A SURVEY OF MARINE REFRIGERATION

By

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The Purpose of Refrigerating Fish

The main purpose of refrigerating fish is to lower its temperature to a desired level so as to slow down the spoiling process such that when the fish is thawed after cold storage, the quality is almost undistinguishable from that of a fresh fish.

Among the merits of refrigeration are the following:

1. The ability to preserve catch aboard fishing vessels when the fishing grounds are far or the fishing operation lasts for a long period of time or when the market and distribution area are far from the source of fish or landing site.

2. It can even-up the supply and distribution of fish during the peak and lean seasons which is one of the problems in the Philippines.

3. It can help decrease the risks due to the unpredictability of fish supply in the fish processing industry where investments, labor and operating costs are high.

4. It helps maintain and meet the quality requirement of the international market for export fish products.

The Causes of Fish Deterioration

Refrigeration is primarily employed to prevent the spoilage of fish due to three primary causes, i.e. enzymatic or autolytic action, oxidative action and bacterial action or the combination of two or all.

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Enzymatic Action

Enzymatic Action — all the living things derive their essential materials from food which is broken down by chemical agents called enzymes. When the fish dies, these enzymes continue actively to digest not only the food but all things they are capable of breaking. The chief observed effects of enzyme activities are the softening of the fish flesh, and in some species like the "tunsoy" where the autolytic action is rapid, the belly walls maybe pierced and the visceral mass converted into a semi-fluid state. Enzyme activity in dead fish can be reduced by lowering the temperature.

Oxidative Action — oxidation and rancidity can be caused by the single or combined action of tissue enzymes, bacterial enzymes and exposure to air. Aside from causing rancidity, oxidation also causes other changes in fish such as fading of pigments and the development of off color and flavor. Again, lowering of the temperature and decrease in contact with warm air slows down this spoilage process.

Bacterial Action — the effects of bacteria maybe described in three stages prior to freezing: in the water, aboard the vessel and at the shore plant.

Bacteria is present in fish and in the water. Studies have shown that the greatest concentration of bacteria are in the bottom waters and substrata which means that benthic species initially contain a large bacterial count than does pelagic species. Bacteria breaks down the complex substance in the flesh and produce increasing amounts of simpler, objectionable compounds such as ammonia. This spoilage process continues until the flesh becomes putrid and inedible. The spoilage is determined in large part by the initial load of bacteria, the temperature of the fish flesh (which is only a little more than the temperature of water), the lapse time-post-mortem and the type of sanitary procedures practiced. Bacterial action is also slowed down by lowering of the temperature.

Processes That Takes Place During Freezing

Since fish is largely water (60-80%) the freezing process in a way converts most of this water into ice. This requires the removal of heat and thereby causing a drop in the temperature. This is shown graphically in Fig. 1.

Stage I represents the rapid drop in temperature as water is cooled down to about the freezing point of water. Stage II represents a steady temperature level with time (due to a change in state of water) and is

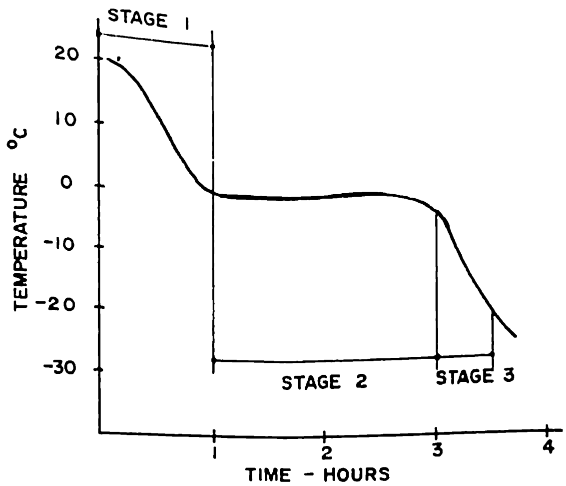


FIG. 1 TEMPERATURE - TIME GRAPH FOR FISH DURING FREEZING

called the Thermal Arrest Period (TAP). In Stage III, when about 3/4 of the water content of the fish is turned into ice, a rapid decrease in temperature follows, until most of the water content is converted into ice.

As the water in the fish is frozen, the remaining concentration of salt and other substances in the remaining water increases thereby causing a depression on the freezing point of this unfrozen water. The result is that complete change into ice is not accomplished at the fixed temperature but over a range of temperatures.

Fig. 2 shows the percentage of water frozen at different temperatures in fish. From this, we can infer that a 5°C, around 80% of the fishwater content is frozen and further reduction of temperature down to about −30°C causes only around 90% of the fish flesh to become frozen.

Quick freezing is preferred over slow freezing because the latter produces inferior quality products due to the denaturation of protein. This denaturation increases as the concentration of enzymes and other compounds in the unfrozen portion increases, and reduced when the temperature is lowered. It has been shown that the temperature of maximum activity is in the range of −1°C to −2°C and slow freezing means a longer time spent in this zone of maximum activity which decreases the quality of the product.

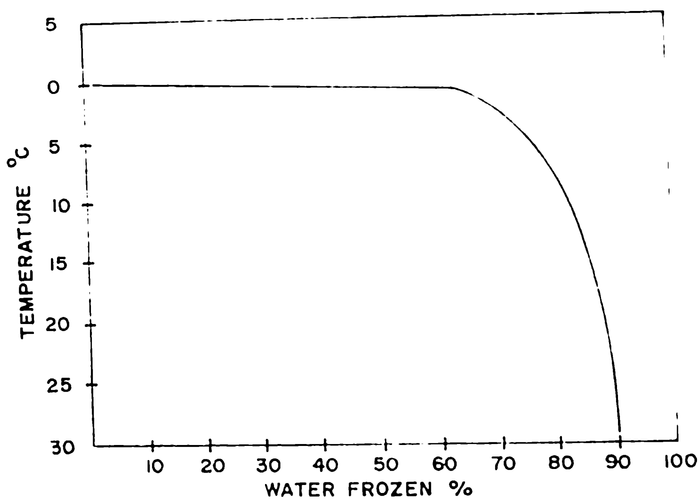


FIG. 2 FREEZING OF FISH MUSCLE. THE PERCENTAGE OF WATER FROZEN AT DIFFERENT TEMPERATURES

Preparation Procedure for Whole Fish for Freezing

Fig. 3 shows the order of the process being followed in the ideal preparation of fish aboard the fishing vessel. However, in actual Philippine practice, this is not followed.

