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Certified that the attached dissertation on

"PRESERVATION & DISTRIBUTION OF FROZEN FOOD."

was submitted by

Virendra Charan.

and accepted for the award of Degree of Master of Engineering in Applied Thermodynamics (REFRIGERATION & AIR-CONDITIONING).

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PRESERVATION AND DISTRIBUTION OF FROZEN FOOD

A Dissertation Submitted
in
Partial Fulfilment of the Requirements
for
The Degree of Master of Engineering
in
Applied Thermodynamics (Refrigeration & Air Conditioning)

By

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MECHANICAL ENGINEERING DEPARTMENT
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ROORKEE, (INDIA)

1961

CERTIFICATE

Certified that the dissertation entitled " PRESERVATION AND DISTRIBUTION OF FROZEN FOOD " which is being submitted by Shri Virendra Sharma, in partial fulfilment for the award of the Degree of Master of Engineering in Applied Thermo-dynamics (Refrigeration and Air-conditioning) of University of Roorkee is a record of the student's own work carried by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

This is further to certify that he has worked for a period of six months from 15th April 1960 to 2nd July 1960 and 17th March 1961 to 4th July 1961 for preparing dissertation for Master of Engineering Degree at this University.

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A C K N O W L E D G E M E N T S.

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P R E F A C E

Refrigeration plays a highly important role in the preservation of perishable commodities, the most important of which are food stuffs. The forces responsible for physical and chemical changes that cause food spoilage and decay are substantially retarded in their activity by their exposure to low temperature conditions.

Thus the principles governing the deterioration of food stuffs form an integral part of refrigeration study as a whole. The knowledge gained as a result of such study forms a basis on which to build a more complete understanding of what is required in the way of effective control measures for each of the individual food items to offset the forces of spoilage and decay. The deterioration of most of the foodstuffs is, thus, suspended by employing low temperature conditions.

In general, refrigeration for food preservation may be employed in two ways, by cooling the food -

(a) Above freezing point

(b) Below freezing point

The refrigerated food cooled below freezing point is known as FROZEN FOOD. The present work is an attempt to study the science and development of frozen foods only. This volume has been divided into three sections. Section I deals with General causes of food spoilage and their remedies; Freezing methods and means of storing frozen food for a longer period. Section II deals with the Distribution aspect which includes Precooling, Preparation & Packaging at the time of freezing; problems relating to frozen food transportation by land, sea & air; also various aspects regarding marketing considerations. In Section III specific examples have been taken and it is investigated how the foregoing principles may be applied to such problems.

SECTION I.

CHAPTER I.

GENERAL

2.01 HISTORY OF FROZEN FOOD

Refrigeration is essential in many phases of preparation, storage and distribution of various foods and beverages. The primary purpose of food refrigeration is to aid preservation which has contributed greatly towards increasing the standard of living as well as reducing the wastage.

Man's effort to preserve foods so that no change in flavour, aroma or texture takes place, dates back many years, but it has been only in the last few years that this dream could actually be accomplished and controlled.

At the close of the 17th century, carcasses of elephants frozen during the Glacial period were discovered and frozen flesh from these animals was still in a good state of preservation. Early Americans froze pies, puddings and meat for future use during winter. Perishable foods were first frozen commercially in the United States about 1875. By 1900 mechanical refrigeration was adopted to freezing foods but only on large applications of cold storage. The cold packing industry had its beginning about 1905 with the freezing of small fruits for manufacture in jams, jellies, pies, and ice-cream. A retail line of packaged frozen foods first appeared on the market in Springfield Mass in 1930. The freezing of consumer size packaged fish, meat and poultry began at that time and its growth has been accelerated eversince. The home freezer and domestic storage cabinet of the present design dates to just prior to World War II, about 1940. Some precooked foods such as frozen crab meat and lobster meat, both of which required cooking as a means of preparation date back to early 30's.

The first volume packs of pre-cooked frozen foods began about 1942. It is now possible with latest developments to freeze foods at any time and store them for fairly long periods.

Frozen food refrigeration has thus grown rapidly in the last few years. The field of frozen foods has touched all consumers; it has caused the development of new types of domestic and commercial equipment, and it has presented new problems in design use, and servicing of frozen food equipment. In fact the problem of frozen food is growing in importance and is being given serious thought today because of their manifold advantages.

1.02. ADVANTAGES OF FROZEN FOODS.

The advantages of frozen foods are many and varied :-

(i) The most important advantage is that it provides the opportunity to preserve a food supply for long periods without seriously affecting the taste aroma or texture.

(ii) It allows the farmer to freeze his surplus foods and hold them until needed.

(iii) Food supply may thus be constant at all times while many important plants and trees produce their entire crop during one short season of the year only.

(iv) Meats, fish and dairy products, although produced continually, may be preserved against the time of distribution to outlying points and kept until required by the consumer which may mean weeks or even months after processing.

(v) Frozen foods offer the house wife a method of preparing foods in quantity and ahead of demand, thus actually reducing her work.

(vi) Foods that are properly frozen reach the consumer in far better condition and consequently command a much higher price.

(vii) Such foods not only look better, they are better because they are fresher, have a better flavour, and retain a much higher content of Vitamin C and other easily oxidisable Vitamins.

(viii) Biologically no other form of food preservation can compare with food freezing and then storing at low temperatures (below 0F). Research has indicated that micro-organisms suspended in water, frozen and stored at freezing temperatures (32°F or below) are soon killed.

(ix) Meat, poultry, and fish have important colloidal changes that must be minimised and low temperatures are an aid in minimising this action.

In analysing the complete subject of food preservation as a prerequisite towards its intelligent preparation for storage and control measures, consideration should be given to the following basic questions (dealt with in subsequent articles).

1. What constitutes food spoilage?
2. What are the causes of food spoilage?
3. What control measures can be taken to allay or to prevent spoilage of foods.

1.03. [illegible]

The effect of spoilage varies in different types of perishable commodities, but the result is similar in all cases since it renders such items unfit for human or animal consumption. However, spoilage is generally apparent through noticeable changes in food substance such as changes in

(i) Odour

(ii) Colour

(iii) Taste

(iv) Physical appearance

(v) Chemical behaviour are some of the traits by which the activity of spoilage agents can be detected once their presence become effective.

(vi) Loss of weight

(vii) Reduction in Vitamin Content

(viii) Molding

(ix) Wilting

(x) Softening

(xi) Souring

(xii) Rotting

These may affect different commodities individually or may be in combined form. Deterioration of some of the common food materials is given below :-

Fruit - As a result of continued chemical activity within the substance they become over-ripe and rotten, if not properly protected. Over-ripeness is followed by the initial stages of rotting, then discolouration of outer surface and finally spotty appearance starts, which soon spreads throughout the mass, causing spoilage of fruit.

Vegetables : Similar to fruit deterioration, wilting being an additional factor.

Meat - They change little in physical appearance. However, spoilage is carried on by 'Putrefaction' which produces gases that have offensive odours. After a period meat surface takes on a slimy coating.

Dairy Foods (Butter & Cheese) - They emit rancid or sour odour. The taste is also affected adversely.

Eggs. - They lose weight due to evaporation and become strong-smelling upon spoiling.

Milk - It sours gradually when exposed to conditions conducive to the activity of spoilage agent. In the final states of deterioration there exists a line of demarcation between the water and more solid components as one separates from the other.

1.04. CAUSES OF FOOD SPOILAGE.

The principal causes of food spoilage are : -

1. Enzyme action
2. Growth of Micro-organism :
   (a) Bacteria
   (b) Yeasts
   (c) Molds
3. Other causes.

1. ENZYMES.

Enzymes are chemical substances of highly complex composition, acting as catalyst to bring about chemical changes within organic materials. They occur naturally in all organic substances. Table 1.1 gives the action of various enzymes under different conditions :

Enzymes are responsible for the normal ripening of fruit and vegetables and, if allowed to continue in their activity uncontrolled, will cause over-ripening, deterioration and ultimate destruction. One of the basic results of enzyme action on food substances is to transform insoluble material to a soluble state, which is thus made available for digestion by micro-organisms present in the matter. Disintegration of fruits and vegetables caused by enzyme action is known as "Autolysis".

Table 2.1 Some Common Enzymes and their Tasks.

Enzyme	Substance on which it acts	Produce.
Diastase	Starch	Malt sugar
Cytase	Cellulose	Sugar
Pepsin	Proteins	Peptones
Trypsin	Proteins	Amino-acids
Lipase	Fats	Glycerin + fatty acids
Zymase	Sugars	Alcohol + CO_2
Ptyalin	Starch	Sugar

It is important to note that enzyme action will take place only when surrounding conditions of temperature and acidity are conducive to its effectiveness. Enzymes cannot be eliminated without changing the chemical structures of the organic substance in which they are contained. Cooking of food substance is the most effective way, as heat destroys these complex proteins. Freezing temperatures, however, will retard their activity without destroying the enzymes. Enzyme action follows the law 2* -

$$\log r = A - \frac{B}{T}$$

$$\text{or} \quad r = 10^{A} \frac{1}{10^{B/T}}$$

* Such numbers refer to Bibliography.

where,

r = the rate at which action occurs

A & B = constants for specific action

T = the absolute temperature

2. <u>MICRO-ORGANISMS.</u>

(a) <u>Bacteria</u>.- They are minute organisms (Fig. 1 a) being the smallest and the simplest form of plant life known. Bacteria in their relation to man's economy can be broken down into two classes.

(i) Those that cause spoilage of food.

(ii) Those employed for food preservation.

The first kind of bacteria occur almost in all organic substances such as meat, vegetables, fruit milk etc. In the living state of body or plant structure the number of these bacteria is limited but there is no limitation, through normal life processes, to bacterial growth in killed animal or in the multiplication of the bacteria (Fig. 1 b), deterioration and spoilage for human consumption are rapid.

The rate of growth of bacterial at ordinary room temperatures is almost incredible. It has been found that bacteria will double in number every 20 to 30 minutes under favourable conditions. It has been estimated that a single bacterium could multiply[3] or reproduce (Fig. 1 c) over a period of 15 hours as given in Table 1.2

Although it is virtually impossible to keep bacteria out of food entirely, the wholesomeness of the food may be maintained by retarding the growth of the bacteria. It is only after bacteria have multiplied beyond certain limits that they become dangerous in food for human consumption.

Table 1.8

Number of Hours	Number of Bacteria
1	4
2	16
3	64
8	65,53 6
15	1,000,000,000

The growth of bacteria, as with plants, is controlled by several factors viz.,

(i) Food

(ii) Heat

(iii) Moisture

(iv) Air

The limitation of anyone of these factors retards the growth to some extent, however, if bacteria are given food, the one other factor which has the greatest effect on their multiplication is heat. All bacteria multiply most rapidly at a certain temperature called optimum temperature. Likewise, there is a low temperature limit called the minimum temperature below which they will not grow. Contrary to popular belief, low temperature ordinarily does not kill bacteria. It merely checks or retards their growth, which is resumed as soon as the temperature is raised. Research conducted by the U.S. Department of Agriculture has established the fact that temperatures below 35°F retard the growth of micro-organisms. Thus with proper refrigeration there is little danger of spoiling of stored food.

(b) Yeasts. - Yeasts are one celled plants (Fig. 1 b) of the fungus group and are destructive to fresh foods. Yeasts require air, food and moderately warm temperature for growth but are killed when exposed to high heat conditions. Yeast cells are hard and will survive for long periods when deprived of food and moisture or exposed to low temperatures. Under such conditions the micro-organism pass into a dormant stage and growth ceases or is retarded greatly. Extremely low temperatures are injurious to commercial yeast, however, and should be avoided wherever the product is handled for storage purposes.

Considering that 45°F is the ideal storage temperature for commercial yeasts, it becomes an easy problem to control such micro-organisms when storage temperature of food stuff is 32°F or below it i.e. freezing.

(c) Molds. - Molds are a class of minute plants (Fig. 1 c), and become apparent by the cottony, thread like structure which appear fuzzy to the naked eye. Molds are much larger in size than yeasts. While most common molds are non-poisonous, some types are injurious to health. All molds are bitter in taste. Mold growth is rapid under the conditions :

(i) Molds thrive in damp locations.

(ii) Oxygen is essential to mold growth

(iii) Molds thrive in the presence of acids such as found in fruit and fruit juice.

(iv) Mold is prevalent on most surfaces where temperatures are above 32°F. Below this temperature the reproduction of mold life is retarded greatly due more to the absence of free moisture than to the low temperature level.

Table 2.3 gives some of the molds and their hosts.

Table 2.3

Name	Host & Effect.
Rhizopus nigricans	Bread mold
Penicillium expansum	Soft rot of apples in storage
Penicillium roqueforti	Spoilage of Dairy products including cheese.
Penicillium italicum	Spoilage of citrus fruit
Aspergillus flavus	Grain mold
Aspergillus niger	Spoilage of general foods.

B. OTHER CAUSES.

Deterioration, a stage between fresh and spoiled food, may be due to certain other reasons apart from action of micro-organisms. They are

(i) Bruising - The substance is broken by impact or squeezing. It is prevalent in most fruit and vegetables.

(ii) Desiccation - It is caused by the decrease of moisture content of a food substance below normal shrinkage allowances by excessive evaporation when exposed to dry atmospheric conditions. Loss of weight, and wilting of fruits and vegetables are the results of desiccation and the food is no longer a good product as the flavour is affected and the product becomes tough.

(iii) Absorption of Odours - Butter, eggs, cheese and meats readily absorb odours given off by other products from outside sources such as Ammonia in direct expansion system. Use of brine cooling has been recommended in such case. Also a thorough knowledge of all products that bring odours with them proven in most then decisions concerning storage locations for various items are to be made.

(iv) Chemical Changes - These are associated with enzyme action which accelerates oxidation and hydrolysis of fats in uncooked foods. Another type of objectionable chemical action in frozen food is the denaturation of proteins. When foods are frozen, water separates out as pure water-ice and not as a simple solution of the natural cell content. The result is a dry, pithy substance made to appear even less appetising by reasons of its discolouration.

(v) Incorrect Storage temperatures - Many harmful effects are brought by exposure of fruits and vegetables to incorrect temperatures. It should be remembered that each item has its own characteristics as related to the temperature to which it is exposed and such characteristics should be considered in order to provide the correct condition for its safe storage for reasonable time interval.

(vi) Respiration - Fruits and vegetables constitute to carry on their living function even after they are harvested, eventually disturbing the chemical balance which is reached at the time of ideal ripeness and cause an increase in compounds that become less palatable as such changes proceed. This respiration consists of several separate but related processes viz.,

(a) Oxygen is absorbed from the air

(b) Carbohydrates become oxidised

(c) CO_2 heat and water are released

Respiration can be retarded by

(a) Reducing the amount of oxygen available.

(b) By exposing fruits and vegetables to low temperatures. It stops completely when frozen.

1.03 CONTROL MEASURES TO BE TAKEN TO PREVENT SPOILAGE OF FOODS

The principle reason for the spoilage of food are now known to be the result of enzymic and micro-organismic activity. Fortunately these agents of destruction are vulnerable to certain extreme physical, chemical or temperature conditions and are greatly retarded in their activity or eliminated entirely when so exposed.

The methods employed in arriving at such extreme conditions detrimental to the life of these agents depend upon the means at hand and final result desired. Before any procedure for food preservation can be adopted, first the characteristics of each type of spoilage agent must be determined. Basically the problem of food preservation narrows down to two important factors.

(i) What are the conditions under which the forces of destruction may be retarded or eliminated ?

(ii) How these conditions may be brought about ?

By establishing the known conditions both favourable and unfavourable to the growth and activity of spoilage agent the answer to the first question may be determined.

Table 1.4 lists all such conditions

Table 1.4 : Conditions favourable and unfavourable to the growth and Activity of Food Spoilage Agents.

Spoiling Agent	Favourable and unfavourable conditions for Growth	
Enzymes	Favourable	(i) Optimum temperature (ii) Free oxygen (air) (iii) Moisture present (iv) Slight Acidity.
	Unfavourable	(i) Low temperature (ii) Boiling temperature (iii) Strong acidity (iv) Strong alkalinity (v) Absence of Moisture.
Micro-organisms		
(a) Bacteria	Favourable	(i) Slight alkalinity (ii) Moisture (iii) Optimum temperature (iv) High oxygen cation
	Unfavourable	(i) Low temperature (ii) Strong Acidity (iii) High temperature (iv) Strong alkalinity (v) Concentrated salt solution (vi) Absence of moisture (vii) Low oxygen cation (viii) Concentrated sugar solution (ix) Sunlight or Ultraviolet-ray (x) Antiseptics present.
(b) Yeasts	Favourable	(i) Optimum temperature (ii) Free oxygen (iii) Moisture
	Unfavourable	(i) Low temperature (ii) High temperature (iii) Sugar present
(c) Molds	Favourable	(i) Dampness (ii) Stagnant air (iii) Low light or Darkness (iv) Slight acidity.
	Unfavourable	(i) Sunlight or Ultra-violet-ray (ii) High temperature (iii) Dryness.

To afford a better understanding of the spoilage control problem it is appropriate to discuss briefly some of the important successful methods employed for the preservation of foods. They are

(i) Canning – This process involves the application of heat to food substances, raising the temperature to a level fatal to all enzymes and micro-organisms and holding in that state for the period necessary to destroy all bacterial spores.

(ii) Fermentation – This process, better known as pickling, is accomplished by submerging certain vegetables and meats in salt brine and keeping them in that solution during both the fermentation and the storage periods. When fermentation is complete, foods that ordinarily would support both bacteria and yeast, are [illegible].

(iii) Dehydration – The process of drying sufficient amount of moisture is carried out by natural means. By eliminating free moisture from food substances unfavourable environment discouraging enzymes and micro-organisms activities is caused to exist.

(iv) Smoking – During the process of exposing meat, meat products, and fish to the smoke of burning wood within a confined chamber, the food substances dries and becomes impregnated with an antiseptic present in wood smoke. This antiseptic (creosote) is highly effective in micro-organism control.

(v) Preservatives – Salt, sugar, vinegar and certain spices are employed in preservation of food because such materials encourage unfavourable conditions for the growth of micro-organisms.

(vi) Freezing and Cold Storage – This is the method mostly employed for preserving perishable for extended periods by employing artificial conditions known as " Requirement in Food Preservation" given in next article.

1.03 REQUIREMENTS OF FOOD PRESERVATION

The successful preservation for perishable food product involves more than the mere maintenance of the low temperature. The factors are :-

(1) Storage temperature - It varies with each particular commodity. Prolonged storage needs freezing and in case temperature level ranges from 10°F to -10°F or lower. Table 1.3 gives effect of temperatures for few representatives food stuffs on their life[9]. The action and theory of freezing will be discussed in detail in next chapter.

Table 1.3 Storage life and temperature on frozen foods.

Food	Maximum temperature °F	Approximate Storage Life. months
Vegetables	0	12 or more
	10	4
Fruits	0	12 or more
	10	4
Meats		
Pork	0	6
	10	3
Beef	0	12 or more
	10	4
Lamb	0	10
	10	3-4
Mildly cured ham & bacon	0	4
	10	3
Fish	0	4
Poultry	-10	12 or more
	0	10
	10	4
Dairy products		
Butter	0	10
	10	3

(ii) Humidity – Maintenance of proper humidity is of great importance in such long storage. If it is too low, air absorbs moisture from stored products causing wilting, shrinking and loss of natural colour. On the other hand if it is too high, growth of mold and bacteria is accelerated, and meat becomes slimy.

(iii) Air-Circulation – It is of vital importance. If the air-circulation is poor, the distribution of temperature will be non-uniform, the result being tainted food. All foods give-off odours which without proper air-circulation, remain inside the store and taint other products. If circulation is good, the air does not remain long in contact with the good but moves past the cold plates of the chilling unit where the odours condence with the moisture and thus the quality of food stuff is retained.

(iv) Condition before freezing – Meats and other non-living substance as a rule present few problems in their preparation for freezer storage, whereas fruits and vegetables require considerable processing before they can be frozen in order to safeguard them against deterioration, while in storage. Obviously food stuffs must be handled properly before they are stored under refrigeration otherwise refrigeration is of little value.

C H A P T E R 2.

SYSTEMS OF FREEZING

that affect the stability of colloids are -

(i) The lowering of temperature renders many colloidal dispersions unstable e.g. formation of gels from agar, soap and starch hydrosols. This phenomenon is followed by shrinking of the gel and exudation of fluid.

(ii) Chemical changes which occur during frozen storage are irreversible. Many of them are due to enzyme action. The rapid deterioration of frozen unblanched vegetable is well known.

(iii) Freezing causes concentration by removing liquid water from the external phase. More concentration, by decreasing the distance between dispersed particles may bring about critical instability.

By the above theories it may be inferred that -

(i) Mechanical damage to cellular structure may be caused by ice crystals especially for some classes of product.

(ii) Osmotic injury to cellular structure is possible but probably plays a minor role in the destruction caused by freezing.

(iii) Irreversible changes in the colloid system appear to be the principal cause for slow freezing damage.

These facts may lead to a mistaken idea that very rapid freezing is desirable for all perishable foods that require preservation by cold. But it should be noted that the need of rapid freezing is much more pronounced for some perishable than for others. Furthermore, the colloidal composition of some products is such that even slow freezing affects the structure but slightly.

2.03 [illegible].

The methods available for rapid freezing, which is governed by

2.01 FOOD PRESERVATION THEORY

Several theories[7] have been advanced to account for the effect of freezing on food. They are :

1. Cell puncture theory
2. Osmotic damage theory
3. Irreversible - Colloidal - Change Theory

(i) Cell-puncture Theory - It holds that the cell walls are punctured by growing ice-crystals and that upon thawing the cell contents leak out through these minute ruptures. It is also held that if the size of the ice crystals can be maintained less than the cell dimensions by rapid chilling, no puncturing with its consequent leakage will occur.

