

With the advent of newer materials for construction and insulation, use of better methods of material handling and increased emphasis on energy conservation, great care is going into the planning, designing and construction of cold storages.