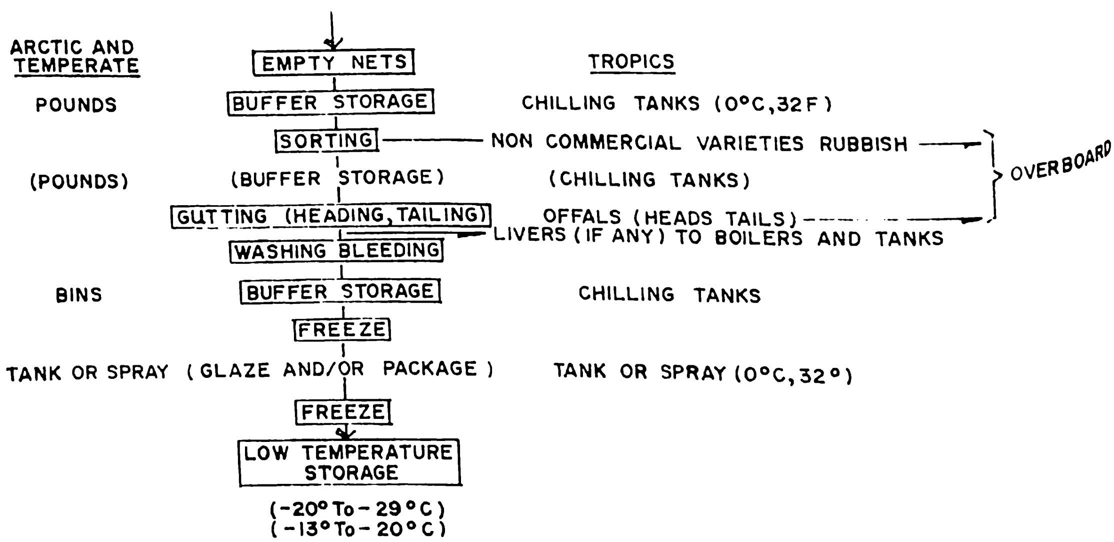


FIG. 3 PREPARATION PROCEDURE FOR WHOLE FISH FOR FREEZING

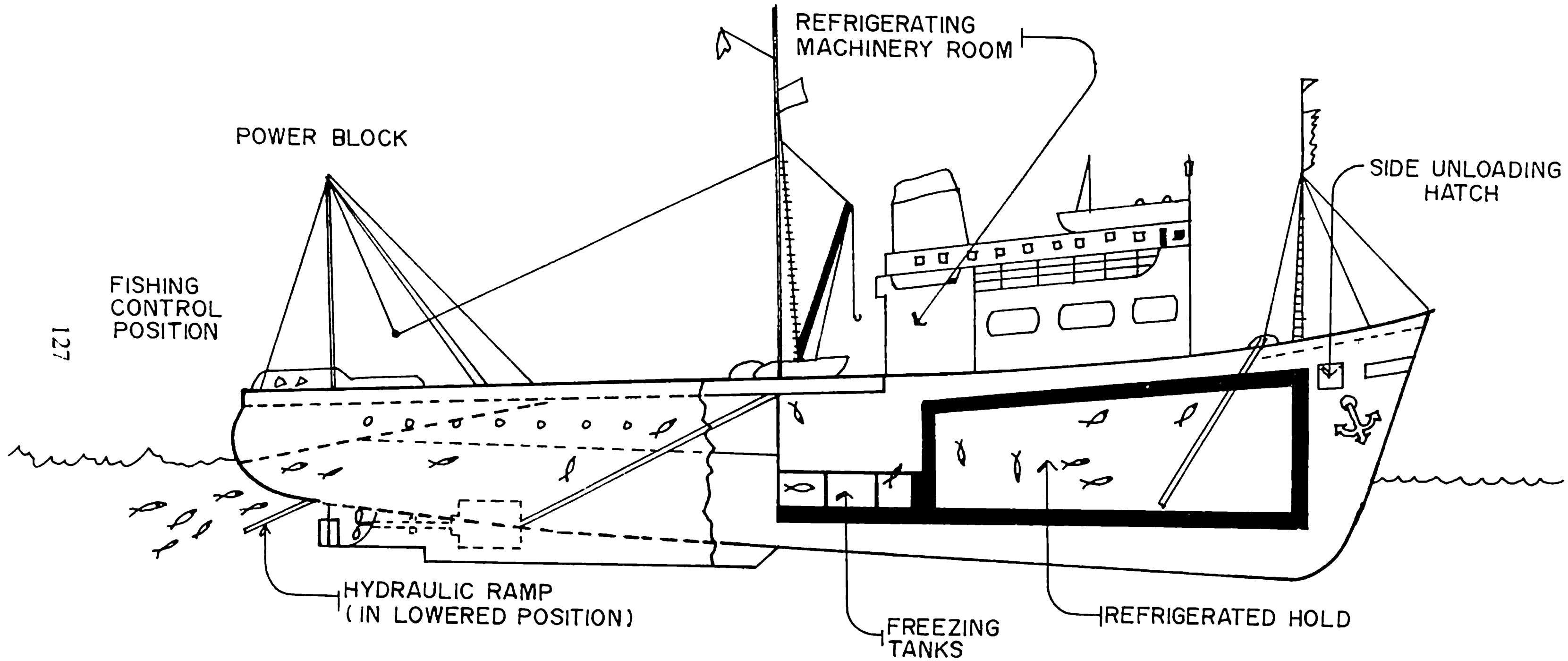
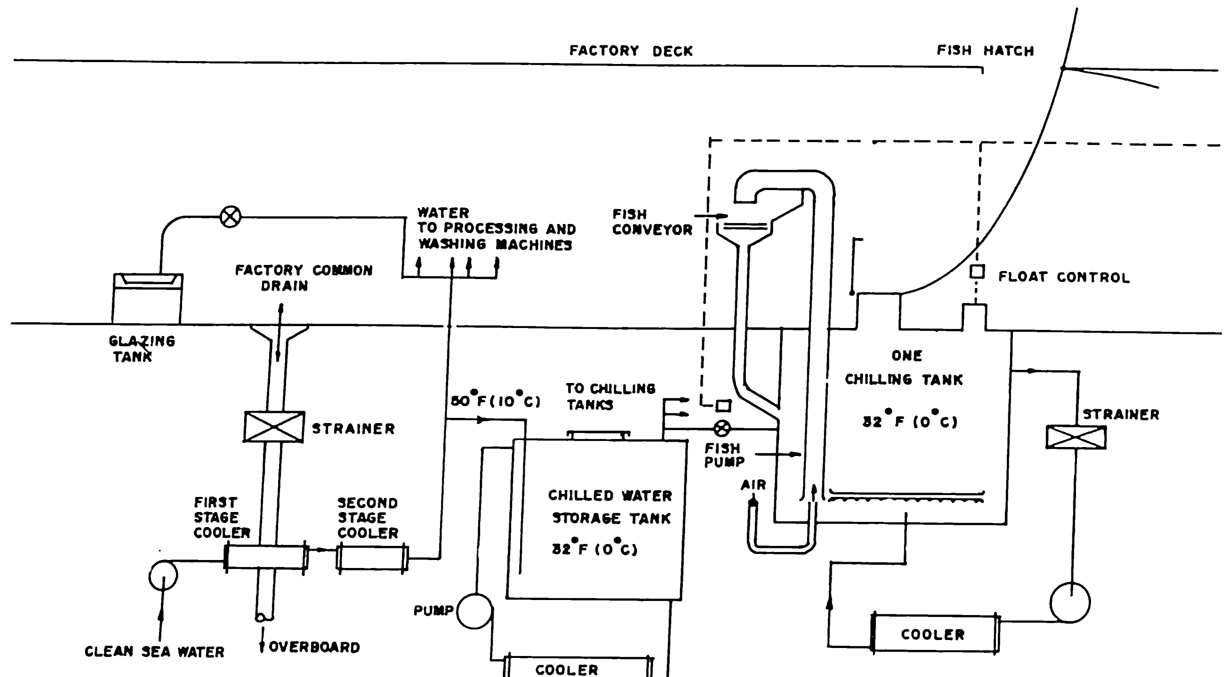


FIG. 4 TUNA PURSE SEINER SHOWING FLOW OF FISH



REFRIGERATION LOADS

GROUP I 35°F (2°C)	GROUP II 15°F (-10°C)	GROUP III 40°F (-40°C)
ACCOMMODATION AIR-CONDITIONING PROCESSING WATER GLAZING WATER MAKE-UP WATER	CHILLED WATER STORAGE CHILLING TANKS FACTORY COOLING	FREEZERS FROZEN FISH HOLDS

FIG. 5 DIAGRAM ILLUSTRATING CHILLING REQUIREMENTS IN HOT CLIMATES

A good layout is necessary for systematic preparation and freezing of fish. As fish is brought on board, say from a trawl net, the fish is cleaned first of debris and non-edible fish species. Then sorting is done unless the catch is large wherein chilling is undertaken first to prevent the effects of *rigor mortis*. Rigor mortis or death stiffening is a physical change that occurs in all animals after death and is characterized by the stiffening and gradual hardening of the carcass brought about by the stepwise contraction of fish muscles. After the stiffening process is completed, the muscles relax bringing about limpness or flaccidity in the fish. Freezing in rigor stage causes damage in the fish while freezing post rigor makes some fish unsalable after thawing.

Fig. 4 shows the flow of fish in a typical tuna purse seiner while Fig. 5 shows the diagram illustrating the chilling requirements in hot climates.

Freezing

At present, there is no widely accepted definition of quick freezing. However, we can state that in freezing, a fish should be frozen quickly to the intended freezing temperature. In the United Kingdom, the latter requirement is defined by stating that the warmest temperature of the fish be reduced to −20°C at the completion of the freezing which means that the coldest part of the fish will be at or near the refrigerant temperature and the average temperature will be at −30°C. In terms of freezing rate, it means only the average rate since the rate is quicker at or near the surface of the fish and slower near the center. Table 1 shows some of the freezing rates for fish while Table 2 shows the factors affecting freezing time.

Table 1. FREEZING RATES

2 mm/h	Slow bulk freezing in a blastroom
5 to 30 mm/h	Quick freezing in a tunnel air blast or plate freezer
50 to 100 mm/h	Rapid freezing of small products
100 to 1000 mm/h	Ultrarapid freezing in liquefied gases such as nitrogen and carbon dioxide

Catching Method in Relation to Processing and Freezing

In considering the fishing method and their effects in the design and quality of the fish, the following should be considered:

1. The manner of death — animals killed suddenly and cleanly will be in a better condition than one that dies slowly and possibly struggling for a long time in the process.