(ii) Osmotic Damage Theory - Peterson proposed that damage to foods during freezing is due to the following mechanism. " that Crystallization first in each cell is pure water. That leaves the remainder of the juice in the cell more concentrated. The resultant increase in osmotic pressure tends to draw water from the next adjoining unfrozen cell. The water coming into the partly unfrozen cell has a tendency to build on to the crystals between the cells when the rate of freezing is so slow that the system approaches equilibrium". However, this theory does not explain the damage which occurs in quick freezing.

(iii) Irreversible Colloidal - Change Theory - Almost with exception perishable foods are colloidal systems in which the external or dispersing phase is an aqueous solution. This has led to the belief that colloidal structure is responsible for changes during freezing, storage and thawing. The factors that affect the stability of colloids are -

(i) The lowering of temperature renders many colloidal dispersions unstable e.g. formation of gels from agar, soap and starch hydrosols. This phenomenon is followed by shrinking of the gel and exudation of fluid.

(ii) Chemical changes which occur during frozen storage are irreversible. Many of them are due to enzyme action. The rapid deterioration of frozen unblanched vegetable is well known.

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2.03 FREEZING METHODS.

The methods available for rapid freezing, which is governed by the type of product to be stored are :-

1. Sharp freezing
2. Quick freezing.

The first one is generally for plants, where storage is the main function. In the second method desired result is obtained in two hours or less between 20 and -0°F. It is utilized largely by processors of fresh food such as fish, fruits, vegetables and eggs.

1. <u>Sharp Freezing</u> - In sharp freezing products are frozen on shelves made of coils in which refrigeration brine is circulated (in an indirect system) or Ammonia is allowed to expand (Direct System). The coils are normally refrigerated to about -20F, but temperature depends upon the type of storage operation carried on. True sharp freezers' are utilized chiefly for the storage of meats received in an unfrozen state and held until temperatures are reduced to the holding temperature after which they are removed to holding freezers.

<u>Advantages</u>

Any size of package can be used.

<u>Disadvantages</u> :-

(i) During the freezing process, which begins immediately following exposure to the low temperature maintained within each compartment, heat transfer is comparatively slow (6 to 20 hours) and results in a decided time lag in passing through the zone of water to crystallization.

(ii) Some cellular damage occurs during sharp freezing - and for this reason meats should be kept frozen until they are prepared for consumption.

(iii) The subsequent loss of fluid upon each thawing considerably reduces the colour, the flavour and qualities of tenderness.

B. <u>Quick Freezing</u> - This method of processing fruits and vegetables has become increasingly important in recent years. Specimen selected for quick freezing must be fully ripened and of high quality for best results.

All items are washed thoroughly to remove micro-organisms adhering to their surface. Usually fruits are covered with sugar syrup then packed for quick freezing in an effort to prevent air from reaching the tissue during storage. Vegetables are blanched or precooked before freezing while blanching of fruits is not practiced. After blanching products are thoroughly dried before packing in suitable moisture proof and air tight container.

The temperature employed for quick freezing ranges from - 10°F to -40°F, after which they are stored continuously at 0°F (even the fluctuation of ± 5 F is detrimental to food characteristics.

<u>Advantages</u> - D.K.Tressler, in 1932, summarized the views of R Plank, H.F. Taylor, C Birdseye and G.A. Fitzgerald, by stating the advantages as :-

(i) With proper precautions in preparation and freezing the products may be stored for a year or so.

(ii) Because of the rapid rate at which the crystalline structure is formed during quick freezing, cellular expansion is greatly reduced, decreasing the number of ruptured membranes.

(iii) The freezing period being much shorter, less time is allowed for the diffusion of salt and separation of water in the form of ice.

(iv) The product is quickly cooled below the temperature at which bacterial, mold and yeast growth occurs, thus preventing decomposition during freezing.

(v) Quick freezing methods have inherent speed and capacity for commercial plants.

2.03 QUICK FREEZING PROCESSES AND FREEZING EQUIPMENT.

There are a number of ways to accomplish quick freezing or in more scientific terms, a rapid extraction of heat. These methods may be grouped into three classes :

(i) Freezing by direct immersion in refrigerating medium

(ii) Freezing by an indirect contact with a refrigerant

(iii) Freezing in a blast of cold air

2.04 FREEZING BY DIRECT IMMERSION.

It is generally considered that freezing by direct immersion in low temperature brine was the beginning of quick freezing fish and the first product frozen successfully in 1911. Fundamentally, the process involves pumping a continuous stream of the refrigerant solution past the products to be frozen and in direct contact with them. Refrigerated media suitable for immersion freezing such as brine, must remain unfrozen at 0°F and slightly below.

Advantages :

(i) There is a perfect contact between refrigerating medium and the product so that the rate of heat transfer is very high.

(ii) The resulting frozen product is not solidly frozen block since each piece is a separate unit.

Disadvantages -

(i) When brine is used as the secondary refrigerant, salt often penetrates into the tissues of the product bringing about undesirable changes during storage.

(ii) By process of osmosis juice from the food are extracted, contaminating and diluting the refrigerant so that it is difficult to keep the medium free from dirt and at a definite constant concentration.

(iii) Even if the food is packaged first to remove above defects this system is not satisfactory.

Several types of freezers and systems have been developed on direct immersion method.

1. 'Z' System or Fog-freezing'.

It was used in New York U.S.A. for freezing of ducks but not other products. The process consists essentially in spraying finely atomized sodium chloride brine at a temperature of about -0°F into the freezing chamber so that products in it are held in a dense wet fog of the cold brine. The products to be frozen are wrapped in a waxed paper.

Advantages -

(i) It does not dehydrate the product.

Disadvantages -

(i) Since brine circulates round and round, it picks up particles of food which do not go through the spray nozzle, so it is necessary to filter the brine.

(ii) Relatively few packages can stand contact with brine fog without becoming soiled.

2. TVA (Tennessee valley authority) or Taylor System.

The TVA freezer consists of an insulated cylindrical tank containing coils of tubing through which the refrigerant is passed. The tank is filled with sugar solution held at a temperature slightly above 0°F. This freezing solution is forced through the coils, and through the trays holding the product. The tray full of product is discharged from the freezer after a freezing period of about 9 minutes. The excess syrup is removed from the product by a specially designed centrifuge.

Straw berries are mainly frozen by this method.

3. Bartlett Freezer[7] (Fig. 3.1)

This machine uses a polyphase refrigerating medium that is in liquid, solid, and gaseous phase during the operation. An aqueous solution of glucose and sucrose is agitated and cooled until a finely divided ice phase is formed and distributed through the body of the fluid.

Articles of food are floated in the cold media and the slow agitation moves the articles with respect to the fluid and also to each other so the individual pieces are prevented from freezing together. After the desired chilling has been accomplished the food is removed from the body of the medium and allowed to drain in a refrigerated compartment.

Advantages :

(1) This method takes approximately one half the time required by liquid cooling when the fluid temperature and other operating conditions are

identical. The high rate of heat transfer is due to the three factors :

(a) Extremely high thermal capacity of the polyphase state.

(b) Increase in thermal conductivity of the fluid film by the suspended ice particles.

(c) Almost complete elimination of feed vapor cooling by the "seeding" effect.

(ii) Polyphase media, may be operated in the metastable state at temperatures as low as -25°F while syrup employed in food freezing are seldom operated below + 5°F.

2.03 FREEZING BY INDIRECT CONTACT.

Indirect freezing may be defined as freezing by engaging the product with a metal surface which is cooled by a freezing brine. In fact this is an old method and different person have patented different methods as below -

1. Peterson Method

This has been the first indirect method for fish freezing by packaging them in molds immersed in brine at -25°F to -15°F. These fish are thawed out from moulds, dipped into water for glazing and then passed to storage room. The process has been reported satisfactory but the following troubles -

(i) Great deal of labour is involved in packing the products in cans.

(ii) Products must fit into one size of can causing inconvenience.

(iii) Since products expand a little during freezing and it is difficult to get them out of the cans, usually resulting in some damage to wrappers.

The Peterson method has been improved by Robert.E.Kolbe[9] as below :-

(i) "Moving-Belt" System.

In it the fish were placed in shallow metal pans having telescopic metal covers. The brine is kept from entering the pans by the air seal which is formed between the pans and the covers.

(ii) "Floating Pan" System.

Kolbe's this system consists of a shallow insulated brine tank with longitudinal baffles alternately fitting close to one end. These alternate series are so designed that the brine entering at one end flows to the other end, carrying the pans through the machine. The temperature of brine varies from 0 to -10°F, the freezer having greater capacity at lower temperature.

2. Al Cook's Freezer

In this machine freezing is done in blocks between halves of recessed hollow heat conductive moulds. In an improved method products are frozen on an endless chain of aluminium plates that progress over a shallow tank of brine at -20°F. Fins project from the underside of the belt into the refrigerant.

All the above indirect freezers are now-a-days obsolete and more developed and are in use. They are -

C. Modern Freezers -

(i) "Double-belt" quick freezing equipment (SDC)

Product is kept between two endless stainless steel belt. The upper surface of the upper, and the lower surface of the lower belts are sprayed with calcium chloride brine at -50°F.

(ii) "Multi-plate Freezer" - (Birdseye and Hall 1929)

This machine consists of a number of superimposed refrigerated hollow metal plates actuated by means of a hydraulic pressure so that they may be open to receive products between them and then closed on the product with any desired pressure. Ammonia or Brine is used as refrigerant.

(iii) Gravity Freezer (Birdseye 1949)

In this product is continually fed in controlled amount at the top of freezer through a vibratory feed hopper. It is moved on plates by means of scrapers until falls by gravity from the other end. Scrapers remove moisture.

Advantages -

(i) Entirely automatic in operation

(ii) Rapidly freezing of foods

(iii) Machine has a capacity that is large in relation to its size and cost.

Disadvantages -

That all packages on a single shelf must be of exactly same thickness and preferably of the same size and shape.

4. Continuous Roto Freezer

It consists of an insulated cabinet containing 24 pairs of freezing plates, mounted substantially parallel, radiating out from and attached to a rotating drum axle. Brine is circulated through the plates from the distribution chamber in the drum. As the drum axle rotates, a pair of plates arrives at the loading slot and automatically spreads apart. The product to be frozen is put on a tray and a tray full of products is placed between the plates. As the loading door shuts the drum rotates, bringing another pair of plates in line for loading. When freezer is completely loaded, the first plate to be loaded has made a complete revolution and has been completely frozen. The tray of frozen product is removed and a tray of unfrozen products put in.

Advantages -

(i) There is never any peak load on compressor as is in many other system loaded to capacity in one operation.

(ii) Inside frosting is eliminated since outside humidity has little chance to enter the small opening for loading and unloading.

Disadvantages -

(i) It requires an exact number of trays of products of uniform thickness fitted into a space, making it virtually impossible to freeze packaged fillets and chickens at the same time.

2.04 AIR BLAST FREEZING.

Air blast freezers are widely used to produce a great variety of quick frozen foods of excellent quality. These freezers differ markedly from sharp freezers in that they are usually designed in the form of tunnels and take full advantage of the heat transfer efficiency of rapidly circulating[10] air. Very cold air is obtained by directing an air-blast through refrigerated coils (Fig. 2.2 & 2.3).

Advantages -

It is excellent for packaged foods but is slow in process, for cold rooms.

(f) Extra elevators or hoists cost more than a floor. Hence multi-floors are not economical and can be ruled out.

(iv) Construction Details -

(a) Firm footings and foundation to prevent floor and wall cracking

(b) Adequate and properly applied insulation throughout.

(c) Expansion joints at wall and floor junctures, especially if ground floor is not insulated.

(d) Curtain-wall construction to eliminate exposure of cold room walls to outside temperature

(e) Maximum temperature rooms located next to walls exposed to outside temperature.

(f) Adequate flashing at all outside structural junctures

(g) Waterproof weather-exposed surfaces, especially roof.

(h) Plastic material between critical layers of structural materials i.e. wall and insulation, roofing and insulation

(i) Insulating roof rather than adjacent ceiling, if possible

(j) Vestibules at doors and other openings to reduce entrance of outside air, since moisture from air condenses on walls and promotes mold growth

(k) Mold resistant paint on corridor and other walls

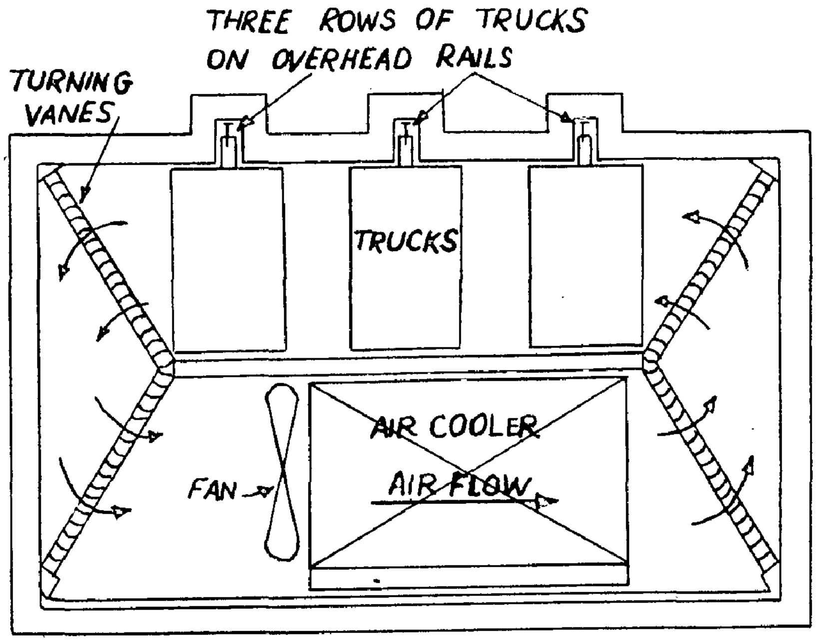
(l) Installation of heavy insulated refrigerated doors.

3. Insulation

(i) Characteristics - It should be -

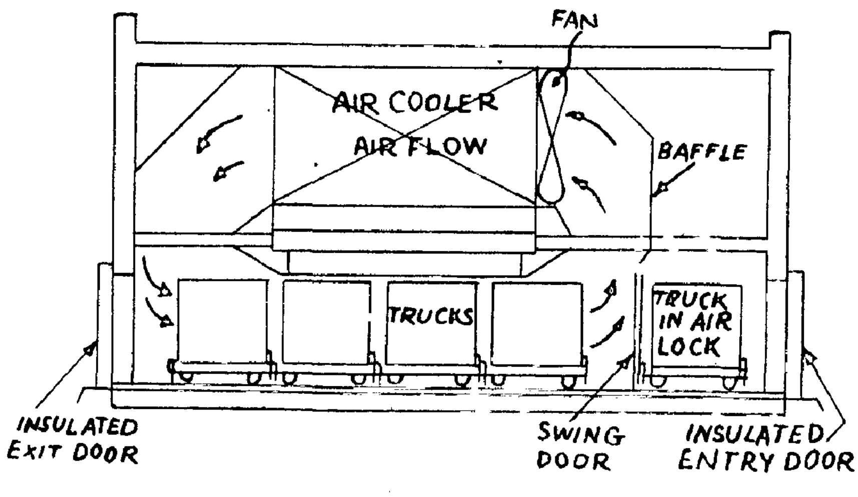
(a) Resistive to heat transfer

(b) Resistive to moisture penetration -- This means the ability of material to maintain its insulating value in presence of water vapour or



SECTION THROUGH AIR BLAST FREEZER WITH CROSS FLOW

FIG. 2.2



SECTION THROUGH AIR BLAST FREEZER WITH LONGITUDINAL FLOW

FIG. 2.3

pair of plates arrives at the loading slot and automatically spreads apart. The product to be frozen is put on a tray and a tray full of products is placed between the plates. As the loading door shuts the drum rotates, bringing another pair of plates in line for loading. When freezer is completely loaded, the first plate to be loaded has made a complete revolution and has been completely frozen. The tray of frozen product is removed and a tray of unfrozen products put in.

Advantages :-

(i) There is never any peak load on compressor as is in many other system loaded to capacity in one operation.

(ii) Inside frosting is eliminated since outside humidity has little chance to enter the small opening for loading and unloading.

Disadvantages :-

(i) It requires an exact number of trays of products of uniform thickness fitted into a space, making it virtually impossible to freeze packaged fillets and chickens at the same time.

2.04 AIR BLAST FREEZING.

Air blast freezers are widely used to produce a great variety of quick frozen foods of excellent quality. These freezers differ markedly from deep freezers in that they are usually designed in the form of tunnels and take full advantage of the heat transfer efficiency of rapidly circulating[20] air. Very cold air is obtained by directing an air-blast through refrigerated coils (Fig. 2.8 & 2.9).

Advantages :-

It is excellent for packaged foods but is slow in process.

<u>Disadvantages</u> -

(i) If unpackaged foods are frozen the surface becomes desiccated.

(ii) The lost water gets deposited on refrigerating coils. Therefore two blast systems may be required in order to have one available for work when coils require defrosting.

(iii) Unpackaged products frozen in an air blast do not keep for long at a given storage temperature.

Many types of freezers have been developed for air blast freezing. They are -

(1) <u>Older Type Freezers.</u>

(i) <u>Tunnel Freezer</u>[8]

It is most commonly used. Basically it consists of a long slow moving mesh belt passing through an insulated tunnel containing very cold air and continuous rapid motion. The motion of air blast and products in tunnel is counter flow. Temperature of air blast ranges from 0 to 30°F. Air velocity range from 100 fpm to 3300 fpm.

(ii) <u>Multi-stage tubular Freezer</u> (W.J. Finnegan 1953)

It was designed to reduce moisture loss occuring in tunnel freezer and employs the conditions as below :

(a) Maintaining a small temperature difference between refrigerant and the contacted air with the product being frozen.

(b) Also maintaining a relatively high humidity in the recirculated air used in freezing.

(c) Keeping air velocity from 1000 to 1200 fpm.

As the name implies tunnel is divided in 6 sections-

First for precooling

Next four for freezing

Last for tempering.

The air is directed in reverse direction in each of the four sections. The feeding and discharge sections have no forced air-circulation as they act as an airlock.

(2) Tower Type Freezers.

(i) [illegible] (Frick Company)

This machine consists of a well insulated cabinet with cooling coils in a bunker at the top with tray trucks. A rapid circulation of cold air passes over the food and back through the cooling coil. Special cooling coils have been developed for this system and it is claimed that temperature as low as -50°F can be maintained.

(ii) York Tray Freezer

It is a recent development in tunnel type freezers. It is said to be well suited for loose freezing and equally as good for packaged products and is designed to handle all types of fruits vegetable, fish meat and poultry.

(iii) York Continuous Tray Freezers

This is a vertical freezer in which trays of product are moved upwards through an air blast. A time clock controls the movement of the trays and is set for a predetermined freezing cycle to meet the needs of the product depending on whether it is loose frozen or packaged.

2.07 IMPROVED SHARP FREEZING PROCESSES.

This is a combination of sharp freezing and air blast freezing. The product is frozen in shallow pans or trays placed on refrigerated coils and subjected to blasts of refrigerated air. Freezing temperature is $-35°F$. This system has all the advantages of sharp freezing as well as of air blast freezing. It is generally used for fish fillets.

Freezing methods discussed so far are only a few of the many methods that have been developed, but are representative of each type of system. The best freezing system depends upon -

(i) the product

(ii) the size of the package

(iii) where it is to be sold

(iv) how it is to be marketed

(v) the kind of material in which it is to be packaged

(vi) and how it is to be closed.

After this information is available, a good way of freezing can be indicated though there is no best way as each process has certain advantages and disadvantages. Nevertheless, after experience usefulness of a method for a particular product may be established.

C H A P T E R 3.

PRESERVATION

3.01 After freezing food at proper temperature it should be stored at required temperature humidity and at proper air circulation so that desired conditions for food stuffs may be maintained. The following type of frozen food stores may be employed.

(i) Cold stores and refrigerated warehouses.
(ii) Locker plants.
(iii) Other refrigerators.

I REFRIGERATED WAREHOUSE

3.02 Refrigerated warehouses are meant for -

(i) Use by a producer, packer or distributor for a large volume of comparatively few items.
(ii) The storage of a wide variety of commodities and packages of many owners with varying needs as to storage conditions, movement of goods and auxiliary services.

A successful design of warehouse can be done if the following aspects are considered :-

(i) Requirements
(ii) Refrigerating machinery
(iii) Design features.

3.03 REQUIREMENTS

1. Humidity

Many problems of constructing and operating a cold storage plant are connected with humidity because moisture is harmful in the way that it

(i) Corrodes metals
(ii) Makes insulating material inefficient
(iii) Causes building to deteriorate
(iv) Sometimes even destroys building if freezing occurs below foundation.
(v) Collects on refrigerating coils, increasing heat transmission co-efficient thus lowering efficiency.
(vi) It also effect goods.

Therefore most of the engineering problems relate to -

(i) the evaporation of moisture from meat body into air.
(ii) Condensation of moisture on a cold surface when moist air is passing over the surface.

The following suggestions[19] have been made -

(i) Goods should be stored as compactly as possible with a minimum of exposed area and with a small transmission coefficient which means a low velocity around the goods.
(ii) The cooling area and heat transmission coefficient (h_c) be as large as possible to avoid evaporation. This can be increased by using forced circulation around the coils.
(iii) Thus low storage temperature, good insulation, large prime surface coil areas and compact piling, all help to prevent weight loss during storage.