2. Interval between time of catch and time fish is removed from the water.

Table 2. FACTORS AFFECTING FREEZING TIME

1. Characteristics of Product	
Variety	
Thickness	
Shape	whole, individual whole, blocks* fillets, blocks* fillets, consumer packs*
Density (specific volume)	
Surface area	
Apparent Specific Heat	Specific heat above freezing Average freezing point Latent heat of fusion Specific heat below freezing
Thermal conductivity	
2. Characteristics of Freezing Methods	
Temperature at entry to freezer*	Thermal Arrest Period (TAP)
Temperature on leaving the freezer (mean)	Hold storage temperature*
Cooling medium (freezing method)*	
Temperature of cooling medium (mean)	Temperature rise (circulation rate) Static head effects — direct expansion, pump circulation
Humidity of cooling medium	Cooler surface area Temperature difference (mean)
Heat Transfer Coefficient Product cooling medium	Velocity of cooling medium Distribution of cooling medium Method of heat transfer Effect of packaging materials and/or trays*
Refrigeration capacity of cooler relative to total freezing time or TAP	

*Usually specified

3. Water temperature and characteristics of the fishing grounds if the fish dies in the gear before removal from the water (as in trawl and gillnet fishery) the temperature of the water is an important consideration. In the Philippine fishing grounds where the temperature of 27° and 30°C are common, fish may spoil before they are removed from the gear in instances of long delay. Fig. 6 shows the average temperature in Samar Sea, one of the trawl fishing grounds of the country.

For (2), remainder usually at discretion of designer/or fixed by product, for (1)

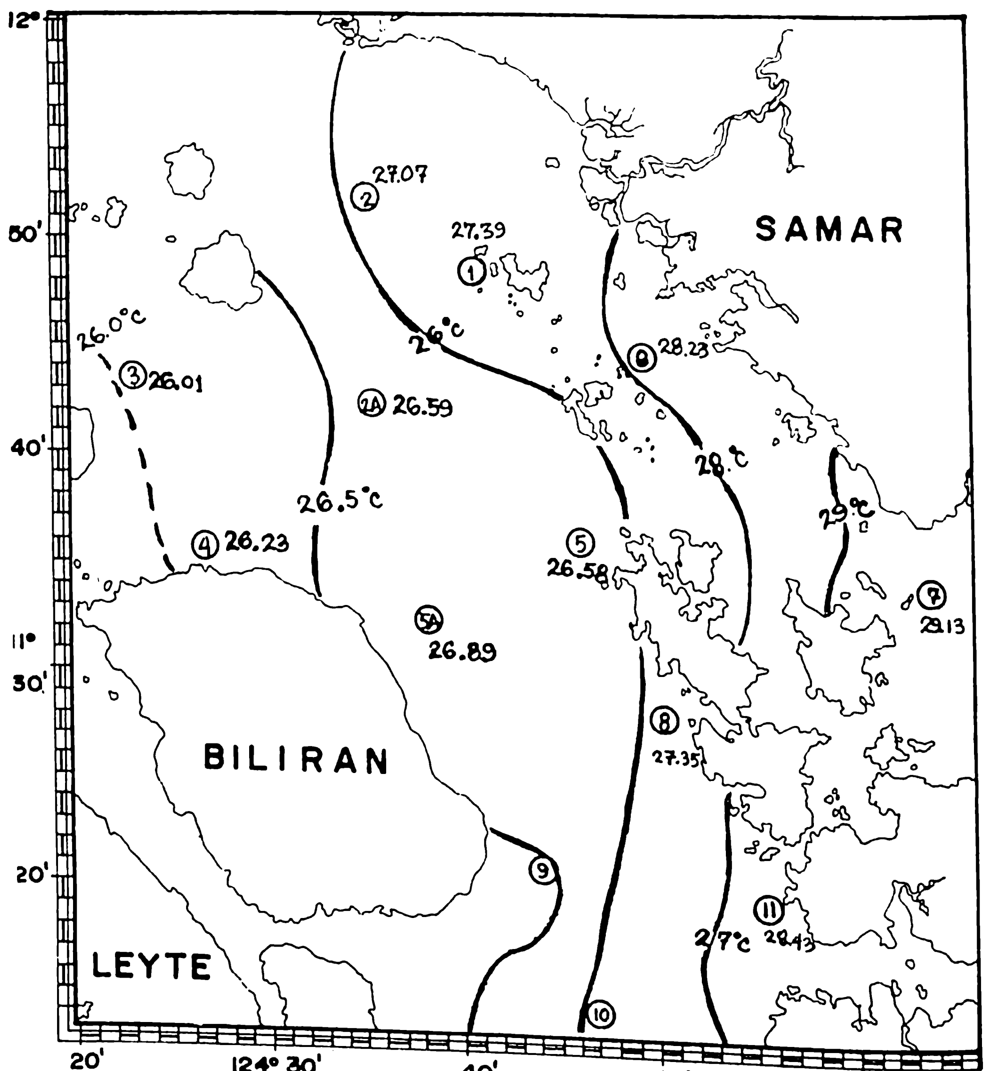
4. Selectivity of the gear — smaller fish species spoil rapidly than the larger ones. However, with purse seines, trawl nets and gill nets, specific species of fish may not be taken because of mesh selectivity and mesh size regulation.

5. Biological factors — gears designed to catch fish in different feeding activities, maturity stages and fishing grounds affect the quality of caught fish. However, in the Philippines, we have multi-species catch composition except in purse seining, with interlapping maturity stages which complicates the proper selection of freezing process.

In the Philippines, the main bulk of the catch of the commercial fishing operators comes from the combined catch of the trawlers, the purse seiners and the local "basnigan". Trawling involves the dragging of trawl nets in the bottom to catch demersal or bottom dwelling species. The dragging operation usually lasts for an hour or two and when fish is landed aboard, the preparation for freezing commences, while the net is lowered again for another drag. This fishing gear can be operated for 24 hours a day. The purse seiner on the other hand is usually operated in the Philippines during the night where scouting or luring of fish by means of light is employed and where the catching is effected by surrounding the fish school with the purse seine net. Most of the catch are pelagic species like tuna, squids, herrings, mackerels and bonitos. Basnigans operate in the same manner as the purse seiners but uses only a small net that is lifted when the fish school below is already of good quantity. Trawlers can catch from 1 to 6 tons per haul, while the purse seine can catch up to 30 tons per haul, with the basnigans up to about 5 tons depending on the size of the vessel, and the fish school present.

Freezing and Freezing Methods

When deciding on the proper equipment and processes to be installed aboard the fishing vessel or in ground stations, three major factors



OCEANOGRAPHIC STATIONS

CRUISE NO. __________

DATE __________

PARAMETER TEMPERATURE (MEAN)

should be considered initially: the feasibility, the financial considerations, and the functional considerations. This means that during the initial selection phase, a number of things should be taken into account like: the capital and running cost of the equipment, the likely losses due to damage or dehydration, whether the freezer is required for continuous or batch operation, whether the freezer is physically able to freeze the product and whether it is possible to operate the freezer in the locality.

There are at present many different types of freezers available for freezing fish but basically, they fall into three major categories:

1. Blowing a continuous cold air over the fish — air blast freezer

2. Direct contact between the fish and a refrigerated surface — contact or plate freezers

3. Immersion in or spraying with a refrigerated liquid — immersion or spray freezers

1. Air Blast Freezers

Air blast freezers operate on the principle of heat transfer from the product being frozen to the refrigeration system usually by means of moving air. Since air is a poor conductor, fans have to be installed to create forced convection, and to enable the product to be frozen in a reasonable period of time, this should be fairly high with even flow over each fish or package.

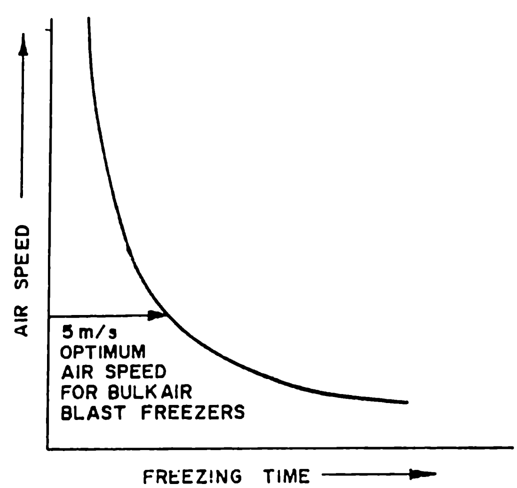


FIG. 7 VARIATION OF FREEZING TIME WITH AIR SPEED

Fig. 7 shows the variation of freezing time with air speed in an air blast freezer. Low air flow rates shows long freezing time but very high air speeds (high fan power) creates only a small decrease in freezing time. A design air speed of 5 m/s has been found to be a good compromise between slow and fast or high fan costs and this air speed is recommended for most air blast freezers.

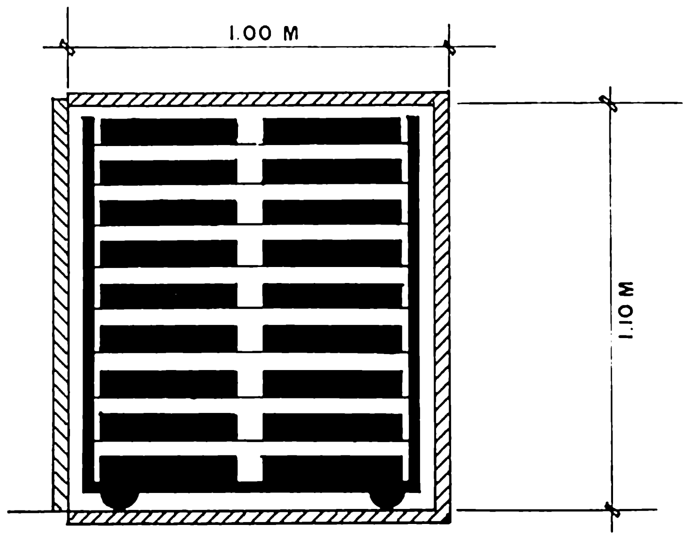


FIG. 8 SHOWS A SIMPLE EXAMPLE WHICH SHOWS HOW THE AVERAGE AIR SPEED IS DERIVED IN AN AIR BLAST FREEZER

Calculated cross sectional area of tunnel,

$1.1 \times 1.0 = 1.1\ m^2$

Calculated cross sectional area of produce and trolley (shaded area) $= 0.7\ m^2$

Air flow (obtained from fan rating) or measured in open part of tunnel $= 2.0\ m^3/s$

Calculated Average air velocity,

$$\frac{2.0}{1.1 - 0.7} = 5\ m/s$$

Another consideration is the temperature lapse rate. A low temperature lapse rate means the quantity of air being circulated is too high. Fig. 9 shows examples of good and bad freezer layouts which demonstrates this point.

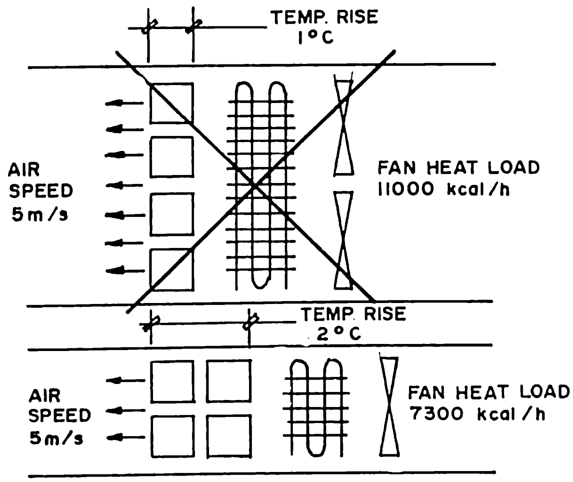


FIG. 9 THE EFFECT OF DIFFERENT LOADING ARRANGEMENTS ON THE FAN REQUIREMENTS FOR AN AIR BLAST FREEZER

Fan load can account for 25-30% of the refrigeration requirement, and in poor design, this may exceed the product load. An average air temperature rise of 1° to 3°C is reasonable and maybe used as a guide. Since this depends on the heat load, it will be higher at the start of the freeze than at the end. The average temperature rise may be calculated from the total heat extracted from the fish and the weight of air circulated during the freezing period as shown in the simple example below:

Weight of fish frozen		100 kg
Heat to be extracted 90 X 100	=	9000 kcal
Freezing time		2 h
Fan circulation rate		150 m^3/min
Density of air		1.45 kg/m^3
Weight of air circulated during freezing 150 X 60 X 2 X 1.45	=	26000 kg
Specific heat of air		0.24
Average rise in air temperature		

$$\frac{9000}{26100 \times 0.24} = 1.44 \text{ deg C}$$

Many of the faults of the air blast freezers can be attributed to poor air flow and the following examples shows the correct and the incorrect fan mountings and air distribution system.