8. Cooling Coils

(i) Location

If coils are placed on the side of the goods, there is always a natural and favourable air movement as long as goods have a higher temperature than the air for there is a downward air movement at the refrigerating coil and rather a strong upward air movement around the goods. Therefore, it is good to place the coils at the walls.

(ii) Type

It has been recommended that the coils of low temperature room should be made as prime surface coils. Fin coils should not be used in freezer storage because with the former defrosting can be easily done and also they can be located on walls.

9. Cooling Systems.

There are two systems -

(i) Direct

(ii) Indirect, where brine is used in coils.

Indirect is recommended because -

(i) Food cannot be damaged by direct contact with refrigerant to produce odours.

(ii) Temperature regulation is claimed to be less difficult in indirect system.

(iii) A direct expansion system contains much more refrigerant than a brine pipe system.

Direct system is recommended because -

(i) Temperature regulations can be made fully automatic

(ii) Coiling is cheaper

(iii) Only suction lines need insulation and pressure pipe lines can be left bare.

(iv) Sectionalising the plant by closing valves so that Ammonia content is split up in great number of coils and pipe lines is more practical.

(v) Recommended for bigger plants.

In most of the plants indirect system has been employed successfully.

6. Refrigeration Requirements.

The refrigeration load of warehouses of same capacity varies widely. It consists of -

(i) Heat leakage through insulated enclosure

(ii) Heat from pumps or fans circulating refrigerated brine or air

(iii) Heat from lights, power equipment, door openings and men working in refrigerated space.

(iv) Heat removed from goods in reducing them from receiving to storage temperature.

(v) Heat produced by goods in storage.

(vi) Heat to be removed in freezing.

(vii) Infilteration.

8. Air Purification (Ozonization)

Mr. A.W. EWELL[20] of U.S.A. has recommended use of ozone to reduce shrinkage and reduce growth of molds. It should be distributed throughout the room by forced air circulation to be a minimum conc. of 0.6 ppm to a maximum of 1.5 ppm. Ozone also acts as deodorant but long exposure to ozone at a concentration of 1.0 ppm may cause headache therefore, ozone supply is switched off when working for long in cold stores.

3.06 REFRIGERATING MACHINERY

1. Compressors

(i) Ammonia compressors are recommended for commercial stores.

(ii) Standby equipment should be provided.

(iii) 3 or 4 smaller sizes are preferred than 2 big ones.

(iv) Power sufficient for 16 hours a day in hottest weather. The source of power may be electricity or diesel.

(v) Speeds - Only medium or high speed vertical multi-cylinder compressors are to be used.

(vi) Valves - Formerly they were of the poppet valve type with conical seats but are being replaced by plate valves.

(vii) Material - For Ammonia Compressor-non-ferrous metals containing copper

For Freon Compressor :- copper, bronze and brass.

2. Condensers

(i) Type

For larger plants they are in two general types -

(a) Water economizing condenser - They are atmospheric condensers and the more improved one is known as evaporative condensers. They are used when water is scarce in hot climate.

(b) Water cooled condensers - They are shell and tube type and may be horizontal or vertical. They are used in colder climates.

(ii) Size and Capacity.

Capacity of a condenser is calculated for 120 to 130% of normal capacity.

Size of the condenser is determined from the point of view of economy. The factors to be considered are -

(a) Power cost

(b) Cost of condenser per square meter

(c) Running time

(d) Cost of cooling water

(iii) Purging Device

It is built around the cold suction line which takes the place of the cooling coil. A high side float-valve is used for drawing off the condenser liquid from the purger into the suction line.

D. Evaporators

They are of two type :-

(i) Shell & Tube type

These are readily adaptable to a closed brine system. The space requirement is limited and the tubes can readily be cleaned and replaced if necessary.

(ii) Coil Type

They are designed such that they have -

(a) Good circulation of liquid

(b) Compact type of coil to get high velocity of liquid.

c. Cooling Coils

Capacity of room cooling equipment in each is designed for the maximum load expected. Temperature difference between room air and refrigerant usually chosen as 9 to 15°F. The following is a typical calculation for plain pipe brine coils :

Design load for room	= 10 tons (120000 BTU/Hr)
Heat transfer coefficient of pipe coils	= 1.5 BTU/hr/Sq.ft/°F
2 in. pipe, having 1.6 lineal ft. per sq.ft. =	
Room temperature	= -20°F
Brine supply temperature	= -30°F
Hence, Brine return temperature (2.5°F rise)	= - 27.5°F
Average brine temperature	= - 28.75°F
Average temperature difference	= 8.75°F
Length of pipe,	= 14630 ft.

9.03 DESIGN FEATURES.

a. Site

It should be such that it provides -

(i) Convenient location for producers and distributors, but with consideration to prevent tendency towards decentralization and avoidance of unduly congested areas.

(ii) Good switching facilities and service with minimum switch changes from all trunk lines to the plant's tracks.

(iii) Easy access from main highway truck routes as well as for local trucking, but avoiding location on congested streets.

(iv) Location where ample land is available for trucks, truck movement and

and for plant utility space.

(v) Situation on land, the cost of which will not result excessive over-all cost of land and building.

8. Building

(i) Space - Sufficient Cooler and Freezer space.

(a) For routine handling of scheduled deliveries to the plant relative to scheduled shipment from the plant.

(b) For heavier than usual demand

(c) To allow for future expansion.

(ii) Platforms - receiving and shipping.

(a) Convenient for the approach to trucks

(b) Receiving platform above shipping dock to exploit gravity handling.

(c) Large enough to avoid congestion and to facilitate rapid loading and unloading.

(iii) Building Stories - determined by these considerations[10]

(a) In large cities where sites have a high value and are restricted it may be necessary to construct a building of several floors.

(b) For economy of power operation for refrigeration the ratio of surface to capacity should be small.

(c) Single story has least cost, simplest and cheapest equipment because no lifts and hoists are required.

(d) Single story gives large ratio of surface to capacity and is bad in this respect.

(e) With multi-floors, the space occupied by elevators etc. becomes excessive thereby reducing the proportion of the total space that can be made available for cold rooms.

(f) Extra elevators or hoists each more than a floor. Hence multi-floors are not economical and can be ruled out.

(iv) Construction Details -

(a) Firm footings and foundation to prevent floor and wall cracking

(b) Adequate and properly applied insulation throughout.

(c) Expansion joints at wall and floor junctures, especially if ground floor is not insulated.

(d) Curtain-wall construction to eliminate exposure of cold room walls to outside temperature

(e) Maximum temperature rooms located next to walls exposed to outside temperature.

(f) Adequate flashing at all outside structural junctures

(g) Waterproof weather-exposed surfaces, especially roof.

(h) Plastic material between critical layers of structural materials i.e. wall and insulation, roofing and insulation

(i) Insulating roof rather than adjacent ceiling, if possible

(j) Vestibules at doors and other openings to reduce entrance of outside air, since moisture from air condenses on walls and promotes mold growth

(k) Mold resistant paint on corridor and other walls

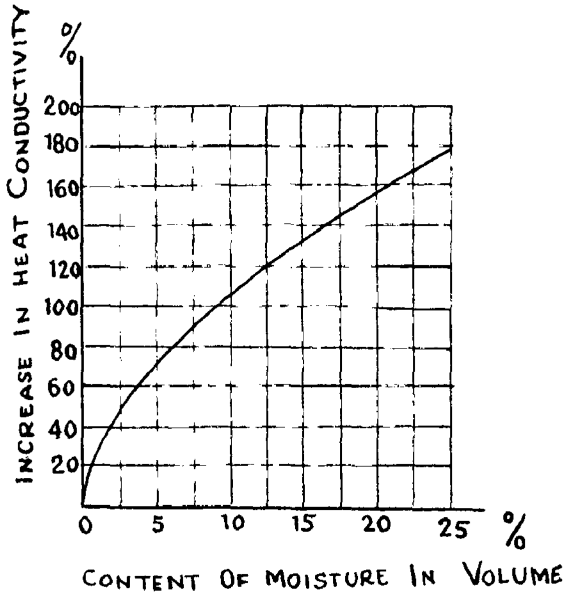
(l) Installation of heavy insulated refrigerated doors.

C. Insulation

(i) Characteristics - It should be -

(a) Resistive to heat transfer

(b) Resistive to moisture penetration :- This means the ability of material to maintain its insulating value in presence of water vapour or



Influence Of Moisture Content On Heat Conductivity Of A Porous Insulating Material

FIG. 3.1

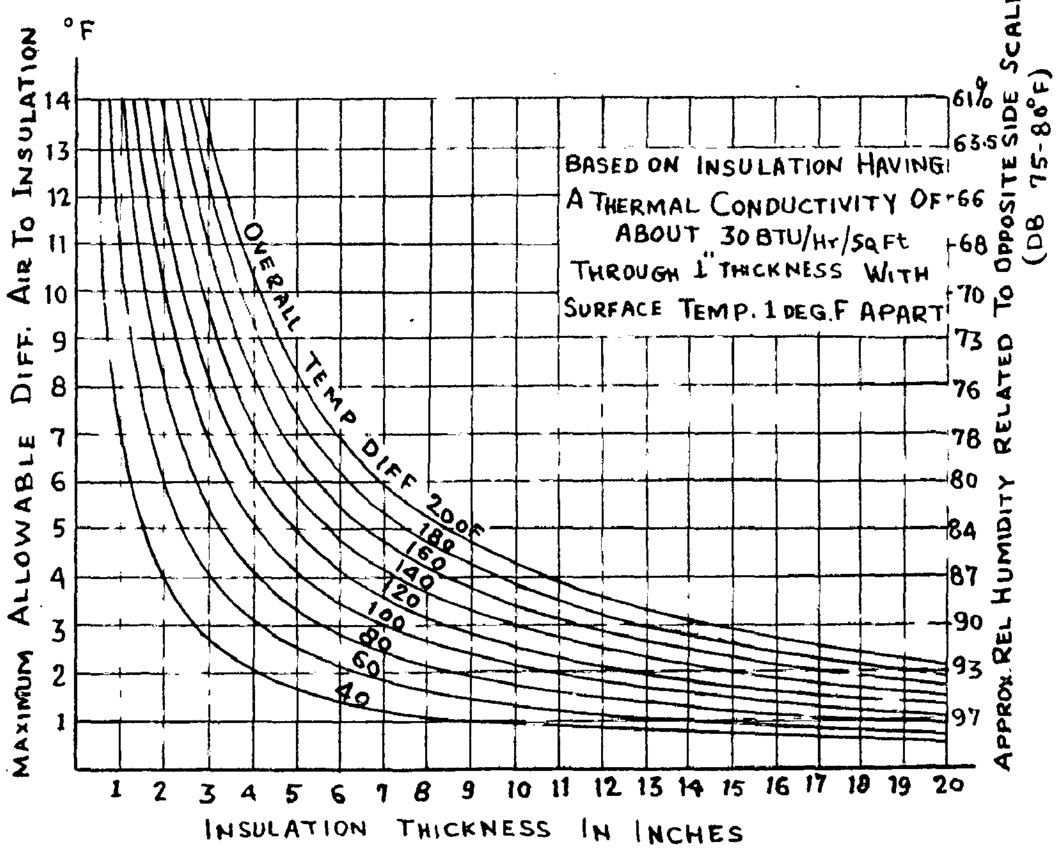


FIG. 3.2

condensed moisture. This is necessary because when this water is frozen in the material the conductivity increases[10] considerably. (Fig. 3.1).

(c) Resistive to fire hazards

(d) Light in weight

(e) Long life

(f) Cheap

(ii) Materials

(a) Cork board has been generally used as insulating material but many others have also been employed.

(b) In addition to cork-board, the more or less rigid materials in board form includes mineral wool or glass fibre with binder; plastic glass or rubber foams and expanded mineral such as a concrete aggregate.

(c) Material for loose fill include granulated cork, mineral wool and shredded redwood bark.

(d) Effective use has been made of multiple layers of metallic foils whose insulating value is due to heat reflection.

(iii) Thickness

The most economic thickness[10] of insulation depends upon the first cost and the cost of power for operation, maintenance, and depreciation of the equipment. First cost includes initial cost of equipment and insulation, and application of insulation. Depreciation cost includes changing properties of insulation with age in addition to its life and salvage value. As the thickness increases its cost goes up but cost of refrigeration decreases. The most economical thickness is the point where sum of these costs per year is least. Besides this the following factors have also some bearing on thickness -

(a) A need of reduced heat loss due to slight increase in thickness.

(b) A need to avoid surface condensation - this requires use of sufficient thickness to insure that the temperature drop from surrounding air to insulation surface is less than the dew point depression. This means for ordinary purposes 1 inch insulation is needed for 20-25°F of overall temperature difference. Graph (Fig.3.8) gives insulation thickness for various temperature difference, humidity etc. e.g.

If air temperature is 100°F, R.H. is 80.5% refrigeration temperature 0°F (overall temperature difference is 100°F) insulation thickness obtained from graph is 6" for a dew point depression of 3.5°F.

Considering various factors it is found that in practice for block type insulation having a conductivity between 0.3 and 0.4 BTU/Hr./sq.ft./inch of thickness (say .35) and mean temperature difference between 50 to 70°F (say 70°F) table 3.1 gives insulation thickness.

Table 3.1

Storage temperature F	Insulation thickness in inches
-45 to -25	10
-15 to 0	8
0 to 15	7
15 to 25	6
25 to 35	5
35 to 50	4
50 to 60	3

(iv) Application

Methods of application and the structures to carry the insulation will vary with the type of insulation but skill of application and attention to effective air and vapour seals are essential to continued effectiveness.

4. Cold Storage Sub-Division.

It is necessary that the incoming goods that are in warm condition must be cooled and frozen in separate spaces before they are transferred to cold storage. Majority of cold stores have accommodations for -

(i) Freezing

(ii) Storage

This has given rise to locker plant.

5. Interior Transportation facilities.

It involves -

(i) Gravity conveyors for loading and unloading

(ii) Inclined conveyors (powered)

(iii) Elevators where more than one storey

(iv) Chain conveyor for ice, if handled

(v) Convenient corridors.

6. Refrigeration Plant accessories.

While installing the plant the following points are kept in view -

(i) Isolations of refrigeration plant from warehouse proper

(ii) Providing adequate standby equipment for emergencies

(iii) Installing humidifiers such as spray heads in chill compartment for moisture control.

moisture control.

(iv) Locating thermometers in all rooms

(v) Using dunnage for air circulation between packages

(vi) Isolating ice making tank and ice-storage from warehouse proper

(vii) Minimizing conversion of freezer rooms to chill rooms. Thawing of ice formed from leaks and condensation damages bonded insulation material such as cork-board. Resulting drippage causes an untidy condition due to accompanying discolouration.

(viii) Installing temperature alarms.

7. <u>Utilities.</u>

This involves -

(i) Insuring of adequate and cheap supply of condenser cooling water or installing appropriate cooling towers

(ii) Insuring of adequate source of power to operate compressor fan, pumps etc.

(iii) Provision of good lighting in all parts of the plant and the warehouse.

(iv) Utilizing sufficient heat from condensers to heat offices where practical.

(v) Providing weighing scales.

8. <u>Control.</u>

For carrying out proper storage management provision for the following is to be made -

(i) Ample office space for carrying on normal business transactions of the warehouse and refrigeration plant. It should be isolated from warehouse proper.

(ii) Checking points established at appropriate locations to control and record deliveries and shipments.

(iii) Access to warehouse possible only at checking points to prevent losses.

(iv) Fire extinguishers to be located for ready use.

III LOCKER PLANTS

9.03

The function of frozen food locker plant is to quick freeze food commodities and reduce their temperature below the low point of the zone of crystallization and hold it at a temperature of preservation until needed. The auxiliary function is to process such commodities in preparation for quick freezing.

A complete locker plant is designed and organized so that the following steps may be taken with full regard to sanitation, preservation and efficiency throughout.

(i) <u>Receiving (not necessarily refrigerated)</u>

Proper facility and space for receiving and weighing commodities to be processed and stored.

(ii) <u>Chill and age (beef)</u>

Meats must be prechilled before being cut into required size. This requires a chill room. Beef is aged in the chill room for several days before processing.

(iii) <u>Evisceration (not necessarily refrigerated)</u>

(a) Meat poultry, fish etc. involves cutting into roasts steaks, chops, fillets etc., grinding, cleaning and preparing poultry and fish must be accomplished before food becomes too warm.

(b) Fruits and vegetables - require washing and blanching.

(iv) <u>Wrapping or Packaging (not necessarily refrigerated)</u>

All commodities must be properly packaged and/or wrapped before freezing during this step the package is labeled to identify its content weight, date and owner.

(v) <u>Quick Freeze</u>

Many small locker plants use blast freezing method. This can be accomplished either by directing a blast of cold air into a water in freezing room or by placing packages in the sharp freezer compartment of a blast freezer unit. Temperature in the blast freezer usually is set at -10°F. Evaporator temperatures are usually lower than that of blast freezers i.e. about -20°F.

(vi) <u>Storage</u>

Lockers are located in the main storage room held at 0°F in which the quick frozen foods are stored.

Fig. 3.3 shows the various steps[12] through which various foods in a modern locker plant. Special attention is given to the relative locations of the component parts of the plant so that the flow of food products may be accomplished with a minimum of handling time and expense. Layouts of freezer and locker plants connected with retail grocery and meat market are shown in Fig. 3.4 & 3.5.

(a) Meat poultry, fish etc. involves cutting into roasts steaks, chops, fillets etc., grinding, cleaning and preparing poultry and fish must be accomplished before food becomes too warm.

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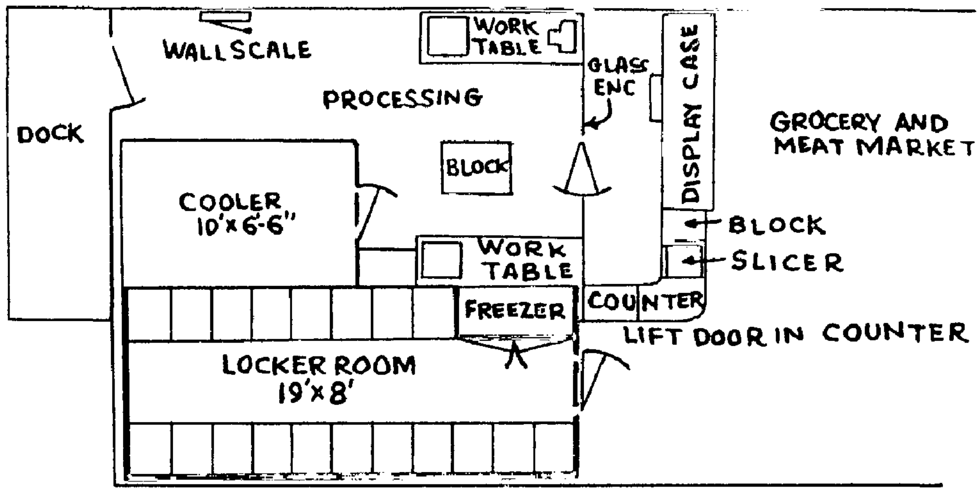
(vi) Storage

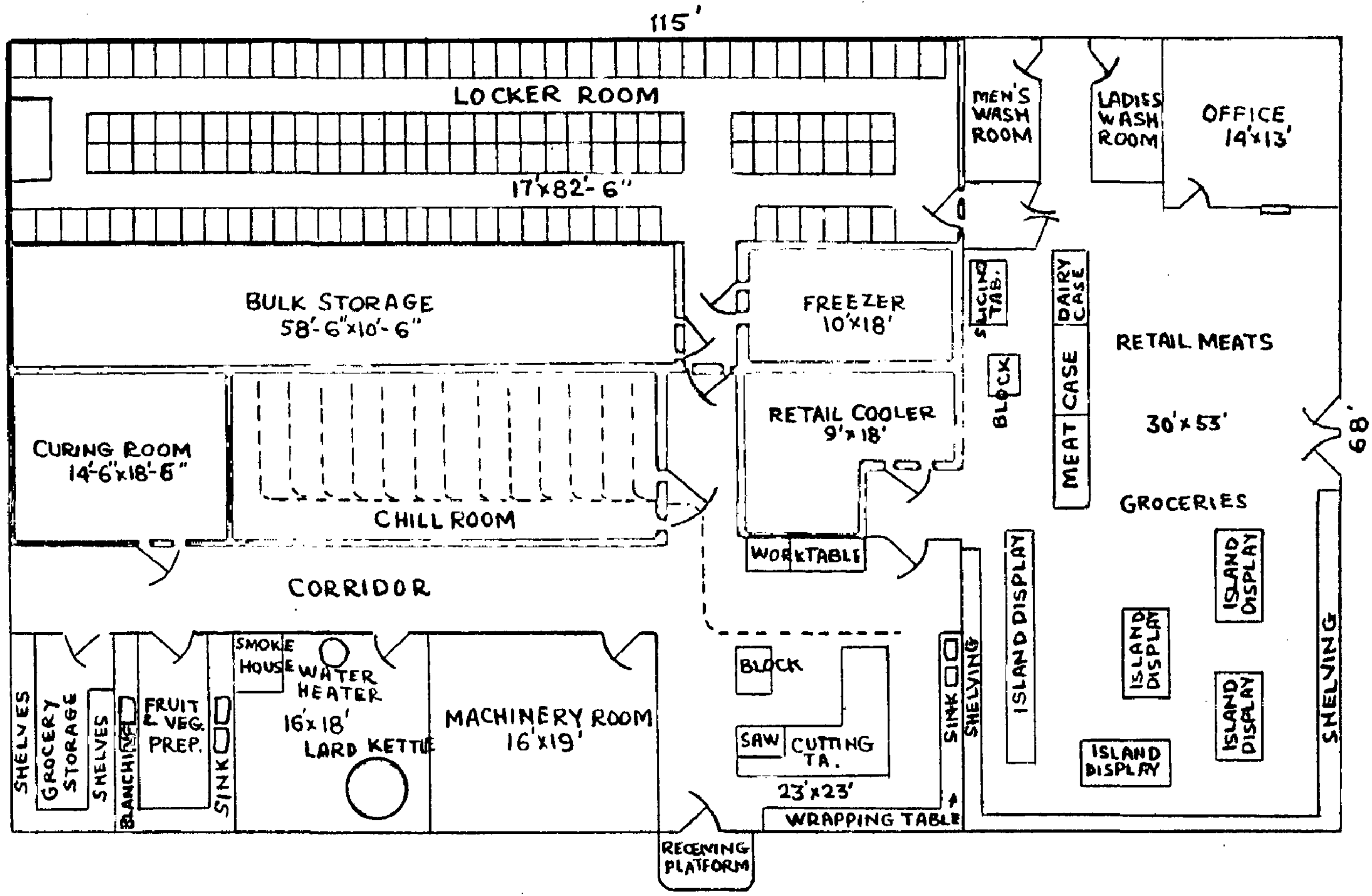
Lockers are located in the main storage room held at 0°F in which the quick frozen foods are stored.

Fig. 2.3 shows the various steps[13] through which various foods in a modern locker plant. Special attention is given to the relative locations of the component parts of the plant so that the flow of food products may be accomplished with a minimum of handling time and expense. Layouts of freezer and locker plants connected with retail grocery and meat market are shown in Fig. 2.4 & 2.5.



LAYOUT OF SMALL FREEZER & LOCKER PLANT CONNECTED WITH RETAIL GROCERY & MEAT MARKET

FIG. 3.4



LAYOUT OF LARGE FROZEN FOOD LOCKER PLANT CONNECTED WITH RETAIL MEAT AND GROCERY MARKET

FIG. 3.5

[illegible] REFRIGERATORS

[illegible] On small scale as for household purposes these refrigerators are in common use. The important one's are

1. House hold refrigerators
2. Home freezers.

1. **House hold Refrigerators.**

They conserve many kinds of fresh and prepared foods and possibly all frozen food. The following factors are decisive for satisfactory conservations of food -

(i) Cleaning of the refrigerator and its equipment

(ii) quality of food conserved

(iii) Temperature of air in cooling space, degree of humidity, and circulation.

In most of the refrigerators the following conditions and features are now-a-days maintained.

(i) Temperature - in evaporator freezer box [illegible]°F

Refrigerator box [illegible]°F

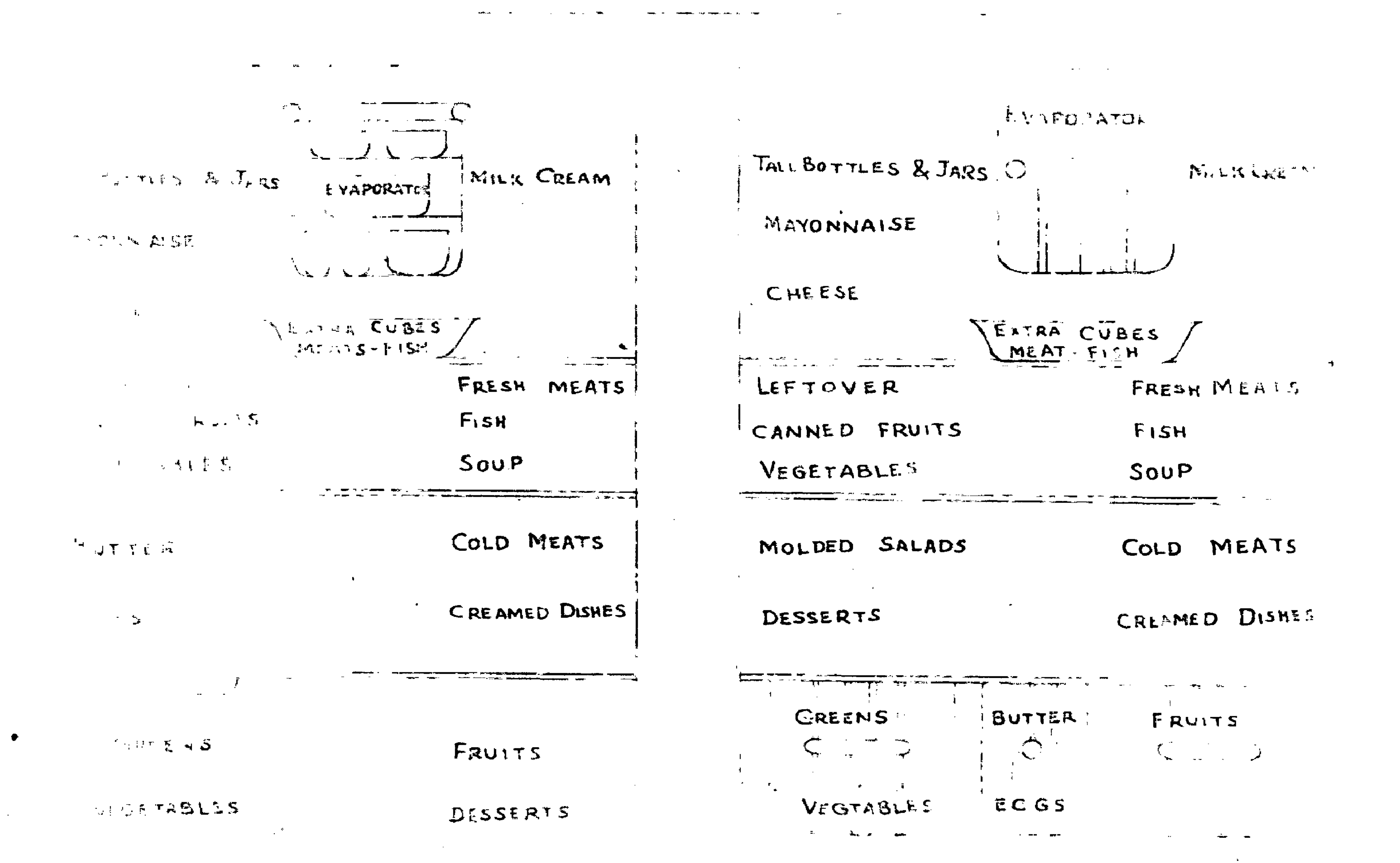
(ii) Relative humidity [illegible]

(iii) Single evaporator (giving satisfactory results)

(iv) Power consumption - for [illegible] cft. capacity power is 1 to 1.[illegible] kwh/day

(v) Frozen food in freezing compartment are wrapped in moisture proof cellophane or something similar.

(vi) Because of different temperatures obtained into different zones of each refrigerator foods require proper arrangement in the cabinets.



ARRAGE[illegible] STORAG[illegible] OF [illegible] CABIN[illegible]

Fig. 3.6 show common types of such arrangmenets. Most perishables are placed in the coldest parts.

2. Home Freezers

In refrigerators (household) raw meats etc. are stored for short period and frozen for 2 to 3 months, however, home freezers can contain considerable quantitites of these things for longer periods. It serves the purpose of a locker plant on small scale.

Home freezers are of two types -

(i) Upright

(ii) Chest type

Factors which affect the freezers' utility are -

(i) Convenience -

Facility with which food can be placed in the freezer for storage or be removed from the freezer for use. Chest freezers provide infinite flexibility in food loading, but at the same time accessibility to articles near the bottom becomes difficult. An upright freezer provides more convenient accessibility because of larger exposed area (fig. 3.7).

(ii) Freezer location -

Possibility of locating freezer at a place where food is made available and prepared for serving. This depends upon the space available and this consideration indicates distinctive advantage for the upright freezer (Fig. 3.8)

(iii) Quick freezing -

For quick freezing good thermal contact between the food and the evaporatory surface is desirable. This depends upon evaporator design. Home freezers have two types of evaporator systems -

(a) Evaporator tubing in good thermal contact with the liner walls (chest type) Fig. 3.9 c.

(b) Evaporator tubing in good thermal contact with plates located in the freezer compartment (upright type) Fig. 3.9a.

(iv) <u>Uniform temperature</u> -

The two types of freezers are designed to maintain proper temperature throughout the compartment. Chest type freezers are less susceptible to temperature changes caused by lid opening because cold air remains in the freezers when the lid is open whereas the cold air in the front opening type spills out when the door is open. The effect on the temperature of the food in the normal use of upright freezer is also exceedingly small (generally less than 1°F).

(v) <u>Defrosting arrangement</u> -

In a chest freezer having refrigerated walls the coldest portion of the evaporator surface is around the top of the liner. When there is no food against the linerwalls, these colder surfaces collect frost which is most easily removed by scraping.

In upright type frost accumulation is on the underside of the refrigerated shelf plates. Refrigerated system is so designed that maximum frost accumulation on the top of the liner ceiling can, when defrosted, drain into the food compartment and be removed.

(vi) <u>Exterior sweating</u> -

Freezers without applying heat to outer case sweat when relative humidity (RH) is high enough e.g. a chest type freezer having 3½ inch insulation with K factor .22 at mean temperature 45°F may sweat at 80% RH when operating at 100°F ambient and -10°F linerwall temperature. Many freezers sweat near about 80% RH hence means such as electrical warmers, of assembling steel tubing in good thermal contact with inside surface of the outer case and connecting this to serve as the condenser, are helpful to check sweating.

(vii) <u>Freezer capacity</u> -

It should be sufficient for normal requirements plus a reserve for unplanned needs.

(viii) <u>Door operation</u> -

Ease of door opening with proper sealing arrangement is a desirable feature. Upright freezers, though, have low costs of hinge construction but present complex design problem as compared to the flexibility and ease of operation in chest type freezers having lid opening system.

(ix) <u>Noise level</u> -

Condenser fans in larger units cause considerable noise. To reduce this condensing unit having larger fan diameter, sufficient speed to deliver maximum amount of air at the required static pressure are employed. An acceptable value is 1000 rpm with a fan diameter 8¾ inch.

(x) <u>Reliability</u> -

Both of them are equally capable of keeping the food safe, in case of power failure.

(xi) <u>Operational cost</u> -

Cost of operation and maintenance depends upon

(a) Power consumption

(b) percent running time and

(c) Cycle per day.

The operating conditions for which these factors may be compared are -

(a) Initial pull down (no storage load) in 110°F ambient

(b) No storage load operation

(c) Partial or full storage load operation

(d) Freezing load operation

(e) Effect of door opening

Summing up chest type freezers with refrigerated linerwalls produce better refrigeration of the load at lower power consumption and are quite popular, however, upright are also in use.

9.08 CONTROLS IN FREEZERS

There are usually three major control job to be done.

1. Temperature control
2. Defrost control
3. Humidity control

(1) Temperature control -

A pressure control at the condensing unit is normally used in all cases, however, in frozen food a thermostat is the control generally used. This is because frozen foods have a critical upper temperature limit; they must not be allowed to thaw. A thermostatic control is advantageous in that it reacts to a specific temperature rather than overall average in the manner of a pressure control. Fig. 9.10 gives such a system[8] then

the freezer temperature rises, it causes the control to close and complete the electrical circuit, which causes the bell to ring.

8. <u>Defrost control.</u>

The type[24] of control vary with each manufacturer. They are -

(i) Above freezing temperature evaporator is cut off by using low pressure control and during this off cycle evaporator defrosts itself. But this is applicable for 32°F or above.

(ii) For temperature lower than above and using thermostat for temperature control a device of time clock is used. It turns off the condensing unit once or more in a day at time previously set.

(iii) This combines time clock and a pressure control. This has flexibility of operation of time.

(iv) But for very low temperature refrigerators some means of introducing heat to the evaporator is used to accelerate defrosting and more quickly return the coil to its normal function of providing refrigeration.

(v) Another system[25] which is in use eliminates the necessity for attaching heaters to the evaporators and introduces mechanical valves into the system (Fig. 2.11). In normal operation a storage tank between the evaporator and the outlet from the capillary tube retains a quantity of refrigerant. To defrost, a heater in thermal contact with a formed tube section between the exit from the capillary tube and the evaporator is energized and the compressor is operated. The heater is of such a size as to evaporate substantially all the refrigerant discharging from the capillary tube. The gas thus generated causes the tank to empty. The entire supply of refrigerant now in circulation floods the system back to a heat exchanger formed by the suction tube and the discharge tube from the compressor. This loads the unit and raises the suction pressure. The refrigerant vaporized by the heat then enters the evaporator, where it condenses, giving up its heat and melting the frost from the evaporator.

8. Humidity control.-

It is achieved simply by the proper design of the air circulating system and correct balance of the cooling units with condensing units.

3.60 REFRIGERATOR CABINETS - MATERIAL & CONSTRUCTION.

1. Finishes -

Large many techniques and materials are available -

(i) Synthetic Enamel

Used for both exterior and interior parts. It has -

(a) light attractive appearance

(b) Extremely durable after proper finishing. The prefinishing treatment is done by covering cleaned metal with phosphate coating and then finished by synthetic enamel and baked.

(ii) Vitreous Porcelain -

(a) It is of high quality but more costly finish

(b) Application is limited to smaller or simpler shaped case panels.

2. Metals.-

Galvanized steel, Aluminum, Stainless Steel. They are used because they are rust resistants -

Galvanized Steel - used for non-visible parts of refrigerator.

Aluminum - Care is taken to avoid moisture and salt laden atmosphere to prevent rusting.

Stainless Steel - Ideal rust resistant but expensive.

3. Shelves.

Since they are in continuous use the requirements are

(i) Strength of metal

(ii) Appearance

(iii) Abrasion resistance

(iv) Finish

Stainless steel wire shelves are found to be most suitable.

4. Insulation

(i) Requirements

Chief requirement of a proper insulating material for a refrigerator are -

(a) Low heat conductivity

(b) Long life without crumbling, settling or decomposition

(c) Freedom from odour.

Glass wool cork and fibre-boards are among the many types frequently used. Recently foam rubber and plastics have proved their worth.

(ii) Thickness

Thickness of insulation depends upon inside refrigerator and outside temperature and upon insulation efficiency (K factor) of insulation. Generally thickness in (table 3.8) may be considered[24] typical.

Table 3.8

Temperature difference inside to outside F	Thickness of Display refrigerators (inch)	Thickness of Walk in refrigerators (inch)
50 – 65	2½ – 3	3
65 – 78	3 – 3½	4
80 – 90	3½ – 4	5
100 – 120	4½ – 5	6

(iii) Insulation sealing.-

Thus air should be properly sealed against penetration of water vapour from outside. It is general practice to allow some breather openings from the insulation to the inside or cold area of the refrigerator. Then the penetrated vapour once pass on into the refrigerator, where it will condense on the evaporator and not in the insulation.

b. Glazing

Since glass is used to allow visibility glazing must be done so that it prevent as much condensation as possible. The following methods are suggested to seal this moisture -

(i) Some manufacturers vent the space between the glasses into the interior of the case by breather tubes.

(ii) Another method widely used is to tightly seal each glass after placing a desicant (Chemical moisture absorbent) within each air space

(iii) An excellent permanent seal is provided by the use of assemblies which are hermetically presealed as a unit by the manufacturer. The air spaces are dehydrated prior to sealing.

c. Lighting

Requirements of display case lighting are met quite adequately by the fluorescent lights. They provide sufficient light, properly distributed and of the correct colour to show the products to best advantage.

S E C T I O N II

CHAPTER 4.

PRECOOLING, PREPARATION & PACKAGING

PRECOOLING

6.01 NECESSITY

For most efficient cooling, food stuffs should be cooled before they are packaged as the package itself greatly interferes with cooling (Fig. 6.1). This precooling of perishables is accomplished by the rapid removal of field heat directly after harvest and is done to achieve the following -

(i) During packaging the temperature of the cold produce may rise 5 to 20°F. This precooling may compensate for this rise and then after packaging produce may be put into cold stores for further cooling.

(ii) Precooling permits the development of full flavour before harvest with the assurance that the commodity can be safely handled for freezing.

(iii) With effective precooling commodities may be allowed to approach more nearly to maturity before harvest and then may be transported under refrigeration with confidence that they will arrive in market in prime conditions.

6.02 [illegible]

Precooling may be accomplished by any one of the following methods in common usage -

1. Cold Air Currents

(i) Fans in cars & trucks

Fans built into the cars are used to cool the loads by forcing air through the bunkers of ice and salt and blowing the cold air over the top of the load. The return air is drawn through the bottom of the bunkers and up through the ice and salt. Graph (Fig. 4.8) gives the rate of refrigeration obtained by this method.

(ii) Stationary Precooling Plants.

Special car precooling units built in at stations by the side of the rail track employ blowing of cold air at 28 - 25°F through a flexible duct the end of which is placed into a bunker through the hatch on the top of the car. Return is through a similar duct and its takes about 8 hours to cool from 75 or 80°F to 40 or 45°F.

(iii) Mobile precooling units.

Mechanical refrigeration unit loaded on trucks may supply cold air through the car door at will, thus providing advantage of portability.

(iv) Tunnel Precoolers

Cold air is directed over the unlidded lugs placed on belt conveyors passing through a tunnel and at a regulated speed.

2. Hydro-cooling.

This is mainly employed for precooling vegetables which are submerged into tank filled with water cooled by ice or mechanical system. Sometimes cold water may shower down over the produce while it is passing over a belt conveyor in a tunnel. Hydro-cooling is very fast process; most commodities cool within 10 - 15 minutes. The most important point in the operation of a hydro-cooler is to maintain water as close to 32°F as possible. At some places addition of bactericide, such as chlorine, to water is also recommended, however, research work is going on to find a suitable substance. Refrigeration requirements can be estimated in usual way.

D. Vacuum Cooling

Application of vacuum for precooling is of recent development and is employed particularly for leafy vegetables such as Lettuce. When commodities are placed in a chamber at a pressure reduced to the boiling point of water at a temperature corresponding to the field temperature of the goods placed therein, evaporation of moisture from goods commences. At 32°F and 4.5 mm of mercury 1 lb of water is evaporated and absorbs about 1100 BTU which is enough to cool 100 lbs of produce by 10°F. Though some amount of moisture is lost from commodities but this is not injurious to produce dehydrating effect. Vacuum may be produced either by steam ejectors or by mechanical vacuum pumps preferably of the rotary vane-type.

Table 4.1 Rate of cooling by Vacuum Process.

Commodity	Vacuum		Temperature of Commodity °F	
	mm Mercury	Interval	Before Vacuum	After Vacuum.
Lettuce –				
Crate of 60 heads each wrapped in cellophane	4.0	8	63	33.0
Crate of 60 heads non-wrapped	4.0	8	70	35.0
Spinach – perforated carton containing 10 cellophane package perforated	4.5	8	70	32.0
Sweet Corn – husked prepackaged in tray over wrapped with cellophane	3.0	20	63	53.0
Oranges – non-packaged	4.5	8	70	70

Though this method has the disadvantage of requiring heavy and costly equipment but it is quite advantageous as it produces uniform cooling. It also offers an advantage for prepackagers in that the produce can be effectively cooled after it has been packaged if the packages are not air-tight. Rates of cooling by the vacuum process of several commodities reported by [illegible] are given in table 6.2.

PREPARATION

6.00 The discussions so far in preceeding chapters regarding frozen food is incomplete if the most important point regarding preparation of food stuffs before actually freezing them is omitted. It involves the picking up those varieties of food stuffs that freeze best. Preparation of different commodities is done in different ways and for a brief reference the following may be taken :-

(i) Vegetables -

They are cleaned thoroughly and prepared as if they are to be served at once. They are blanched in boiling hot water for a definite period to preserve natural flavour, texture colour and food value and to stop enzyme action. After this they are cooled in cold water and packages are made and then frozen as soon as possible at -10 to -20°F.

(ii) Fruits -

Only apples need blanching. Fruits are packaged in syrup, dry sugar or without sugar. After packing these fruits in containers they are frozen.

(iii) Meats -

The freezing of meat is very simple, requiring only that it be cut in pieces suitable for table use, packaged in moisture vapour proof covering and then frozen. Freeze the meat as quickly as possible to retain the best flavour and quality.

(iv) Poultry -

Though it is possible to prepare and control undrawn poultry in the laboratory the safest and the best practice in poultry preparation is to draw all birds. The reason being that when entrails containing partially digested feeds and digesting acids are allowed to remain within the carcass, there will be migration of these off-tastes and bitter acids to the flesh of the poultry. Such osmotic and vapour pressure action cannot be entirely stopped by freezing of the undrawn carcass even when the temperature is very carefully controlled. Dressing of poultry[24] is done by -

(a) Dry picking

(b) Semi-scald picking

(c) Scald picking methods

Now examination of the condition of entrails is made to insure a safe healthy products. The finished birds are then graded frozen and sent to the market.

(v) Miscellaneous Foods -

For many other frozen foods the preparation is quite simple. Simply prepare the food as is done for immediate consumption, package in an appropriate container and freeze. The list includes, cooked dishes, sauces, soups, melons, dried fruits, packaged foods, pies and pastries bread and rolls, lunches, desserts and salads.

PACKAGING

6.04

It is well known that retention of quality in frozen food is dependent to a considerable extent, upon protection against -

(i) Moisture losses, which result in loss in weight and fresh appearance of the product.

(ii) Exposure to air, which results in oxidation, rancidity or change in colour and flavour;

(iii) Enzymatic activity

(iv) Loss of vitamins

The first two items can well be checked by packaging which is an attempt to replace or improve upon that which gets destroyed during preparation for freezing. Packaging though defined in many ways, is the wrapping of produce in a container of size and shape suitable for consumer use without repacking in stores at the time of sale.