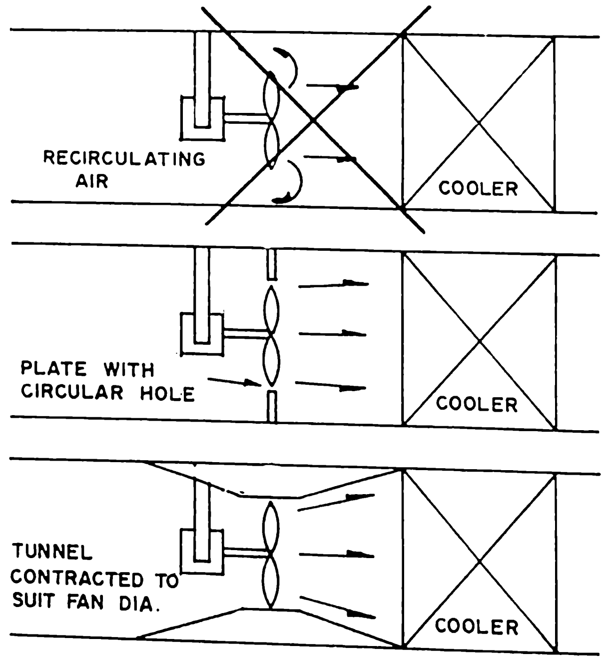


FIG. 10 BAD AND GOOD FAN MOUNTING ARRANGEMENT FOR TUNNEL AIR BLAST FREEZERS

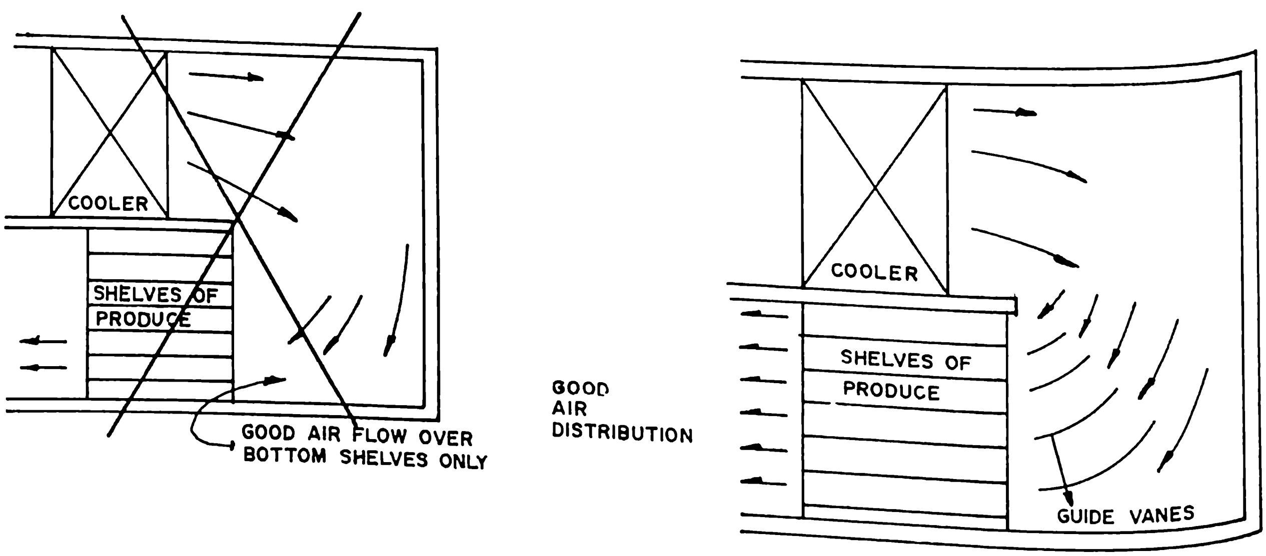


FIG. 11 POOR AIR DISTRIBUTION IN A TUNNEL AIR BLAST FREEZER AND THE CORRECTION MADE BY THE USE OF GUIDE VANES

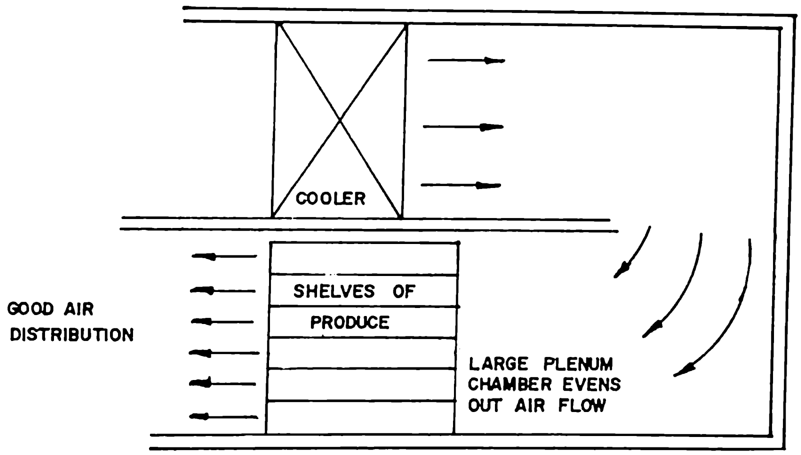


FIG. 12 GOOD AIR DISTRIBUTION IN A TUNNEL AIR BLAST FREEZER USING ADJUSTABLE BAFFLES AND A PLENUM CHAMBER

Type of Air Blast Freezers:

Continuous Air Blast Freezers — in this type of air blast freezers, the fish move through the freezer, usually entering from one end and leaving at the other. For this purpose. trucks, trolleys or continuously moving belts or conveyors maybe used. Fig. 13 shows an example of this type of Blast Freezers.

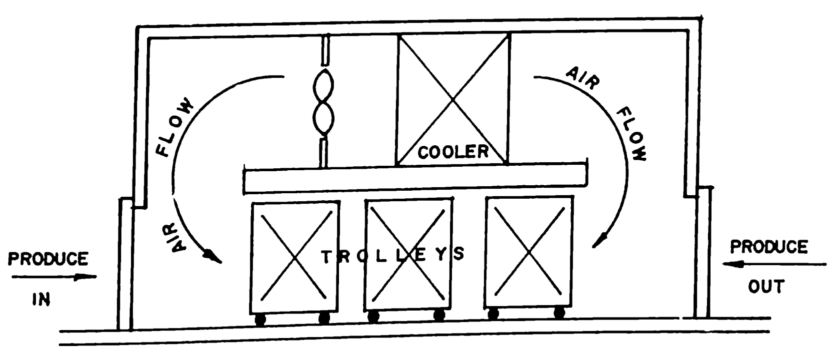


FIG. 13 BATCH - CONTINUOUS AIR BLAST FREEZER WITH COUNTER FLOW AIR CIRCULATION

To avoid moving trucks within the freezer, a batch continuous freezer can be designed with a cross flow air arrangement and the freezer maybe loaded from the side as shown in the next figure.

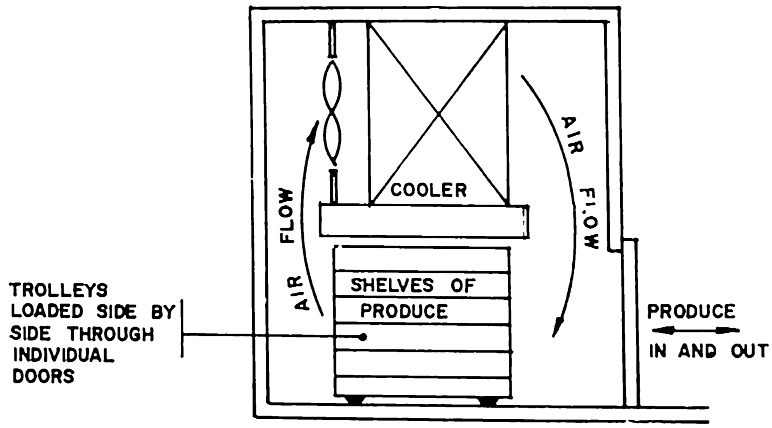


FIG. 14 BATCH - CONTINUOUS AIR BLAST FREEZER WITH CROSS FLOW AIR CIRCULATION

The succeeding figures shows the different designs of good and poor –

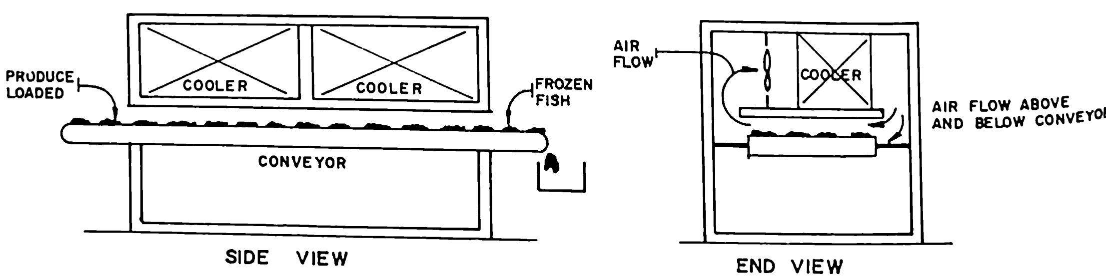


FIG. 15 CONTINUOUS BELT AIR BLAST FREEZER WITH CROSSFLOW AIR CIRCULATION (ALSO CONSTRUCTED WITH COUNTERCURRENT SERIES FLOW AIR CIRCULATION)

If the product is frozen easily, that is with a freezing time of less than 30 minutes, a continuous air blast freezer can be used as shown in Fig. 15.

The freezing time, the freezing requirement in kg/h and the loading density of the product in the belt are the factors which determine the freezer dimensions as shown by the sample calculation below:

Freezing requirement		200 kg/h
Freezing time		20 min
Load on belt	$200 \times \frac{20}{60} =$	66.6 kg

Belt Loading Density			3 kg/m^3
Belt width			1 m
Belt loading per unit length	$\frac{3}{1}$	=	3 kg/m
Belt length	$\frac{66.6}{3}$	=	22.2 m

Allowing for the loading and unloading of the fish outside the freezing space, the length of the freezer required for the above requirement would be about 25 m.

Continuous belt freezer can be constructed with a crossflow or seriesflow circulation of air. In the series flow arrangement, the coolest fish should meet the coolest air in the direction of flow. The design of the entry and exit should keep the rate of air infiltration to the minimum. Another consideration is on the degree of use. A continuous freezer left in operation but not fully loaded will give rise to higher freezing costs per kilogram of the product frozen.

2. *Batch Air Blast Freezers* — In batch air blast freezing the products are loaded in containers and placed inside the freezers. When the freezing is completed, the freezer is emptied and another batch is reloaded. This gives rise to bigger fluctuations in the refrigeration load than continuous or batch continuous freezers. Figure 16 shows the relationship of the three types of air blast freezers.

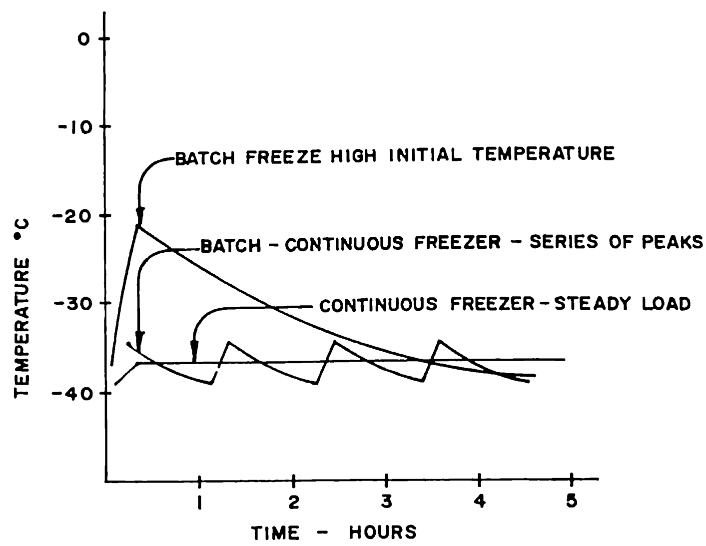


FIG. 16 FREEZER OPERATING TEMPERATURES FOR DIFFERENT TYPES OF AIR BLAST FREEZER

The succeeding figures shows the different designs of good and poor batch freezers and the proper and improper arrangements of containers.