6.05 ADVANTAGES OF PACKAGING.

(i) It simplifies self service in retail markets

(ii) It gives protection to the packaged produce

(iii) It reduces waste from trimming by customers

(iv) It reduces water loss and wilting

(v) It saves much shipping space if packaging is already done in production area.

(vi) Packages are sanitary.

6.06 PACKAGING REQUIREMENTS.

The packaging materials should have the following characteristics-

(i) They must be non-toxic, chemically stable and odourless

(ii) Should have high degree of resistance to the action of substances such as food juices, fruit acids, and fats.

(iii) Should be flexible at low temperature and be capable of effective sealing.

(iv) Mechanical strength should be sufficient to withstand stresses of usual handling.

(v) Should have low permeability to air, water vapour and other volatile substances in order to keep proper flavour of substances.

6.07 PACKAGING MATERIALS

Frozen food packages may be classified[88] into three general types -

(i) Non-rigid, impermeable bags, pouches or wrappers; closed by dead fold, heat sealed or ends twisted and tied; used in stockinet as inner liners; or as over-wrap for cartons. The materials have the following trade specifications -

Aluminium foil	- plain 0.0015 gage, or laminated 0.0003 or 0.0005 gage
Cellophane	300 MST 58 or 450 MSD 8
Polyethylene	- plain 0.002 gage, or laminated 0.001 gage
Polyvinyl chloride (Vi[illegible])	- plain 0.002 gage or laminated 0.001 gage
Polyvinylidene chloride (Saran)	-plain 100 gage Type 517 or laminated 75 gage Type 517

Rubber hydro-chloride (Pliofilm) – 120 FF or 200 FF

Rubber latex (spray-on) – 0.002 gage

Waxed (paraffined) – 25 #/ 100 – glassine paper or parchments.

Moisture vapour transmission such papers as studied by Isbell and Trossler[33] is given in table 4.3.

Table 4.3 Moisture vapour transmission of wrapping papers and liners at 0°F.

Material	Average loss in grams per sq.meter per day.
Paper waxed two sides	24.8
Paper waxed one side	32.7 – 53.4
Parchment no coating	225.0
Parchment waxed, one side	20.0
Parchment waxed, two sides	13.0

2. Rigid, relatively impermeable – wide mouthed cups, cartons pans or trays made of –

(i) Waxed (paraffined) round containers with slip in or slip over lids.

(ii) Waxed, rectangular, brickshaped containers with cut up or telescope cartons usually over wrapped and heat sealed.

(iii) Waxed paper board pans or trays.

They are used for fruits, vegetables and fish.

3. Rigid impermeable containers –

(i) Aluminum cans, trays or pans with crimped, slip over covers

(ii) Glass jars with wide mouth straight or tapering sides and screw or clamp-on-covers.

(iii) Polythylene or other plastic cartons jars or trays with slip in or slip over covers.

(iv) Tin cans with double seam, slip in or slip over covers (may be vacuumized).

4.08 TYPE OF CONTAINERS

They are made in two varieties –

(i) Wholesale containers –

Large containers especially for products such as berries and eggs which are to undergo further processing after being thawed out.

(ii) Shipping containers –

The prime function is to protect the smaller unit packed in them for which they should have necessary mechanical strength.

Fibre board cases are most generally used as shipping containers for frozen food. The cases are so designed that their contents fit compactly and adhesive of taping be capable of withstanding long periods of cold. All closing parts, edges, corners are sealed with such tape to make it water vapour-tight.

4.09 STANDARDISATION OF PACKAGE SIZES

Standardizing[14] the size of package is of great economic importance as the frozen food industry is taking up rapid advancement, especially because of the important export sizes given in the table 4.8 are usually adopted for fruits and vegetables.

Table 6.[illegible]

Material to be packaged	Dimensions				inches
Fruit	8	x	6	x	2[illegible]
"	8[illegible]	x	6	x	2[illegible]
"	8[illegible]	x	6	x	2[illegible]
Vegetable	8[illegible]	x	6	x	2[illegible]
Fruit	8[illegible]	x	6	x	2[illegible]
"	8[illegible]	x	6	x	2[illegible]
Vegetable	8[illegible]	x	6[illegible]	x	2[illegible]
Fruit	8[illegible]	x	6[illegible]	x	2[illegible]
Vegetable	8[illegible]	x	6[illegible]	x	2[illegible]
Fruit	8[illegible]	x	6[illegible]	x	2[illegible]
Shrimp	8[illegible]	x	6[illegible]	x	2[illegible]
Fruit	8[illegible]	x	6	x	2[illegible]
"	8[illegible]	x	6	x	2[illegible]
"	8[illegible]	x	6[illegible]	x	2[illegible]
"	8	x	6	x	2[illegible]
Shrimp	8[illegible]	x	6	x	2[illegible]

These days different standards are being kept in different countries but now they are going to standardize it all over the world.

6.10 PACKING SPEED

Filling and closing are the two basic operations in packaging. Depending upon the design of package, operation such as unfolding, cutting up, cooling and/or wrapping are added. The tendency is to restrict the process to the two basic operations but this is not always possible. It is very difficult to avoid manual work when packing a product such as fish fillets but efforts are being made towards that end. With highly developed machines 80-100 cartons/mt. of peas have been packed and the effort is being towards increasing the number to 180-200.

6.11 FUTURE TRENDS

With the development of new plastics packaging in industry is developing. For instance a new dip coating "Products to be packed are dipped for a moment in the melt thermoplastic which stiffens at room temperature. When the product is thawed out for use, the coating is simply stripped off."

CHAPTER 5.

TRANSPORTATION

5.01 MODES OF TRANSPORTATION

The methods of transportation of frozen food are by -

1. Land
   (a) Trucks and trailers
   (b) Rail road cars.
2. Air
3. Water

To date most of frozen food have been transported by rail and truck. Air transport is quite expensive and is used mainly for the shipment of samples or emergency shipments of small quantities. As to water, many of ships are equipped with freezer boxes to carry frozen foods for the transient feeding of passengers and crews, and larger compartments to transport a considerable tonnage of frozen produce at 0°F. However, in order to get the produce to the airlines or to the ship side truck or rail transportation is required.

TRUCKS & TRAILERS

5.02 HISTORY

Earlier attempts to refrigerated delivery dates long back. Attempts were made by packing a can of ice cream in a wooden tub filled with crushed ice and salt and delivering it by wagon. In 1920 truck bodies specially designed for ice-cream delivery were made. As improvements were made Peterson[5] in 1931 estimated ratio of truck weight per gallon of ice-cream as 16 lb. gallon from 40 lb. gallon. These days it is about 10 lb gallon.

Stagg estimated that 10000 trucks and 1000 trailers were adapted to refrigeration in 1933 and they have increased to 200,000 and 40,000 in 1953 in U.S.A.

9.03 TYPES

Thore are two types of vehicles in common use by the trucking industry -

(i) Trucks

They are used in operations which require more door openings per day for retail delivery.

(ii) Trailers

Almost all long distance hauling is done by trailers which are towed by a truck tractor, and may vary in length from 20 to 40 ft. Standard outside is 8 ft., height of the insulated enclosure varies from about 5 ft. to a maximum of 9 ft. Temperature requirements vary from 70 to 25°F, with from 3 to 6 in of insulation being the standard.

9.04 PRINCIPLES

An understanding of refrigeration load and basic principles of transportation involved is of primary importance. The heat, that is considered for the refrigeration load, comes from three sources -

(i) The sensible heat of the commodity

(ii) Heat of respiration of fresh commodities

(iii) Heat that passes through the insulation and leaks in around doors and other openings.

In case of frozen food first two are insignificant as the last one is the heat causing major load. The amount of heat that gets through depends upon -

(i) The nature and the thickness of insulation

(ii) the temperature differential between the air outside and that in the load space. The greater the temperature difference the more heat can flow because of high infiltration due to stack effect. Graph[33] (Fig. 5.8) gives heat gain due to air leakage into vehicle with an interior temperature of 0°F, at various temperature and relative humidity.

Besides above, some moisture can enter the insulation space by diffusion through cracks. If the moisture is permitted to move through the insulated space some of the water vapour is left behind to cause trouble in several ways -

(i) Increased heat gain due to latent heat of vaporization and fusion

(ii) Corrosion

(iii) Increase heat gain through insulation

(iv) Coating of coils with frost with loss of refrigerating effect.

(v) More frequent defrosting

(vi) Physical damage to insulation

(vii) Rotting of wood such as

(viii) Odour

5.03 Body Design

The primary function of body is to permit economical control of the environment around the commodity being transported. The necessary features are determined by the type of service intended. Trucks may have doors on the two sides rather than at the rear, but most trailers are equipped with full opening rear doors, large enough to permit fork lift trucks to be given into the vehicle. Many trailers are also equipped with curbside door. Floor surface may be of wood or metal. Wooden floors are tongue-and-groove treated lumber well sealed against water penetration. Metal floors are water tight, and if separate floor racks are not furnished the floor surface is provided for air movement under the load. A metal skirt reaching at least six inches up the walls is bonded to the floor so that water running down the wall and collecting on the floor will not enter the insulation. Refrigerated equipment is provided and in many cases ventilating equipment becomes necessary.

It is considered to be a good design if it provides for enough insulation, for tight bodies, for the right type of insulation, for proper vapour sealing, for light weight with more loading area, and for proper air circulation passages. Mr. H.B. Green[49] in frozen food conference pointed out the following points for judging an ideal refrigerated trailer -

(i) A trailer where the superstructure or metal structural parts do not penetrate the insulation in such a manner as to nullify the effect of insulation installed between these metal members.

(ii) A trailer where the exterior skin is sealed against vapour transmission through the use of a barrier material.

(iii) A trailer using insulating material that is impervious to the effects of moisture.

(iv) A trailer where the lining of the inner wall is also impervious to moisture.

(v) A trailer where proper arrangement is made for distribution and circulation of air.

9.03 <u>INSULATION</u>

For trucks the insulation should have

(i) Reasonable cost

(ii) Easy to install originally and during repairs.

(iii) Light in weight

(iv) Low thermal conductivity

(v) Good air vapour and liquid water resistance

(vi) Sufficient strength to withstand on-the-road mechanical stresses

(vii) Be capable of being conveniently installed with a minimum number of seams and of being treated suitably for air vapour resistance at the unavoidable joints.

The requirements are not found at their best in any one insulant. Cork-board, expanded polystyrene, expanded rubber well sealed with hydrolene for emulsified asphalt are frequently used for insulation for floor and fibrous glass. For walls and ceiling the insulation is cut slightly oversize, roller coated with hot hydrolene and forced into position, eliminating voids. For frozen foods a full 6 inches thickness has been found satisfactory[30].

To check moisture entry it is of paramount importance to make the exterior surface of the refrigerated enclosure vapour tight. By lining the inside of the exterior skin with a non-permeable vapour-barrier such as Aluminium foil coated with a plastic binder which can be sealed at joints. Use of fibrous glass belt with a specially designed paper foil covering to provide necessary air, vapour and water resistance is coming into light.

9.07 AIR CIRCULATION

Regardless of the type refrigerating equipment satisfactory product temperature during transportation will not be maintained unless load is surrounded by proper air which should be circulated continuously. Improper air circulation (Fig. 9.8) where refrigerated air is blown and drawn back from the top of load give rise to " Hot Spots" having a much higher temperature than of at which commodity is transported. To give better circulation (Fig. 9.9) under the load, a return air duct is built so that air is drawn from the floor of the trailer and produce a circulation around the load.

An important problem in design is that the spaces that are under the load provided by the floor strips and that along the sides are not enough to allow the movement of air necessary to remove adequately the heat entering from outside. Floor racks with clearance[4] 3" - 4" and 1" along the sides are desirable. Cross sectional area of return space is usually kept equal to or larger than that of the inlet unit, if full capacity of the fan is to be utilized.

9.08 REFRIGERATION SYSTEMS

Several methods used for providing refrigeration are -

1. Use of product precooling
2. Ice and Salt
3. Dry ice
4. Hold over systems
5. Mechanical refrigeration

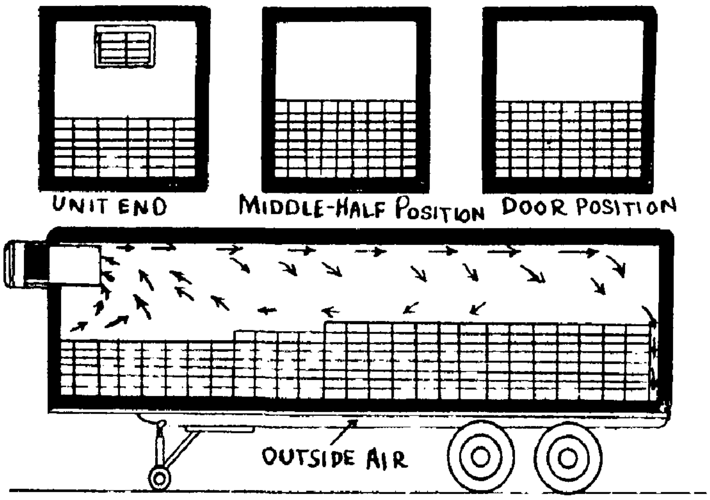


FIG. 5·2 (LEFT)

DIAGRAM OF NORMAL LOADING PATTERN IN MECHANICALLY REFRIGERATED TRAILER WITH UNIT MOUNTED IN NOSE, SHOWING LACK OF AIR-CIRCULATION BECAUSE THE RETURN AIR INLET IS IMMEDIATELY UNDER THE DISCHARGE OPENING.

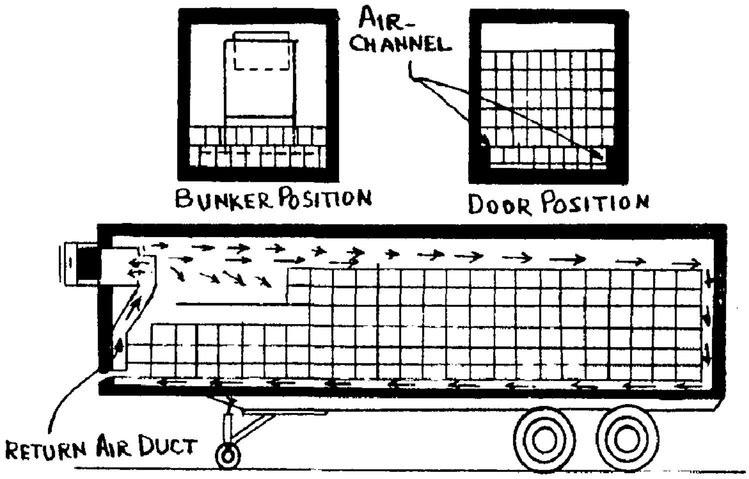


FIG. 5·3 (LEFT)

RETURN AIR DUCT INSTALLED TO INCREASE AIR-CIRCULATION UNDER AND AROUND LOAD IN MECHANICALLY REFRIGERATED TRAILER. ALSO SHOWN IS MODIFIED LOADING PATTERN TO PROVIDE AIR CHANNELS ALONG EACH SIDE TO INCREASE AIR MOVEMENT BETWEEN LOADS AND WALLS.

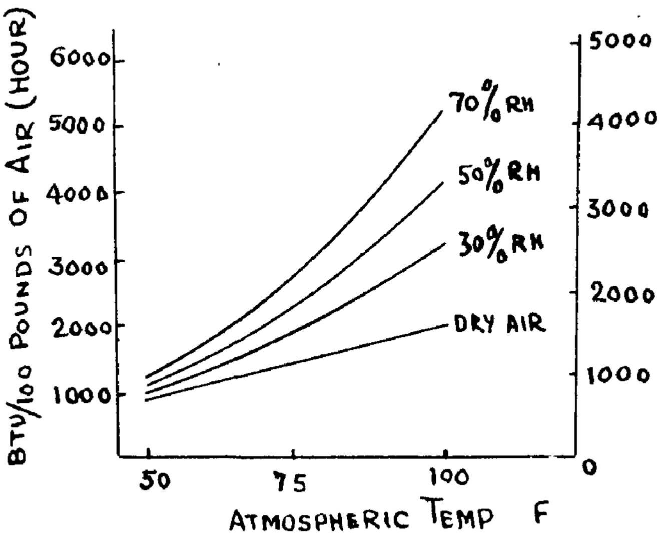
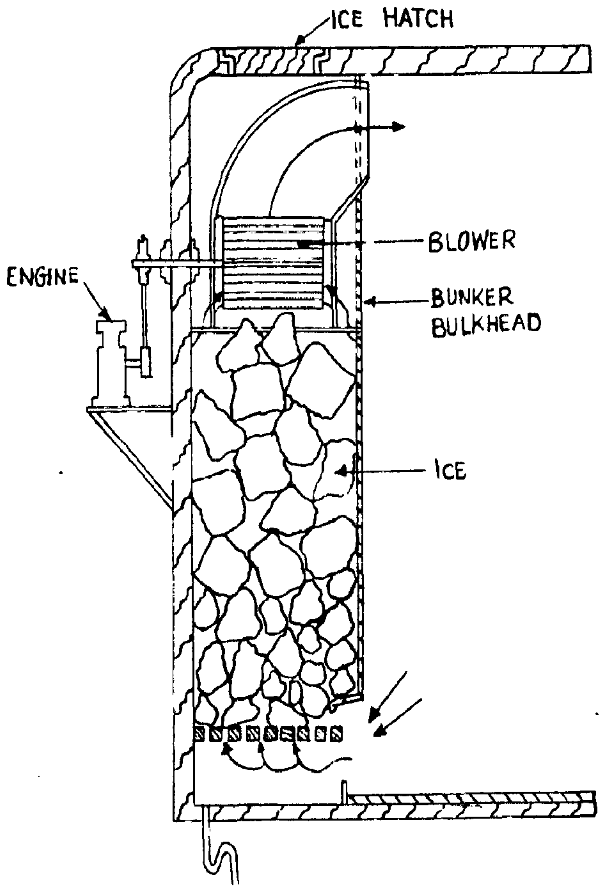


FIG. 5·1 (LEFT)

HEAT LOAD DUE TO AIR LEAKAGE OF A REFRIGERATED VEHICLE WITH INTERIOR TEMPERATURE OF 0°F



TYPICAL WATER ICE BUNKER TRAILER
(SECTION SHOWING AIR FLOW AND LOCATION OF BLOWER)

FIG. 5.4

1. Use of Product Sub-cooling

This involves the utilization of the heat absorbing capacity of the product itself due to subcooling before loading to a temperature below the maximum that it can tolerate. For example 32000 lb. of frozen strawberries warming from -15 to 0°F during a 30 hr. haul will absorb 267,000 BTU or 8900 BTU per hour, through the trip and in some cases it would be sufficient total refrigerating effect.

2. Ice and Salt

Water ice and salt are mixed in a brine tank usually in the nose of the vehicle and a separate motor is used to pump chilled brine in cooling coils over which air is circulated by fan. This method has become obsolete because ice and salt are heavy and require a great deal of labour to pack. In addition, the resulting brine is corrosive to truck bodies and makes an undesirable discharge on the streets and garage floor.

3. Dry Ice

Many trucks operate on the use of dry ice. Three systems are in use -

(i) Dry Ice on Load

Here the ice is scattered over the load. Care is exercised in handling of dry ice to avoid burns due to the low temperature and precaution against suffocation due to lack of oxygen in closed body containing dry ice.

(ii) Dry Ice in Bunker

Blocks of dry ice are placed in a bunker (Fig. 3.6) and the air to cool the vehicle is drawn up through the ice and forced into the cargo space by motor driven fans, which can be controlled by thermostat to hold a desired temperature in the vehicle. Power for the fan motors is taken from the truck or tractor electrical system.

(iii) Dry ice with Secondary brine Circuit

Anti-freeze solution or brine chilled by dry ice in a container is pumped through cooling coils either on the ceiling or on the side. Flow is controlled by a thermostat located in the refrigerated space while temperature of brine is varied by means of a mixing valve. For frozen food brine temperature may be lowered as required. The ability of the system to operate without any outside power source is an advantage for trailers.

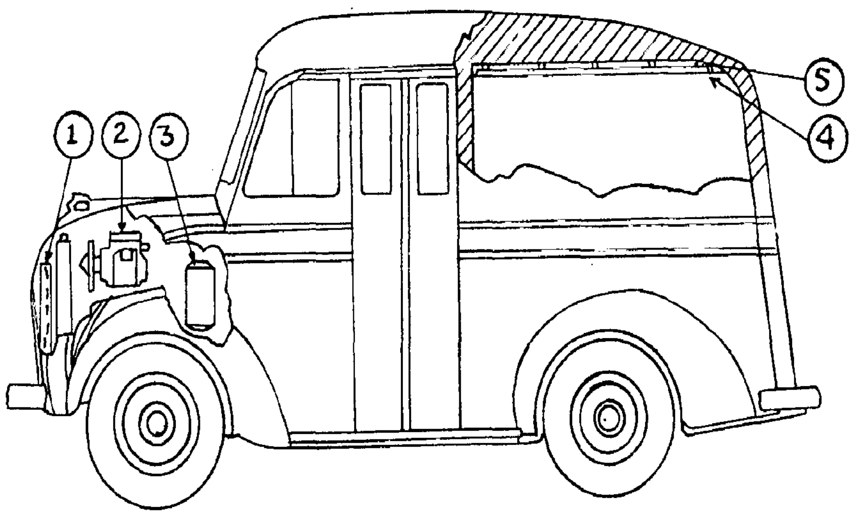
6. Hold-over System.

A hold-over plate consists of a coil for the primary refrigerant mounted inside a thin tank filled with eutectic solution (Table 5.1)[illegible] with a freezing temperature sufficiently low (about -[illegible]°F) to meet the required conditions.