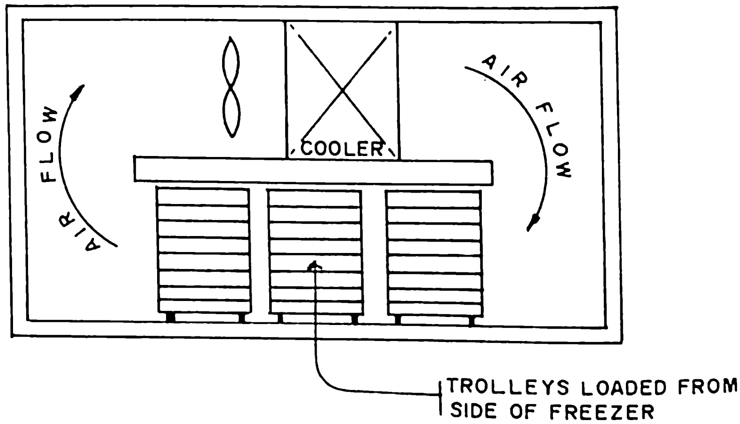


FIG. 17 BATCH AIR BLAST FREEZER WITH SIDE LOADING AND UNLOADING

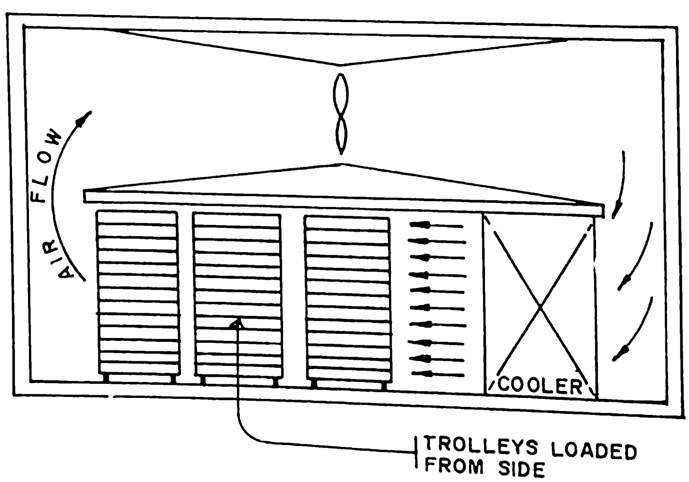


FIG. 18. AIR BLAST FREEZER ARRANGEMENT SHOWING THE COOLER ACTING AS AN AIR DIFFUSER

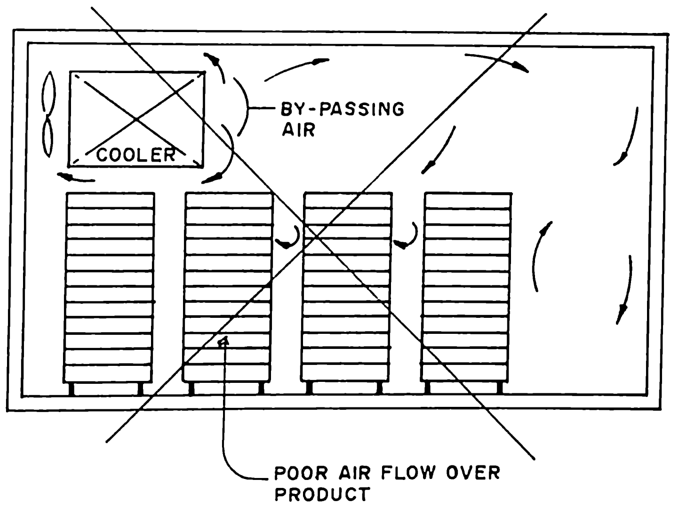


FIG. 19 ROOM FREEZE WITH POOR AIR FLOW OVER THE SURFACE OF THE PRODUCT

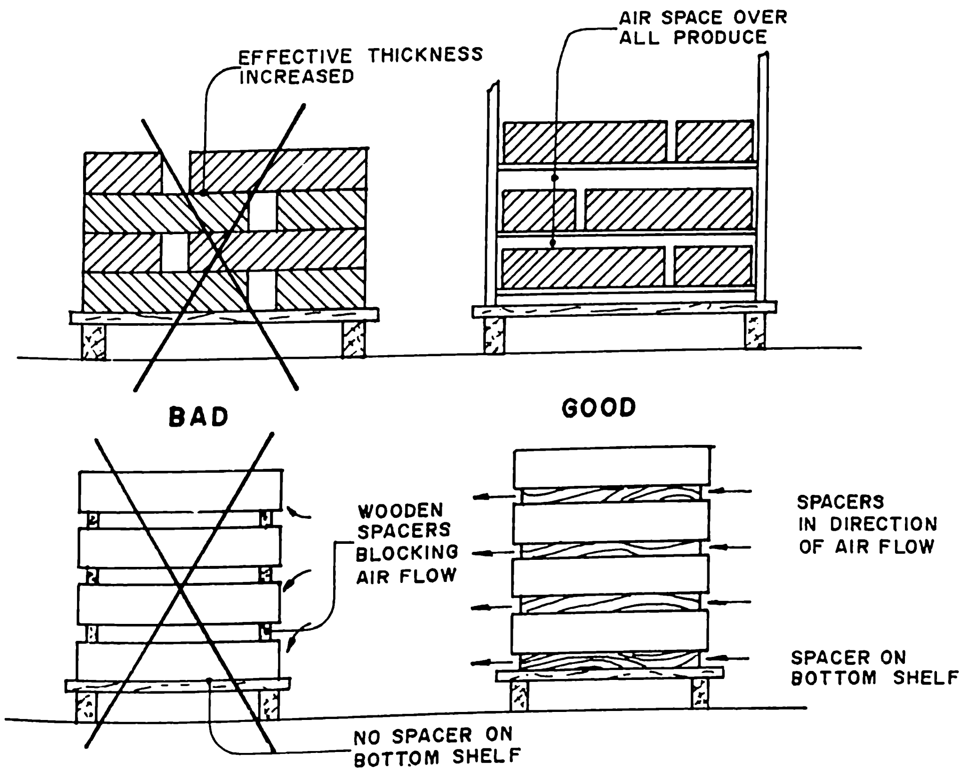


FIG. 20 BAD AND GOOD PALLET POSITIONING IN AN AIR BLAST FREEZER

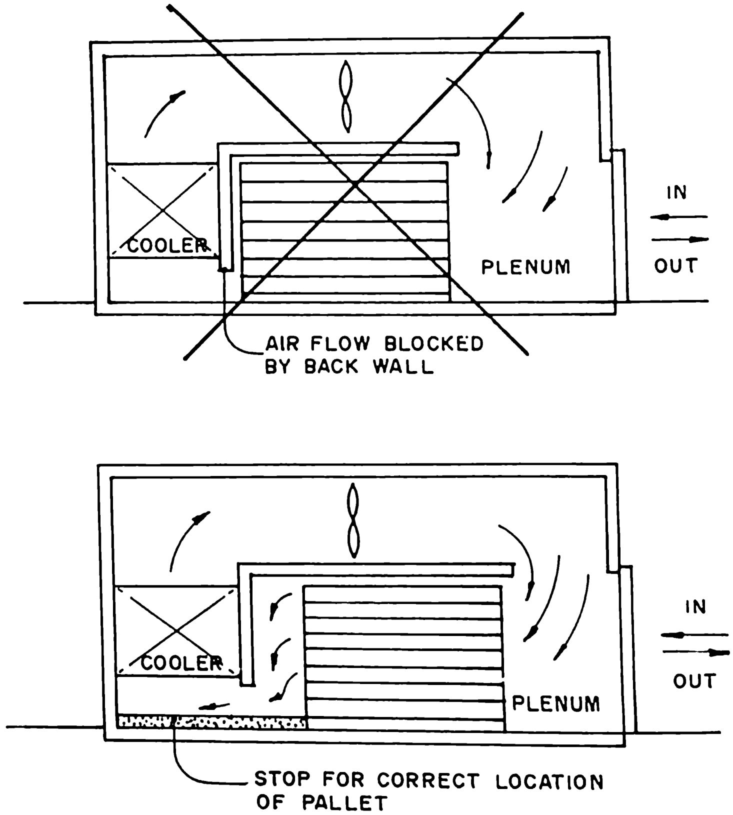


FIG. 21 BAD AND GOOD PALLET POSITIONING IN AN AIR BLAST FREEZER

3. *Semi-fluidized Freezers* — This type of freezer was originally used for freezing peas, where a strong blast of air is continually supplied from the bottom as the product moves along the conveyor. However, this type is not yet in use aboard the fishing vessel, only in the shore plants for freezing shrimps and small cuts of fish. Figure 22 shows the Lewis fluidizing freezer.

Plate Freezers

Plate freezers and air blast freezers are the types of freezers most commonly used for freezing fish in industrialized countries, however, one disadvantage of plate freezers is that they do not have the versatility of the blast freezers. Plate freezers can be arranged with the plates oriented in the horizontal or vertical position.

a. VERTICAL PLATE FREEZERS (VPF) — When the plates are arranged in the vertical position, we have the vertical plate freezers. They have an advantage over the other freezer in that the fish to be frozen need not have containers. Figure 23 shows the general set up of this freezer.

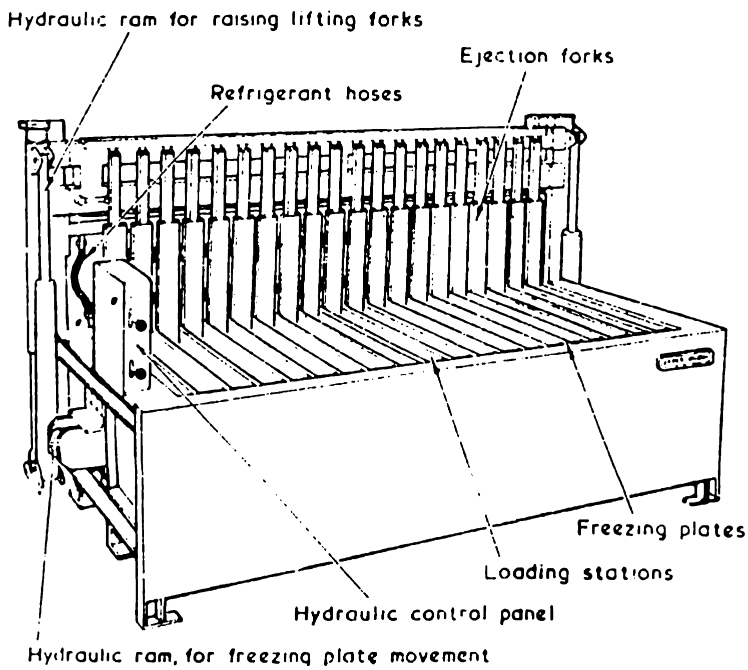


Fig. 23. Twenty-station vertical plate freezer with top unloading arrangement.

b. HORIZONTAL PLATE FREEZER (HPF) — When the plates are arranged in a horizontal orientation the contact freezer is called a horizontal plate freezer, and needs packages or trays of 32 to 100 mm in thickness which needs to be compressed a little for greater contact and hence heat transfer. Figure 24 shows a typical example of this type of freezer.

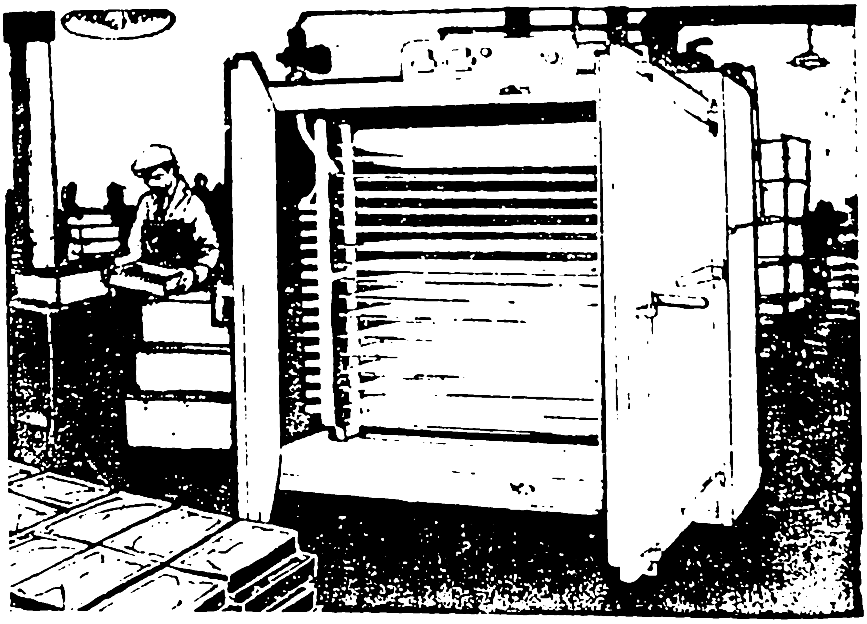


Fig. 24. Horizontal Plate Freezer.

Modern plate freezers have their plates constructed from extruded sections of aluminum alloy arranged in such manner as to allow the refrigerant to flow through the plate and then provide heat transfer surfaces on both sides.

Immersion Freezers

Since the transport of heat through air is slow, the use of liquid for the same purpose is sometimes done. This has however several limitations, as the lower the temperature, the higher the viscosity of the fluid and many of the suitable liquids (i.e., the liquids that have suitable refrigeration and heat transfer properties) are not used because they either change the flavor or the color of the product when placed in direct contact.

Brine water is often used for this purpose especially for tuna which are intended to be marketed as a canned product. (Refrigerated Sea Water or RSW can also be used for this purpose). The most effective brine freezing technique is the use of eutectic solution of common salt which contains about 22.4% salt and the remainder — water which can be maintained at a temperature of −21°C which is circulated at a rate of about 0.2 m/s, a rate low enough to prevent damage to the fish by agitation and at the same time good enough to provide circulation so that there is no stagnant water in the brine tank.

The whole process however is messy and corrosion of the ships' parts and the brine tank is a problem. Aside from these, sodium chloride brine does not allow the fish to be frozen down to a storage temperature of −30°C. These limitations as well as the above makes the method to be gradually phased out.

There are other types of freezers like the automatic plate freezers, drum freezers, continuous freezer with brine cooling, liquid nitrogen freezer, and others but they will not be discussed as they are not wisely used and accepted in the industry.

Ordering Freezers:

In buying freezers, the buyer should provide as much of the following information:

The kinds of fish product to be frozen
The shape, size and packaging of each product
The freezing time of each product
The product initial temperature
The intended cold storage temperature
Required daily output for each product in metric tons or kilogram
Normal freezer working day in hours
The average air temperature required in the freezer section
The average design air speed required with sketch plan
The position of freezer in factory or in the fishing vessel with a sketch of the plan to show its location in relation to other parts of the process.
Maximum headroom available at the freezer location
Availability and specification of present electricity and water supply
Reliability of electrical supply and quality of water
Maximum ambient temperature
Spare parts required
Availability of maintenance facilities and skilled labor for plant operation

The following additional information should also be specified by the contractor:

Refrigeration Machinery:

Number and type of compressors
Compressor operating conditions
Total refrigeration capacity

Refrigeration capacity for each compressor in kilocalories per hour at design conditions

Power of compressor meters in watts or kilowatts

Maximum electrical power requirements in watts or kilowatts

Compressor safety arrangements

Condenser, number and type

Water consumption in cubic meters per hour

Circulating pumps for condenser

Fan power requirements for condenser

Sketch of machinery layout showing total space required

Refrigeration system:

Refrigerant used

Type of system

Initial refrigerant charge in kilograms

Power of circulating pumps for refrigerant

Standby arrangements, if any

Temperature control limits

Freezers

Sketch of freezer layout showing total space requirement

Weight of load for each product specified

Output in metric tons per hour or kilograms per hour for each product specified

Output in metric tons or kilograms for normal working day including allowances for loading

Recommended loading procedure

Air temperature in freezing section

Number and capacity of fans

Air speed in empty freezer in meters per second

Air speed over the product in meters per second

Air temperature rise over the product

Method of defrosting

Instrumentation supplied

Type of insulation

Thickness of insulation in millimeters

Method of erection of insulation

Type of vapor sealing

External finish

Internal finish

Door arrangements

Door heaters

Frost heave precaution, if any

Lights

Cold Stores

After freezing and glazing or packaging, fish are placed in the cold storage compartments or rooms to reduce spoilage due to proteination, fat changes and dehydration, at temperatures appropriate for the species, type of product and intended time of storage. The International

Institute of Refrigeration recommends a storage temperature of −20°C for lean fish and −30°C for fatty species.