Table 5.1

Salt	Formula	Freezing point °F	Concentration
Potassium Sulphate	K_2SO_4	0.0	[illegible]
Potassium Chloride	KCl	12.7	10.0
Ammonium Chloride	NH_4Cl	4.3	20.0
Sodium Chloride	NaCl	-[illegible].0	[illegible]
Magnesium Chloride	$MgCl_2$	-[illegible].3	22.0

1- Condenser Coil
2- Compressor
3- Receiver Tank
4- Aluminum Evaporator
5- Wood Spacer



Location of various elements of Refrigeration System in which Compressor Is directly driven from Truck Engine.

(Capicity Control device permits steady Out-put in spite of Varying Compressor speeds.)

Fig. 5·5

In earlier form, the solution was sealed into metal cylinder, frozen in the plant cold room and then mounted in the turuck body on racks. In the process of melting solution provides refrigeration. Now-a-days in some instances the complete refrigeration system is mounted on the truck by including a condensing unit to freeze the solution. The unit may have an auxiliary drive for operation when vehicle is in use, and an electric motor drive for standby. The system provides continuous refrigeration even though the engine is idle when the truck engine is off.

5. Mechanical Refrigeration

Many systems of mechanical refrigeration have been devised. A light weight, compact refrigeration that would furnish even dependable, temperature has been the goal. These systems can be divided into two categories -

(i) Power from truck engine

There are two main points on a truck engine from which power may be transmitted to an auxiliary drive -

(a) from the frontextension of the crankshaft and

(b) from a transmission power take off

(a) Front power take-off

Two means are available, one is direct and the other is through a belt, gear, or chain. The direct connection is obtained by mounting an electric generator in front of the truck between the radiator and the bumper. The other method is to mount a generator, refrigeration compressor, or power take off shaft under the hood[53] (Fig. 5.5), support it from the engine, and supply power by a belt gear or chain. The first one can operate on the electric line in the garage but the second one furnishes refrigeration only as long as the truck engine runs. This has yet another draw back that it requires a pressure regulating by pass valve to keep the pressure (varying on account of varying speed of compressor) and hence temperature constant.

(b) Transmission power take-off

They are direct mechanical drive, hydraulic drive and magnetic drive identified by the name of the clutch used. Direct mechanical drive has been used by belting the compressor to a shaft connected into the transmission power take off. An eddy current clutch has also been used with the power take off to regulate the speed of the compressor but it is heavy and expensive. A magnetic clutch has been developed for the same purpose and showed some promise. Hydraulic system is effected by employing a hydrostatic gear type of clutch. This system transmits almost direct drive upto a predetermined speed then hydraulic pressure is relieved. The principal obstacle to a transmission power take-off drive has been its interference with normal gear shifting of the truck. During shifting the power take-off must be disconnected. Thus another complex problem is involved.

(ii) An auxiliary gasoline engine

This supplies power to the system. This system has the advantage that are inherent in a hermetic system. Secondly electric heating element can be built into evaporator coil to provide heat for quick-defrosting. Thirdly gasoline engine is physically separated from the refrigeration system, thereby simplifying service and reducing the hazards of leaks from vibration.

This independent unit has proved to be quite dependable. An automatically refrigerated truck body allows more flexible operation of the vehicle. Longer routes may be established and there is no need to unload at the end of a run to put the product in a cooler.

5.03 LOAD CALCULATION CRITERIA[47]

The items involved are –

(i) Conductance – By combined process of radiation, convection and conduction heat flow is given by

$$q_c = U \times (t - t_o) A$$

where,

$t - t_o$ = temperature difference in °F

U = overall coefficient of heat-transfer

A = Area

(ii) Insulation Allowance

It is taken as 10% or 20% of the transmission heat according as the area used is outside or inside.

(iii) Direct entry –

Heat entering through service opening is difficult to compute and is taken between 25 – 50% of conductance heat gain.

(iv) Cargo heat –

While in transit refrigerated and insulated body is not expected to cool the cargo, heat from this source is assumed to be ≈ 50% of conductance heat gain.

(v) Air infiltration

Due to this heat gain is given by

$$q_A = VLR$$

where,

L = length of crack

R = sensible and latent heat removed in cooling.

from ambient (110°F 70 ?) to zero °F) For local) conditions

and 100% RH. Given in BTU/cft.)

V = volume of air passing through the open door

at a pressure corresponding to truck speed as

given by table 5.2.

Table 5.2

Wind Velocity	Wind pressure on a flat surface, inches of water.	Air infilteration through insulated truck wall section with open doors cu.ft. per hr. linear ft.
10	0.05	53
20	0.20	69
30	0.43	103
40	0.80	153
50	1.20	200

5.10 ILLUSTRATIVE EXAMPLE

At present no valid method of determining the heat gain characteristics of a refrigerated vehicle is available. Rule of thumb values are used to approximate the heat transfer effect of frosting air-leakage etc. For local delivery frozen food truck the following examples gives an idea of computation of eutectic plate equipment under the following conditions :-

Conditions (assumed)

Inside body length = 10'

Inside body height = 5'

Inside body width	= 6'
Insulation (Cork board), K = .28)	= 6" thickness
U for insulation and framing (3" wood outside)	= .0403
Ambient conditions	= 110°F , 60% R.H.
Body conditions	= 0°F , 100% R.H.
Wind velocity	= 30 m.p.h.
Length of delivery schedule	= 10 hours (5 hours for Delhi-Meerut & 5 hours for distribution)
Number of stops per day	= 20
Assumed roof temperature	= 120°F
Assumed floor temperature	= 110°F
Seam length	= 0'
Average product load (frozen food)	= 5000 lb.(loaded daily at - 10°F)
Specific heat of product	= 0.5 BTU/lb.
Eutectic plate temperature	= -8°F (Manufacturer's recommendations)
Eutectic plate K	= 2.0 BTU(sq.ft)(F)(hr)

Calculations

Outside surface of roof and floor (each)	= 11.5 x 7.5	= 86.3 sq.ft.
Side walls (each)	= 11.5 x 6.5	= 74.75 sq.ft.
Front & rear	= 7.5 x 6.5	= 48.75 sq.ft.

(i) Heat transmission through insulation

roof	= 88.8 x 120 x .0(?)5	= 4(?)5 BTU
floor	= 88.8 x 120 x .0(?)5	= 420 BTU
Side walls (two) =	76.75 x 110 x .0(?)5 x 2	= 805 BTU
front & rear walls =	6?.75 x 120 x .0(?)5 x 2	= 4?? BTU
	Sub-Total (q_1)	= 2020

(ii) Allowance for framing and other heat source at 10% of q_1 = +2?0 BTU

total (q_2) = i + ii) = 2?00

(iii) Allowance for service load

(a) Direct entry (q_3) = .5q_2 = +1075

(b) Cargo heat (q_4) = .5q_2 = + 1075

Total heat gain (q) = 4?00 BTU

(iv) $q_A = VLR = \frac{125 \times 6 \times (34.1 - .8)}{14.5}$ = +2705 BTU (Table 5.8)

6050

(v) Allowance for refrigeration effect of warm-up to 0°F and ½ the product load

$= \frac{.8 \times 8000 \times 20 \times .8}{20}$ = +[illegible]

Net refrigeration load = [illegible] BTU/Hr.

Hence about [illegible] BTU/hr. refrigeration will be needed and the plates are required = $\frac{[illegible]}{[illegible] \times 8}$ = 820 sq.ft.

Further equipment may now be selected.

RAIL ROAD CARS

5.11 HISTORY

The first refrigerated rail shipment of butter taken took about 120 years ago (1851) from Northern New York State to Boston in a box car insulated with saw dust and provided with water ice. Salt was used to obtain lower temperature in 1870. At the end of World War I, U.S. Standard Cars were designed with insulation 3" instead 2". By 1935 light steel framed, steel sheathed, and steel roofed cars with 3" insulation replaced the older wooden cars. In 1946 United Fresh Fruit & Vegetable Association made definite recommendations for an all purpose car 40 ft. in length, with standard inside dimensions, with insulation from 4 - 6" and incorporation of air circulation by fans. Since then lot of development have been made in rail road transportation.

5.12 TYPES

Association of American Rail Road classifies[24] them according to method of cooling and other equipment as below :-

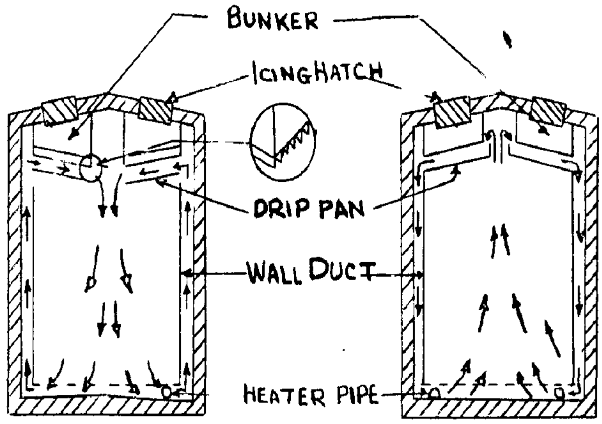
RA - A car equipped with insulation and brine tanks. Used chiefly for meats and packing house products.

RAM - Similar to RA but equipped with beef rails.

RP - A fully insulated car provided with mechanical refrigeration equipment operated by power generated inside car.

RPM - Similar to RP but equipped with beef rails.

RCD - An insulated car with solid carbondioxide as primary refrigerant.



COMPARISON OF STANDARD (RIGHT) AND MODIFIED OVERHEAD ICE BUNKER SYSTEM

FIG. 5·6

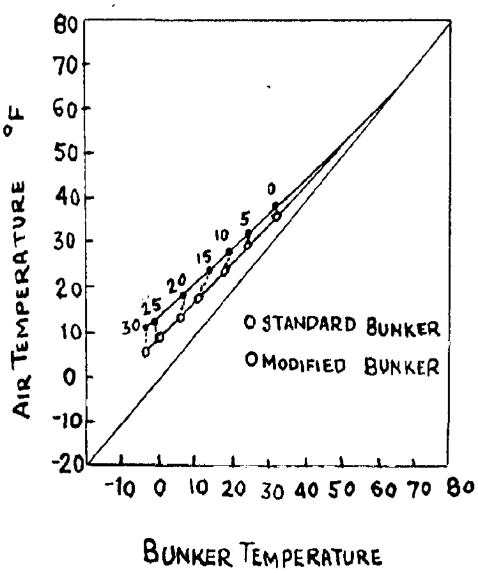


FIG. 5.7

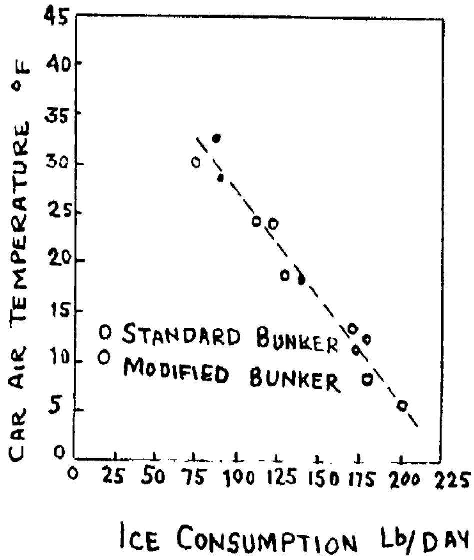


FIG. 5·8

5.13 REFRIGERATION SYSTEMS

(i) Dry Ice

Since 0°F is commonly accepted as transportation temperature for frozen commodities, simple water ice is unable to produce satisfactory results. Dry ice was one of the first other refrigerant considered in the attempt to lower bunker temperature. Its use was ruled out in 1940 because of its high cost and limited availability.

(ii) Water Ice & Salt

An eutectic solution of water ice and sodium chloride (30 lbs salt per 100 lb ice) gives a bunker temperature of -6°F. The problem of producing still lower temperature was attacked on two lines.

(a) attempt to find a refrigerant that would lower bunker temperature in over-head cars.

(b) an investigation of bunker design to obtain better heat transfer.

(a) Salt Ice mixture

Ice, Sodium Chloride and various proportions of Ammonium Nitrate give uniform and lower[34] temperature (about 5°F lower than the conventional mixture).

(b) Modified Bunker

The modification[34] of the bunker design (Fig. 5.6) produced temperatures of 5-6°F lower[30] (Fig. 5.7) than those normally obtained with maximum salt and 8.5°F with no salt. The bunkers in the modified car are somewhat larger than those in the standard car, have extended surface in the form of transverse fins, and slope downwards the longitudinal axis of the car, and with drip pans parallel to the bottom of the bunker but spaced away from the side walls of the car.

Thus the combination of the produce bunker temperature of about -10°F and car air temperature of about 0°F. Also because ice consumption is a linear-function[20] (Fig. 5.8) of car temperature new bunker system actually uses less ice to maintain a given temperature, the saving amounting to 10% at 0°F as stipulation by table 5.8.

Table 5.8

Average car air temperature °F	Salt required per 100 lb ice		
	Standard Bunker	Modified Bunker	Difference
30.2	0.0	0	0.0
32.7	5	2.0	3.0
23.3	10	6.5	3.5
24.6	15	9.0	6.0
19.45	20	14.0	6.0
10.9	25	18.0	7.0
11.4	30	23.0	7.0
0.0	-	29	-
0.7	-	30	-

(iii) Mechanical Refrigeration

The ice bunker system involved installation of icing station for reicing the cars at regular intervals, involving waste of time. Also eutectic brine caused corrosion of car bodies. All this led pioneers in the transportation industry to think of mechanical system of refrigeration and for the first time in 1901 Fruit Growers Express Co., U.S.A. adopted.

Frigidaire Compressor System with a 24 HP diesel engine, Freon 12 as refrigerant and fan forced air-circulation. Since then these cars are in use in frozen food industry. Details about the system are dealt in subsequent articles.

3.24 ADVANTAGES OF MECHANICAL REFRIGERATION

(i) Better Protection of Foods in Transit

Maintenance of sub-zero temperature is highly important for frozen food. Mechanical car has amply demonstrated its ability to produce constant desired temperatures conforming to accepted stationary practice (plus or minus 2°F).

(ii) Fewer Car Overhauls

The damaging and corrosive effects of salts and water ice are eliminated and the life of car is increased from 10 - 18 years.

(iii) Reduction of Way Damage

Besides car body drip water damages rails, switches, bridges etc. this is eliminated with mechanical cars.

(iv) Better Car Insulation

With new designs thicker and better insulation may be provided resulting reduced operating cost as the stopping of cars to dry out for insulation replacement may be eliminated.

(v) More Usable Space

Space occupied by mechanical equipment and extra insulation is less than that occupied by two ice bunkers. This mechanical cars provide approximately greater revenue load space.

(vi) Lower Light Weight

Mechanical cooled car is lighter than ice bunker car as below —

40 ft car by 10,000 lbs

50 ft car by 15,000 lbs

Hence more load can be hauled in car of same dimension.

(vii) Operating system

Since no time loss is caused in switching cars to icing stations and icing them, thereby providing more time available for the cars to operate. It results in fewer cars needed to provide required service.

(viii) More Available Revenue Hours

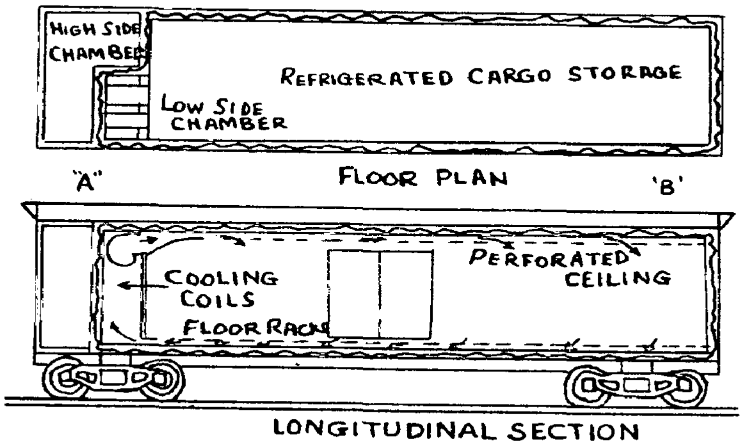
Precooling of mechanical cars to 0°F takes 10-15 hours instead of 24 to 36 hours (when ice is used) and this can be done during hauling hours. Thus these cars can be used for more time as the loading may be started immediately on arrival.

5.15 DESIGN ASPECTS

The following points are to guide equipment design and the application of mechanical refrigeration to Rail Road Cars.

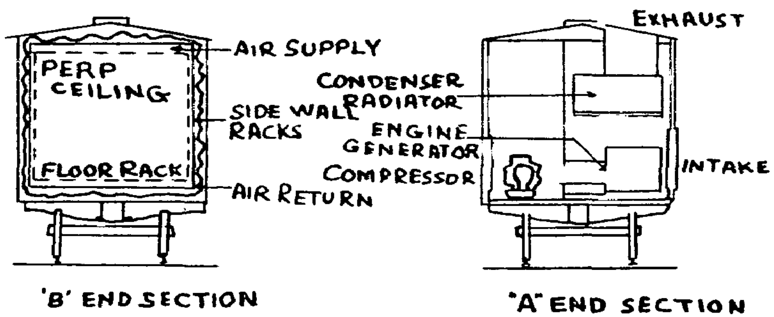
(i) Operation of cars out of train

Cars must be capable of operation both in motion and standstill either in a train or out of a train. This rules out direct axle driven system. Steam engine may be used but I.C. engine seems to be the best solution as a source of prime power. A diesel engine drives a three-phase, direct connected self-excited alternator. The power so generated drives three-phase motors which in turn drive the refrigerator compressors and fans required for circulating cool air within the car. A diesel engine is more reliable for constant duty and is preferable to a gasoline engine.



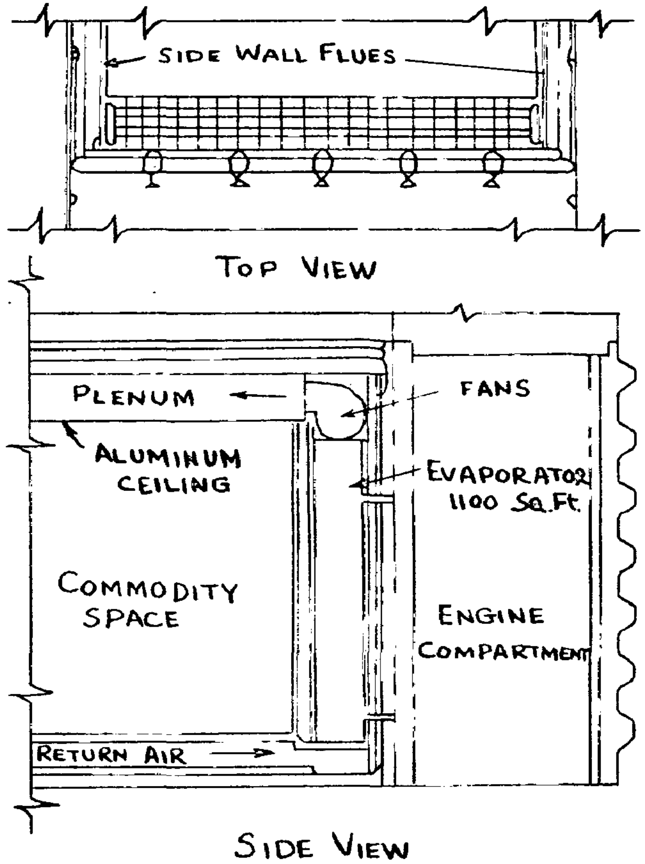
MECHANICALLY REFRIGERATED FROZEN FOOD CARS
(DIESEL DRIVEN GENERATOR)

FIG. 5.9



END VIEWS OF CARS SHOWN ABOVE

FIG. 5.10



LARGE COOLING UNIT PLACEMENT

FIG. 5.11

(ii) Even temperature distribution

Even temperature distribution and circulating air must be provided without excessive air velocities through the interior of the car. It is a practice to envelope the product in a layer of refrigerated air by providing side wall flues, with the air supply either delivered in the space over the product or in a plenum chamber in the ceiling, the return[illegible] is under the floor racks (Fig. 5.9 & 5.10). Most frozen product cars do not have a solid wall flue but permanent racks on the wall to provide 1" space for air travel.

(iii) Moisture content of car air

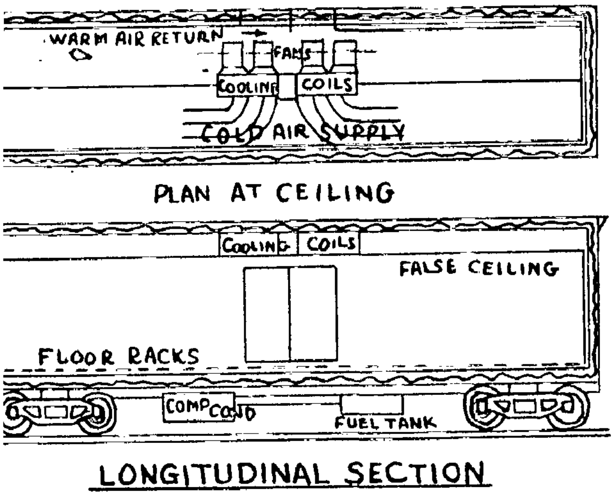
Cars must maintain high moisture content to keep dehydration of the load to a minimum during transit. Use of large surfaces in the cooling units and maintaining a small differential between the air temperature of the storage space and the refrigerant temperature inside the cooling unit, is helpful.

(iv) Defrosting

It is essential to keep the evaporators in the cooling units as free as possible from frost and ice formation otherwise, the refrigeration system becomes ineffective. This is also handled by electric heaters and proper automatic defrosting control with a time clock set for 8-0 hour interval. In order to reduce the rate of frost deposit and at the same time accumulating a lesser amount of frost without reduction in heat transfer capacity by using new cooling units as given by Trane Co. Mechanical Equipment[illegible] (Fig. 5.11).