Factors Limiting Storage Life

Aside from protein changes and fat changes, dehydration changes or "freezer burn" causes decrease of weight in fish and makes the surface dry, opaque and spongy and as time progresses, this penetrates deeper making the fish flesh a fibrous, and very light substance. This increases with increasing relative humidity and air temperature.

Therefore, the important factors to be kept in mind when designing and operating a cold store are:

Low temperature	Good air distribution
Uniform temperature	Minimum rate of air circulation
Steady temperature	Minimum heat

Types of Cold Store:

1. Jacketed Cold Storage — this system is the ideal method of construction but is costly. (Fig. 25). The inner storage is completely isolated from the jacket of air thus it ensures small temperature differences within storage spaces and high relative humidity.

2. Gridded Cold Store — plain pipe grids are installed on the roof and walls of a store which generally gives good storage conditions since heat entering the store is absorbed at once by the refrigerant with even temperatures all throughout. However, this costs more and difficulties arise during repairs and maintenance.

3. Finned Grid Stores — this is the same as the second one but uses fins which promote the necessary heat exchange. Only roof grids are installed thereby reducing cost. However, since they do not cover walls, storage will not be as good as with plain grids, and defrosting finned grids is also difficult.

4. Stores with Unit Coolers — this is the most widely used method of cooling cold stores wherein unit coolers with fans for circulation of air lower the temperature inside the cold store. This is relatively cheap to install, requires a relatively small charge of refrigerant and can be readily defrosted without interfering too much with the store conditions and does not require heavy structure for supporting the units. The main disadvantage of this, however, is that uniform distribution and cooling of air is not attained. (See Fig. 26.)

To alleviate these, false ceilings are usually made as in Figs. 27, 28 and Fig. 29.

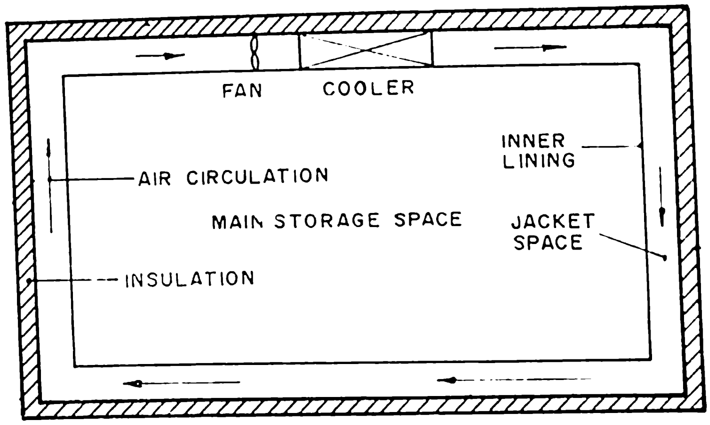


FIG. 25 A JACKETED COLD STORE

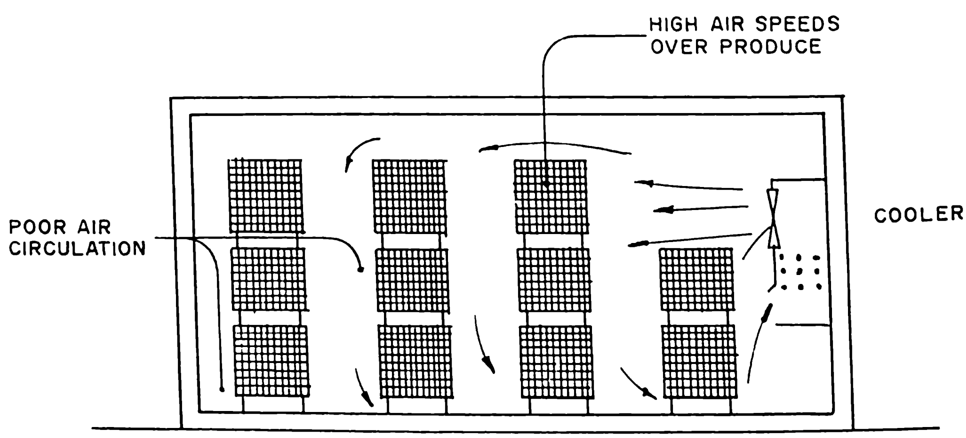


FIG. 26 UNEVEN AIR DISTRIBUTION IN A STORE WITH A UNIT COOLER WITH FAN CIRCULATION

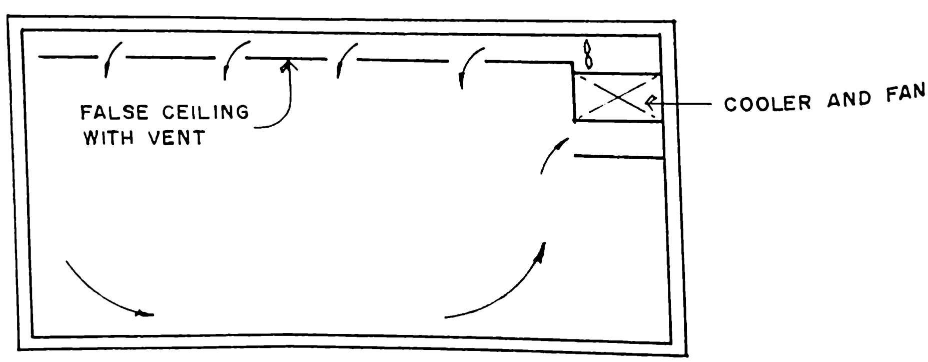


FIG. 27 COLD STORE WITH A FALSE CEILING AND VENTS TO GIVE UNIFORM AIR DISTRIBUTIONS

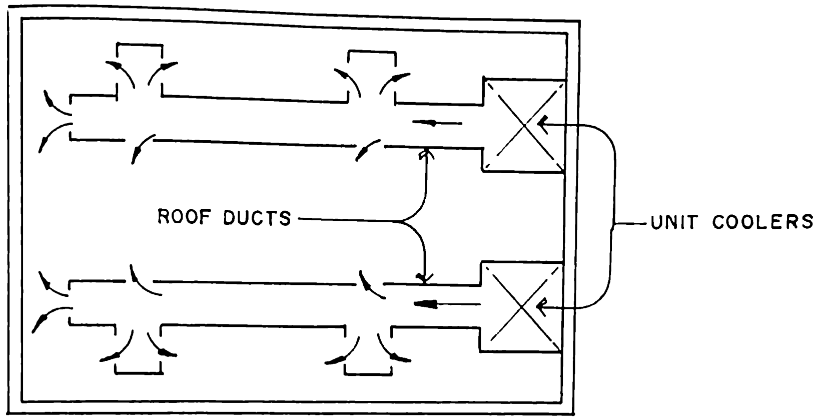


FIG. 28 PLAN VIEW OF A COLD STORE USING ROOF DUCTS TO GIVE UNIFORM AIR DISTRIBUTIONS

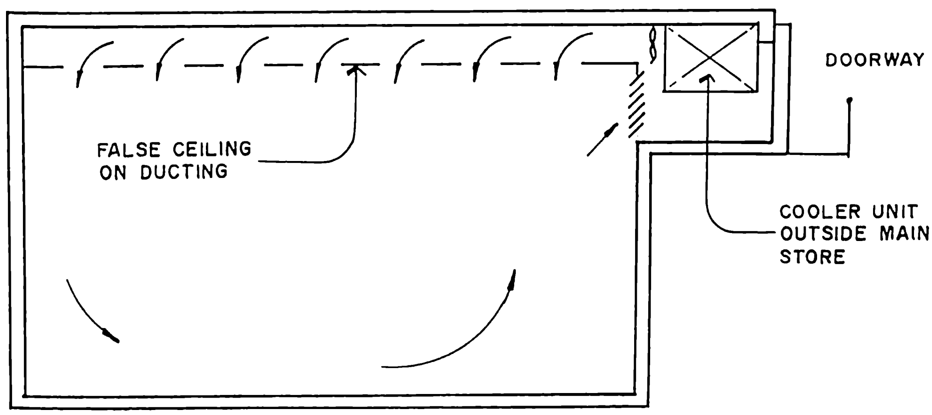


FIG. 29 DUCTED-AIR COLD STORE WITH COOLER UNIT OUTSIDE THE MAIN STORE

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