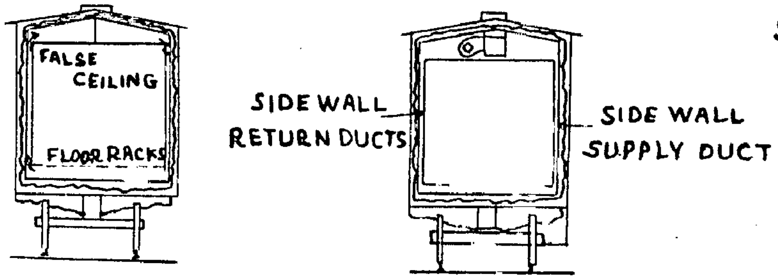
(v) Ruggedness of equipment

Equipment must be rugged and stand the shock of the service in



MECHANICALLY REFRIGERATED CAR IN WHICH ENGINE COMPRESSOR & CONDENSER ARE MOUNTED UNDER CAR & EVAPORARS ARE MOUNTED AT TOP CENTRE.

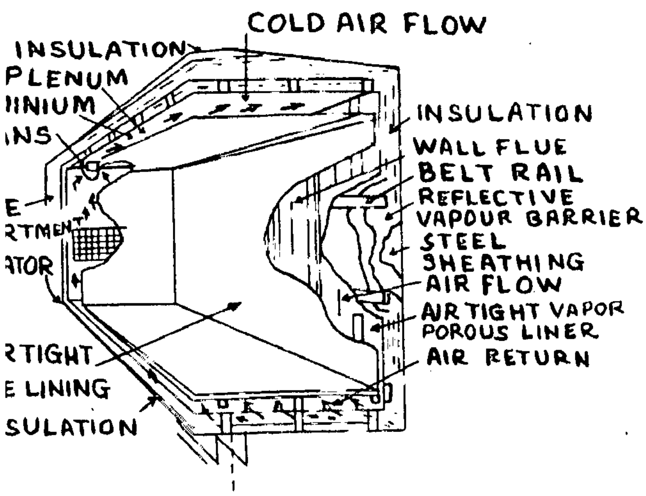
FIG. 5.12



END SECTION CENTRE SECTION

CROSS-SECTIONAL VIEWS OF CAR SHOWN ABOVE SHOWING ARRANGEMENT OF BLOWER & FALSE CEILING.

FIG. 5.13



"COMPLETE ENVELOPE" DESIGN FEATURES ARE SHOWN BY CUT AWAY DRAWING

FIG. 5.14

freight trains i.e. "stretchout" of long trains when moving up grade and the "take up" of slack after the top has been passed and the down grade movement begins. Steel frame cars maintain a rigid body and do not permit racking and the resulting damage to insulation. Steel outside sheeting and steel roofs provide a good vapour barrier too.

(vi) Reliability

Mechanical equipment of refrigeration should have maximum reliability because unlike trucks attention payment and repairs cannot be done immediately after the failure is detected. In motor truck a driver can move his load into a warehouse and hold it under refrigeration until repairs can be made, while mid road cars need to be taken to next station.

(vii) Ease of maintenance

The design of machine compartments must provide ready and safe access to any of the components of the system for in-place maintenance work. The unit assemblies such as diesel alternator, compressor, condenser, evaporator and fans must be capable of removal and suitably located[26] (Fig. 5.12 & 5.13).

(viii) Availability of service parts

Service parts must be readily available not only for the present but for the future due to anticipated long life of equipment. This needs use of standard components in making up various assemblies.

(ix) Insulation

The effect of radiant heat from roof and floor makes the insulation requirement of mobile installation more severe than stationary installations. For an ice-refrigerated car 3-4" was considered adequate insulation. Recently in mechanical cars removal of more structural members from the car construction and substitution of insulation of 6-8" is coming in practice and is helpful in weight reduction of car. The use of uncombustible light weight insulation material of fibrous type is a rule in the railroad refrigerator car field.

(x) Minimum weight and space of equipment

Refrigeration and associated equipment must use minimum of space and weight must be kept to a minimum. Present systems occupy little more space than that of two ice bunkers. Attempts are being made to make it more compact.

(xi) Moisture

Weight increase amounting to thousands of pounds per car, due to moisture pickup, is recorded[58] by refrigerator car companies. Breathing taking place when a space is pulled down in temperature due to reduction of air volume, infiltration through cracks and holes during movement of the vehicle, and diffusion due to the difference between the partial pressure of water vapour in the air outside and inside the insulation wall, cause water vapour to enter into a refrigerated car structure. The amount of diffusion of water vapour through a uniform material can be expressed by the equation[58]

$$\frac{dW}{dt} = -KA\frac{dp}{dx}$$

Where,

$\frac{dW}{dt}$ = the instantaneous rate of vapour flow through area A perpendicular to the direction of vapour flow

K = diffusion coefficient of the substance

$\frac{dp}{dx}$ = the rate of change of partial water-vapour-pressure with respect to the distance of flow.

The problem of moisture has been carefully considered and application of vapour-barriers have been tried. A suitable form is a corrugated aluminium foil, which at the same time acts a radiation and convection barrier when combined with ordinary fibrous materials of very light weight. It has also been suggested[52] to use two inside walls instead of one, that is, a vapour porous partition facing the insulation and a vapour tight lining facing the commodity space with air space in between. By placing evaporator in this air space and circulating the cooled air around the lading space it is possible to continuously remove moisture from the insulation space without picking up moisture from the commodity. This design is termed as an "envelop design"[52] (Fig. 9.14).

(xii) Door design

In 1962-63 six foot wide heavy sliding door together with heavier or metal floor racks was developed[53] to facilitate palleti and lift truck loading and unloading of frozen foods, because warehouse trucks can be lied out so as to bring the car closer to the loading platform. But at the same time these sliding doors greatly increase the loss of temperature when they are opened for inspection or for unloading. To overcome this a new type split-door[53] has been developed. This design consists of a left-hand 4 ft. swing door and a right hand regulation 8 ft. hinged door, giving a total 6 ft. clear opening when both doors are opened wide. Further attempts are being made to improve the design.

(xiii) Controls outside car

Engine and temperature monitoring controls should be located outside the car. These include START, HOLD and STOP button for the engine.

The hold button by-passes the low oil pressure and low voltage protective circuits during engine start up. Also on the panel, lights indicating that the engine is operating; the D.C. amperage of the storage battery; whether defrost cycle is in operation; total engine hours in use; and interior cargo temperature should be there. An eddy current clutch between generator and compressor controls the compressor's cycling according to refrigeration demands.

5.10 EQUIPMENT DETAILS

Equipment depends upon the type of system used by various companies. The various details for current Frigidaire Systems are -

1. Power Plant specifications

Diesel engine

(i) Two cycle - two cylinder

(ii) Rpm - 1800

(iii) H.P. 24 at full load

Generator - 10 KW, 3 phase, 220 volt, 60 cycle, self excited AC.

2. Condensing Unit -

Frigidaire type X - 3 unit has

(i) Air cooling arrangement fin and tube type

(ii) F_{12} refrigerant

(iii) 3 HP sealed reciprocating compressors

(iv) 3 phase motors.

Here the coolest outside air is always available, being brought from the outside of the car by the fan directly to the condenser and then discharged into machine compartments.

3. <u>Cooling Units</u>

(i) Two evaporators (fin and tube type) have two condensing units, one unit for standby

(ii) 6000 watts heating element incorporated for defrosting

(iii) Capacity about 2½ tons (when 8°F car and 100°F ambient temperature)

(iv) Pressure - Suctions 6 lb. and head pressure 1[illegible] lb.

4. <u>Controls</u>

They include -

(i) Defrost controls

(ii) a thermostat to cycle refrigeration to produce desired temperature in loading spacing.

(iii) Dual pressure cut out and oil pressure safety switches.

5. <u>Accessories</u>

(i) Receiver to hold most of refrigerant charge

(ii) Dehydrator to remove moisture from circulating refrigerant

(iii) Strainer to remove foreign matter

(iv) Solenoid valve controlling flow of refrigerant to evaporating coil

(v) Expansion valve throttling liquid to lower pressure and controlling distribution to coil.

(vi) Heat exchanger, to prevent liquid droplets from reaching compressor and to improve cycle of efficiency.

(vii) Discharge by-pass line to unload compressor at starting.

D.27 <u>[illegible]</u>

(i) Dimensions : [illegible] ft. long, [illegible] ft [illegible]" wide, [illegible] ft. [illegible]" high (capacity [illegible] cft)
[illegible] ft. long, [illegible] ft [illegible]" wide, [illegible] ft [illegible]" high (capacity [illegible] cft)

(ii) Air change : 1200 cfm

(iii) Loading : By space = 80% by product load

By weight 80,000 lb frozen food in 40 ft. car

120,000 lb frozen food in 50 ft. car.

Thus larger cars are advantageous.

MARINE TRANSPORT

5.19 DEVELOPMENT

The first successful transportation of frozen meat was done in 1880 in England. Though marine shipment is continuing since then but not much is known about its development. In recent years with the discovery of Freon much progress has taken place in this field. Use of refrigerated van as large as 8 x 8 x 40 ft has come into existence and show a great promise for frozen foods.

5.20 STORAGE & PLANT LAYOUT

The location and arrangement of compartment within the hull is subject to limitation of dimension. Compartments for late loading and early discharge are located under top most deck to the hull. In general refrigerators are arranged symmetrically about the ship's longitudinal centerline. Following rules are followed in making plant layout -

(i) Layout should have optimum of simplicity without the sacrifice of reliability.

(ii) The central machinery plant is usually located in or immediately adjacent to the main propulsion machinery room there extent which can easily be done. This results in economy of space and close connections for power and pumping facilities.

(iii) Machinery room should have enough space for operations, maintenance and repairs.

(iv) All machinery should have sturdy foundations for vibrations set up by them or the main propulsion plant.

5.10 CONSTRUCTION.

A. Requirements

The assembled boundary of a ship's refrigerator has the requirements that –

(i) It must be able to withstand heavy floor loads and also severe wall thrust of cargo when vessel rolls or pitches in a heavy sea.

(ii) It must be able to flex with the hull structure being stressed in any angle of the three dimensions.

(iii) The assembly must resist damage by forces occasioned by vibrations caused by the propelling machinery or the sea and by the careless handling of cargo.

(iv) The moisture-vapour-seal of all surfaces must be preserved under all of these conditions.

B. Design

There are three principal parts to the structure –

(i) Envelope or basic structure

(ii) Insulating material

(iii) Room lining

The envelope is usually composed of ship's hull and the water-tight deck from outside. The unboarding lining, too, should have equal ability to resist moisture. A continuous steel bulk-head with lap seams and welded stiffeners provides a boundary of adequate strength and tightness.

D. <u>Insulation.</u>

<u>Requirements</u>

Marine insulation has many more complicated problems as compared to stationary installations. The chief requirements are -

(i) High insulating value

(ii) Impervious to moisture from any source

(iii) Light in weight

(iv) Flexible and resilient to accommodate ship's stresses and loading

(v) Good structural strength

(vi) Resistant to infiltering air

(vii) Resistant to disintegration or deterioration

(viii) Fire-resistant or fire proof

(ix) Odourless

(x) Not conducive to harboring rodent

(xi) Reasonable installed cost

(xii) Variable in Construction.

<u>Materials</u>

Fibrous insulators are generally fire-resistant but are air-permeable and are used only at constructional joint where insulation-blocks cannot be placed.

Granulated or powdered insulators, though flexible are subject to packing, settling and some are flammable. These are not suitable for ship board.

Cork board is good insulation which has sufficient resilience to yield to the flexing of the hull structure without acquiring a permanent deformation.

In recent years mineral wool installed in bottoms of thickness about 12-20 inches is placed in the space between the shell, bulk head and interior lining.

Application.

Mode of application depend upon type of insulation. Fibrous battings are secured to steel work with welding studs. Packing type insulators are stuffed into spaces formed by two room lining surfaces.

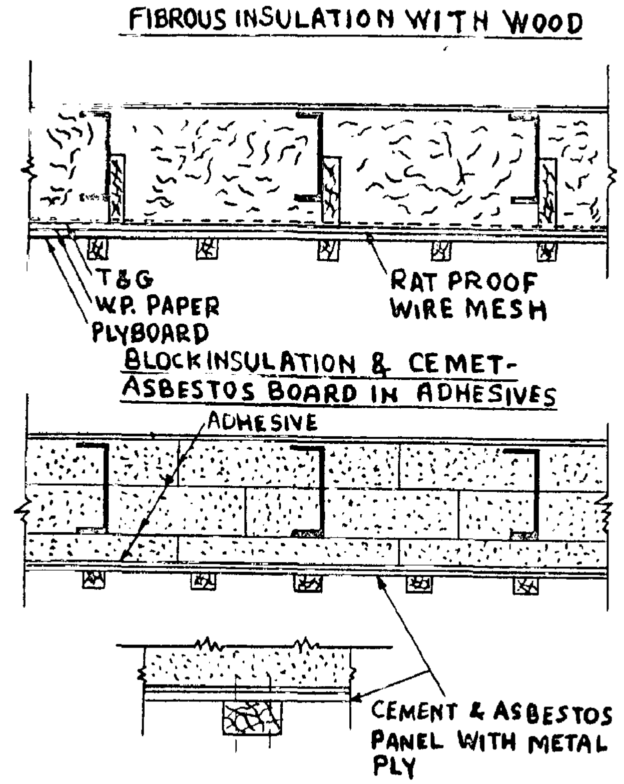
A satisfactory means to secure block insulators is to apply a complete envelope of adhesives after cutting and fitting. Heated asphalt has been greatly in use. Besides this, use of adhesive cements for marine refrigerators has been tested over an extended period and has proved to be a practical method.

A. Room Lining.

The inside surface of room must be of such construction as to withstand the impacts of frequent loading and handling of cargo. Steel lining have been thought of, but installation cost, difficult maintenance and ship repairs do not permit their use. Method of lining for different parts are given below :

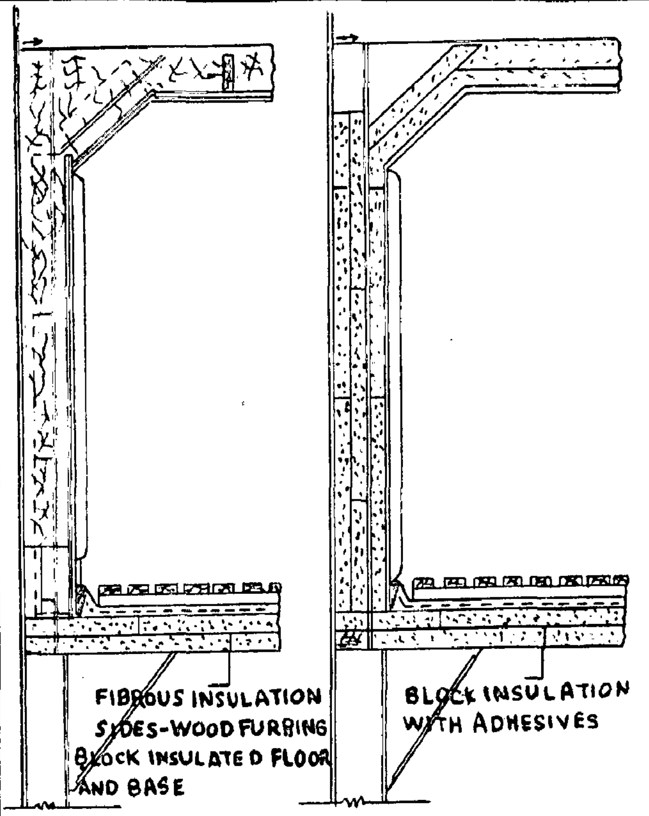
(i) Walls.

U.S. Public Health Service has recommended use of [illegible] panel



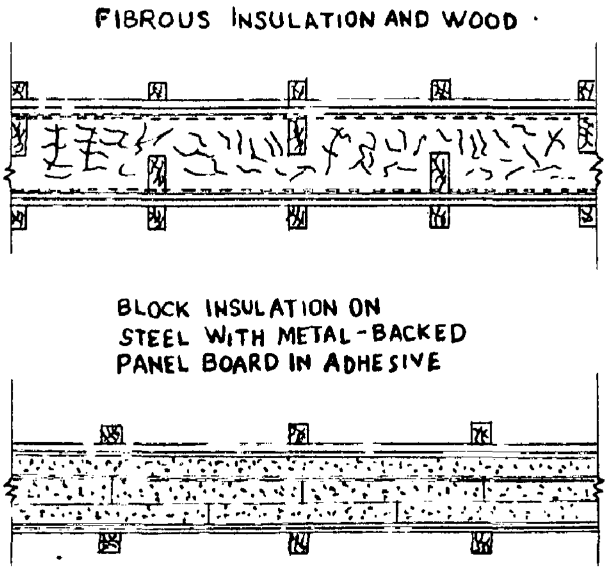
TYPICAL LONGITUDINAL SECTIONS (CEMENT AND ASBESTOS PANEL WITH METAL PLY) - SHIP'S SIDE

FIG. 5.15



TYPICAL TRANSVERSE SECTIONS AT SHIP'S SIDE

FIG. 5.16



TYPES OF WALL SECTIONS (DETAIL)

FIG. 5.17

backed with ½ x 200 wire mesh. Newer installations are now having cement asbestos panels laminated with aluminum. The walls are fitted with vertical cargo battens 18– 23" centers to hold the cargo clear of the insulated wall in order to permit circulation of air. (Fig. 9.18, 9.20 & 9.27) show the method of lining and insulation.

(ii) Floor

Floor covering should be elastic as well as moisture proof. The most satisfactory material is a mastic composed of emulsified asphalt, sand and cement. The material is applied cold, reinforced and expansion joints are kept to accommodate shrinkage and adjustment to movement of the ships structure.

Floor is usually subjected to much of water. For this, lead-pan is said red at all joints and drains (Fig. 9.18) are provided. They are led directly through the deck insulation and deck, and well below the steel deck a trap is located. This is insulated before and after the trap.

9.21 REFRIGERATION EQUIPMENT.

(i) Refrigerant

Fr-12 has now replaced the older use of dense air, carbon-dioxide and anhydrous ammonia.

(ii) Compressors

Reciprocating motor driven Fr-12 compressors are standard and are sized to fit the particular load. Capacity control may be affected by speed-variations or by automatic cylinder cut-outs. To give flexibility, reliability and plant efficient reserve units are installed as given in table 9.6.

Table 5.4

No. of units 100% load	Additional or Reserve Unit %	Total number of units
1	100	2
2	50	3
3	33⅓	4
4	25	5
5 or more	20	6 or more

(iii) Condensers

Shell and tube freon condensers, with sea water circulating through the tubes prove satisfactory but for the metals used in construction. A combination of silicon bronze tube sheets with bronze heads, together with zinc pencils and sufficient baffling to prevent erosion are in common use.

(iv) Receivers

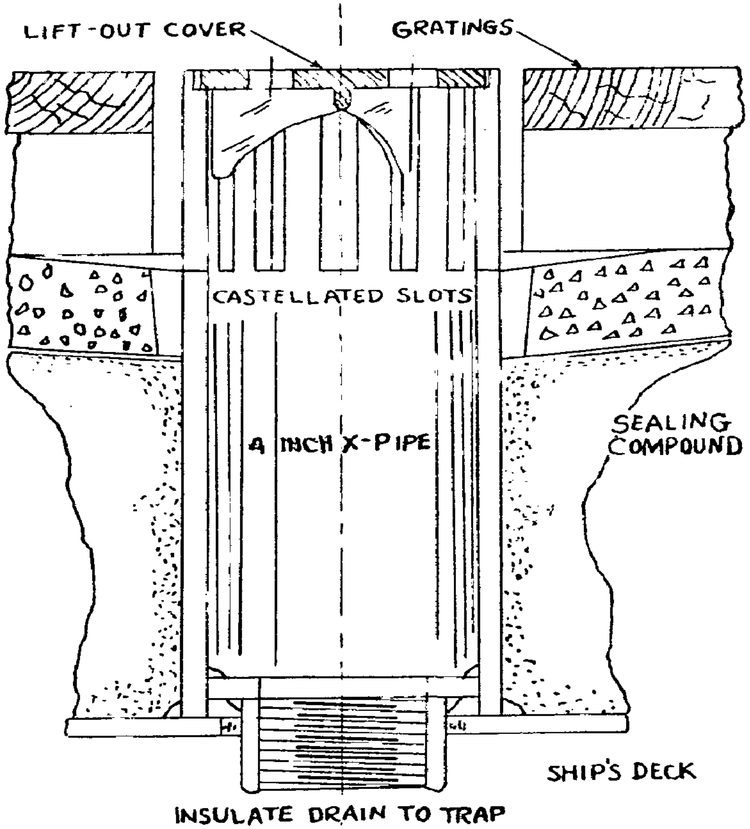
They are of welded steel of 20% reserve capacity and arranged to insure sub-mergence of the liquid outlet under all sea conditions.

(v) Evaporators

Besides the requirements of condensers, it should be able to resist corrosive effects of the brine. Cooling coils are finned type, fins being 8 per inch are in common use. Multiple parallel expansion results in improved flexibility, increased reliability, and better control at partial loads.

(vi) Fans

Static pressures are in standard practice. But 10-20% above the



FLOOR DRAIN FITTING

FIG. 5.18

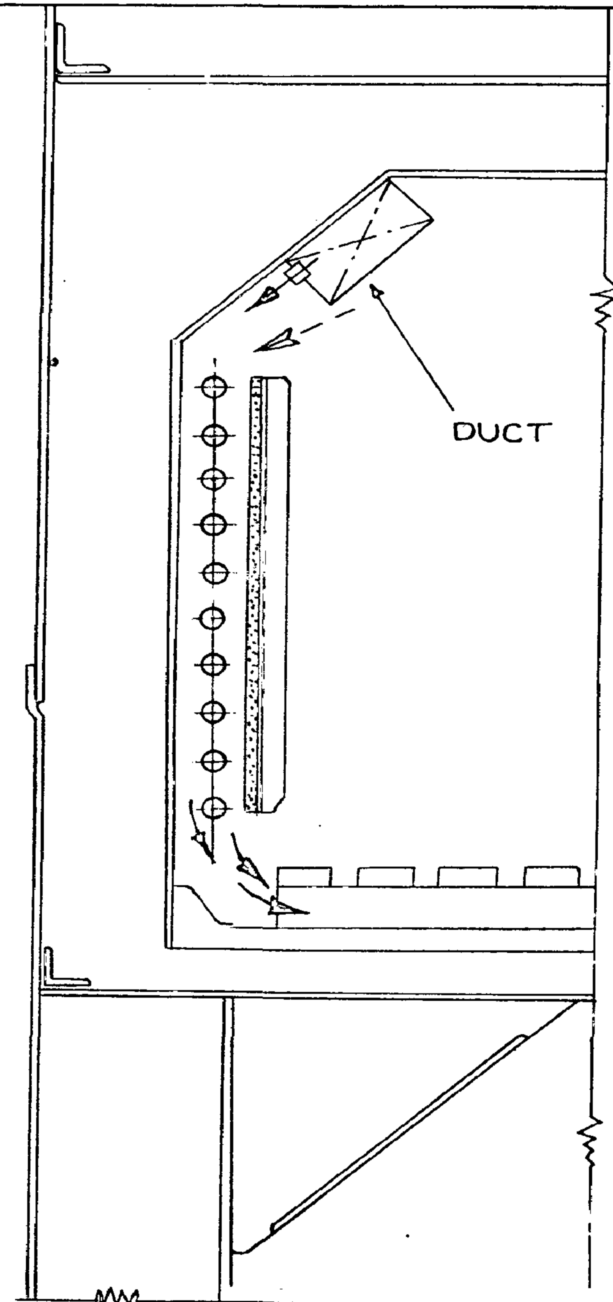


FIG. 5.19

SECTION SHOWING WALL COIL BAFFLE AND DUCTS design (assumed) static pressure results in shorter cooling-down periods and more even distribution of cooling air throughout the compartment.

9.33 AIR COOLING SYSTEM

1. Direct or Indirect System

Due to the following reasons an indirect system using calcium chloride brine is preferred over the Direct System of expansion -

(i) Flexibility of operation

Different temperatures required for different compartments is easily achieved by indirect system.

(ii) The brine having large sensible heat capacity, absorbs abrupt variations and eliminates the unwanted sensitivity of control.

(iii) Control such as manual may do the job of obtaining required room conditions.

2. Air Cooling Equipment

They may be any of the following -

(i) Wall coils (Fig. 9.20) Brine wall coils -

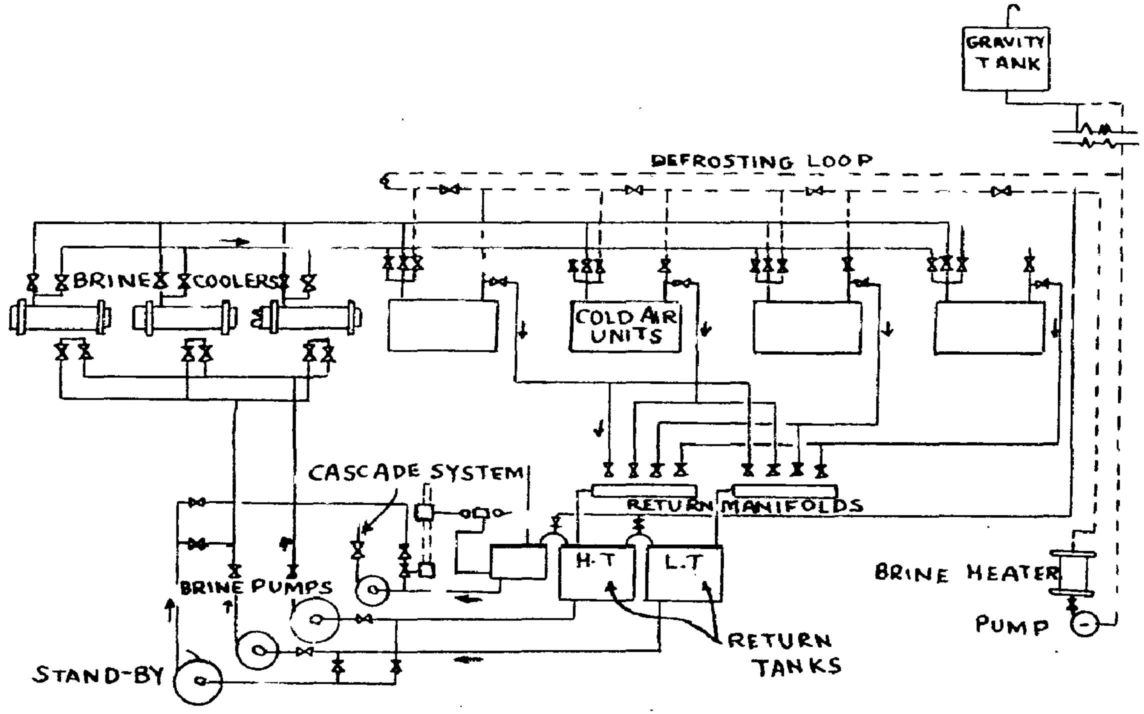
(a) have short, broad path of air circulation

(b) have low air velocities

(c) provide effective refrigeration

(d) minimise loss of moisture

These wall-coils have the limitation of providing refrigeration to a limited horizontal distance of 2½ times of wall height. Solid baffles over the face of the coil extended from near ceiling to near floors are provided. Circulating fans are installed at the ceiling and accessible from entrance [illegible] ducts discharge over the coil but not be enclosed



TWO-TEMPERATURE BRINE SYSTEM (RETURN TANKS OPTIONAL)

FIG. 5.20

between coil and baffle. These fans not only increase the efficiency of coils but effectively prevent stagnant air-space. Normally these coils are 1¼" pipe.

(ii) Diffusers.

They are installed when wall coils are too small to provide refrigeration. Diffusers are packaged units easily and cheaply installed and are fitted with distributing duct systems outlining the room.

3. Defrosting[60]

For direct system hot gas or hot sea water defrosting may be used, but the former involves much complications.

For indirect system defrosting is achieved by passing heated brine through the coils.

4. Brine distribution

Mostly marine plants operate over a wide range of temperature. To accommodate for providing temperature for fresh products and frozen food it has been suggested to use a two temperature brine plant with two circulating piping system served by two pumps on the line and a standby pump available for either system. Layout of such a system, as suggested[61] by WESTLING L.L. of Matson Navigation Corporation, U.S.A. is given in Fig. 5.20.

5. Temperature Control

For direct system control of air temperature is accomplished by a thermostatically operated solenoid valve and expansion valve metering the amount of liquid freon admitted to the cooling coil.

In indirect system liquid coolant (brine) between evaporator and the air acts as storage of refrigeration. This coolant itself is controlled thermostatically either by modulating valve or by means of pneumatic or electrical modulating devices.

Temperature recording devices like thermometers and disc charts recorders with gas operated thermal systems are in use[13]. For frozen food, a tolerance of ½ degree plus or minus at 0°F is considered satisfactory.

AIR TRANSPORT

5.23 SCOPE

The scope of air transport is on account of its speed. For commodities which get deteriorated due to slower speed of other modes of transportation, this is proving advantageous. During the months when ship passage is blocked by ice and also flowing of early season products into distant market, then high prices prevail, further increases its utility. Fruits and vegetables, flowers, poultry and baby chicks, meats and live animal are thus being transported.

5.24 EFFECT OF FLIGHT CONDITIONS (1).

(1) Temperature

This depends on the altitude, latitude, time of the day and season of the year. The outside temperature is subjected to wide variations[88] of about 5°F per 1000 ft., nevertheless, inside air ship temperature is not much affected during flights of 1-2 hours.

(ii) Pressure

At higher altitudes lower pressures are experienced. Test have indicated that even upto height of 30,000 ft no bad effect is created in quality however, reduced air-pressure results in an increase in the rate of water loss from certain commodities.

(iii) Humidity

Besides moisture-loss, rarefied air at high altitudes is low in water content. Tests indicate that during trans-continental flight humidity as low as 10-20% in June-July and 40% in November is experienced. But desirable conditions are of high humidity (90 - 95%) is accomplished by adding moisture to the package.

9.29 TEMPERATURE CONTROL

Temperature is affected by -

(i) Air temperature in cargo compartment
(ii) the initial commodity temperature
(iii) the nature of package and insulating material
(iv) method of loading
(v) Physical nature of the product.

The need of temperature control begins before delivery to the carrier and extends beyond delivery. Very little information is available regarding methods of obtaining suitable temperatures during transit. It has not appeared feasible to put mechanical refrigeration on cargo carrying planes. Undesirable temperature changes during transit are protected by -

(i) Cooling insulated compartments

In some cargo air craft, low temperature outside air (temperature may be even -60°F at high altitudes) is used to cool the compartments by means of thermostatically - controlled ventilation.

(ii) Special shipping cases

Frozen foods are packed in these containers made of wood.

(iii) Load blankets

Serving as insulation over the containers

(iv) Supplemental refrigeration such as package icing.

Dry ice placed in a plastic bag or wrapped in many layers of paper and tied to one of the cleats of the container is used extensively with frozen products. The amount depends on the type of container and the length of the journey.

5.11 GOOD HANDLING

All of the advantages of speed can be lost if the shipper, carrier and receiver do not follow good handling practice. Precooling, delivery by insulated refrigerated truck are of high value in addition to temperature control during transit.

C H A P T E R 6.

MARKETING

MARKETING

0.01 TECHNOLOGY

This involves -

(i) Production, packing and storage

(ii) Transportation

(iii) Marketing.

The first two have already been discussed and have a great effect on the marketing technology. A change in production, in freezing, in packaging or in transport may have an impact on other aspect of marketing scheme. However, marketing itself plays an important role in frozen food industry. A study of technical problems involved in it justify the good deal of attention paid to this aspect.

0.02 MARKETING PROBLEMS

During the earlier periods of the industry pioneers in the field had to face, and still face to some extent the unwillingness of the consumer to accept frozen food as equal to fresh unfrozen food. The reason is not far to seek. In adequate facilities for freezing, storing and transporting such foods may result in poor quality and therefore, low prices; and low prices create tendency towards freezing only the poorest grades of raw materials. This causes a downward spiral[67] in quality.

Opposition to frozen products may come on account of the reason that mass processing at production point would eliminate meat butchers, poultry dressers and fish butchers in retail stores.

Besides this the complicated steps in marketing cause troubles. It is not advisable to market frozen perishable products in the same way as non-perishable products since the latter can be more easily handled. The former have to be brought from the production point to the processing plants and shipping centres by special transport and stored carefully in sizable quantities both at processing and receiving centre. All these require careful drawing of scheme. In other words, producer has to follow goods until they reach the ultimate consumer (Article 6.03).

Establishing a chain store organisation is another aspect to be considered. Lack of such a system may result in improper and untimely distribution in the entire country.

Restriction of trade by agreements and exchange regulations both influence international trade and, therefore, become part of the technique of marketing. A study of all these problems may enable to find correct way of marketing frozen foods.

6.03 DISTRIBUTION CHANNELS.

The handling of product from manufacturer to consumer is complicated enough. Every transfer point offers unlimited opportunity for mishandling. The various steps[60] are -

(i) From freezing room to manufacturer's holding room (on and off the truck)

(ii) Possibility of movement from manufacturer to public warehouse space

(on and off the truck)

(iii) On truck to destination warehouse then off again.

(iv) Into the warehouse space

(v) Out of the warehouse on trucks to

(vi) Chain store warehouse for storage, or chain store break up room for immediate delivery, or distributor's warehouse for breakup and delivery to small chains and/or independent stores.

(vii) Product now goes to chain store back-up freezer or from distributor to individual stores.

(viii) It moves out of store back up freezer to floor freezer.

(ix) Moving to customers car or store delivery truck.

(x) Finally to home freezer space.

6.04 QUALITY CONTROL

For high quality frozen foods it is an absolute necessity that only strictly fresh products be frozen. Apparently it may seem to be beneficial to hide quality defects in frozen products which could be seen in raw material. But when such products reach the consumer and are thawed for cooking the defects are sure to appear. This is damaging to the trade in a frozen food. Hence introduction of fresh products is first "must" in the marketing scheme for frozen food.

Producer of frozen food must see that products during transit are handled properly otherwise if it reaches the consumer in bad condition, it slaps right back to the packer. With many other kind of preserved food, a bad product may only cause the consumer to change the brand. But if he gets a bad frozen product he may blame it all on the fact that it is frozen, and may even like to buy it. This hurts not only the individual packer but the entire frozen food industry.

6.05 PRICE CONTROL

Price of many frozen foods are higher than other type of preserved foods and is, therefore, main obstacle to increased consumption. In order to reduce its production marketing must be rationalized. Greater production, greater quantities frozen and stored and greater quantities for transport result in reduced cost of production, more efficient use of machinery and storage space, and lesser transportation cost. With this improvement frozen food come into line with other foods.

Technical development in food freezing help to reduce cost of production. Better methods of transport, thawing and cooking of frozen food lead to better marketing and distribution.

6.06 OTHER CONSIDERATIONS

(i) Marketing investigation

For introducing a new product market investigation leads to the nations consuming population but large quantities of consumers products are handled by brokers and special buyers. These men usually know the market demands and are on the look out for new superior goods. The investigation by brokers will be more analytical than investigators inquiries into market channels.

(ii) Acceptable packaging

When special containers of distinctive nature are used the curious and discriminating buyers are attracted and they may feel that they are buying something superior.

(iii) Variety acceptance studies

If it is learnt that certain variety is not accepted in market it should be frozen by newer and better freezing methods to produce better quality.

(iv) Need of cooperation

All of the distribution work must be done by organised effort; the farmer and the fisherman, the scientist and the technician, the labourer and the tradesman must work on together. The technology of production of sowing and harvesting, the technology of industry-of freezing and packing, and the technology of marketing-of buying and selling, if accompanied by the technology of cooperation and human relationship will make a good future of the frozen food industry.

S E C T I O N   III

C H A P T E R 7.

ILLUSTRATIVE EXAMPLES

7.01

Investigations so far discussed may now be carried out by considering certain illustrated examples where the foregoing principles are applied. In India consumption of fruits and vegetables depends upon their local availability, however, certain products are produced at one corner of the country and consumed at the other. Some of those products which utilise freezing for transportation etc. will be discussed here. They are -

1. Meat
2. Fish

MEAT

7.02 SELECTION OF MEAT

The conventional list includes ham, steak, pork chops, lamb-chops, roasts and other miscellaneous cuts in fresh meat line. Products containing salt such as ham, bacon and pork are not frozen. The products for freezing are all made from the standard wholesale cuts such as round and chuck. Freezer storage life depends upon the selection of these cuts because oxidation changes, that continue in storage, is a function of storage temperature, packaging condition and the initial quality of the meat.

7.03 PREPARATION

The yield of product from standard cut depends upon the amount of bone, fat and trimmings removed which approximate about 40% of total dressed carcass weight. This enables better by-product utilization by the packer, saving of freight cost and storage space.

The trimmed and boned cuts are then given a quick chill at a temperature under 28°F before the slicing operation starts. This makes meat firm and rigid so that neat and accurate slices of uniform thickness are easily obtained. The chilled meats are cut to any thickness as per package requirements.

Sound sanitary practices are required to get meat into best possible condition. This involves good control over temperature of working rooms (nearly °F), age of raw materials, sanitation inspection of equipment, and sanitary handling throughout.

7.04 PACKAGING.

1. Requirements -

The main function of a wrapping material is to prevent moisture loss from meat. An ideal material for packaging meat should have -

(i) Low moisture vapour transmission rate

(ii) Low gas transmission rate

(iii) High wet strength

(iv) Grease proofness

(v) Flexibility over a temperature range including below zero.

(vi) Freedom from odour, flavour and any toxic substance

(vii) Easy handling

(viii) Reasonable price.

2. Materials

There are many good packaging materials available. Notall packages are of two types -

(i) Inner wrap with outer package -

They are -

Vinyl coated paper

vinylidene coated

Polyethylene paper lamination

Polyethylene foil lamination

Polyethylene coated paper

Polyethylene tubing bag pouch

Cellophane foil lamination

Plastic coated paper

Silicon treated paper

Wax coated paper

Cry-O-Vac bag or pouch

Aluminium

(ii) Single layer material

They may be boilable film pouches, laminated foil and a wax dip coating compound similar to cheese wax.

(iii) Operation

Packaging must be neat, light and attractive. Wrapping should be so well done that it is free of air pockets. Even pin hole sized pockets are to be avoided since visibility will be lost when moisture condenses in the cavity forming snow or frost due to different in moisture content at different temperatures before and after freezing of meat. Additional trouble encountered during handling and shipping is the loss of surface contact between meat and the wrapping material. The solution of the problem[70] can be had by the use of transparent window consisting of a sheet of transparent material laid over the display side of the product prior to wrapping in a manner to exclude air. This has the following advantages -

(i) An air pocket occurring during wrapping can be easily worked out by hand.

(ii) The package can be handled before freezing without fear of losing surface contact even if the over-wrap is not airtight.

(iii) The bond between the meat and the window is not easily broken after freezing by consumer handling.

(iv) The film will act as a second moisture-vapour-proofing barrier.

The application of window material with some moisture absorbing qualities will have the following additional advantages -

(i) The absorbed moisture will increase the film flexibility to give better conformation to the meat surface.

(ii) The bond between the meat and the window is strengthened during packaging and after freezing.

(iii) The moisture may act as a second moisture vapour proofing barrier for the meat.

(iv) Meat bloom and colour can be retained longer during storage since moisture will be lost from the window material before leaving the meat surface.

7.05 EFFECT OF FREEZING TEMPERATURE ON MEAT

Quality of meat is effected by freezing temperature in the following manner -

(i) Colour of Meat

Meat frozen at different temperatures -20°F, -10°F, 0°F, 10°F show different colours and are brighter at lower temperatures.

(ii) Flavour

There is no marked effect of temperature on flavour

(iii) Structure

The size of ice crystals and area of ice between fibres decreases with lower freezing temperature. At very low temperature (-114°F) fibres split longitudinally but at higher temperature (20°F) large interfibrillar ice crystals are present.

(iv) Tenderness

Toughness decreases gradually with lower temperatures.

7.06 FREEZING METHODS

Freezing methods differ for different types of meats e.g.

1. Fancy meats (Livers, Hearts, Kidneys, Brains & Tongue of Hog and Beef)
2. Other packaged meats.

It is worthwhile to consider them separately.

1. Fancy Meats -

For chilling and freezing fancy meats the methods are -

(i) Overnight chilling

It consists of placing the meat on trays or pans to a depth of 2-4 inches with trays arranged vertically 8 to 10 inches apart on a tray

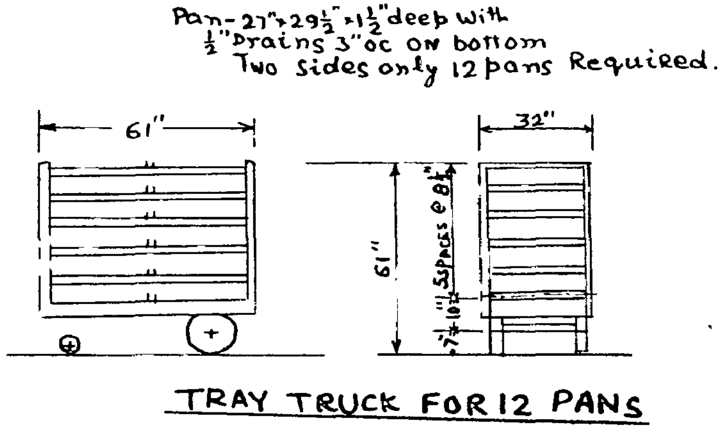


FIG. 7.1

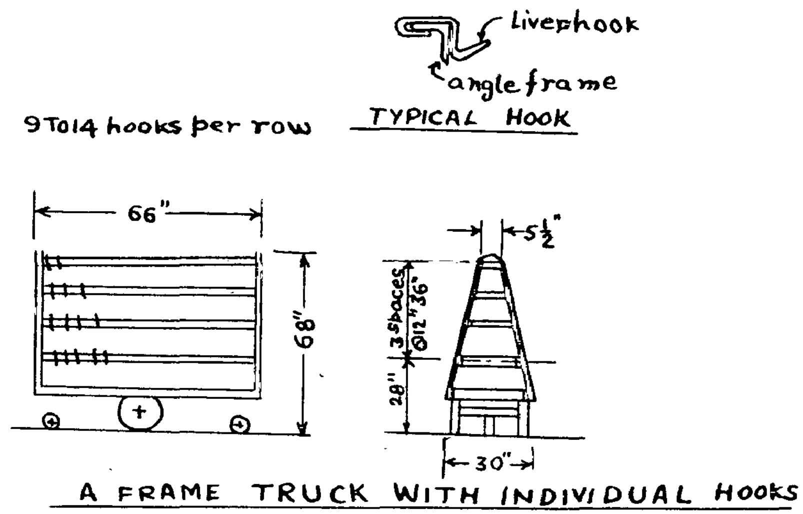


FIG. 7.2

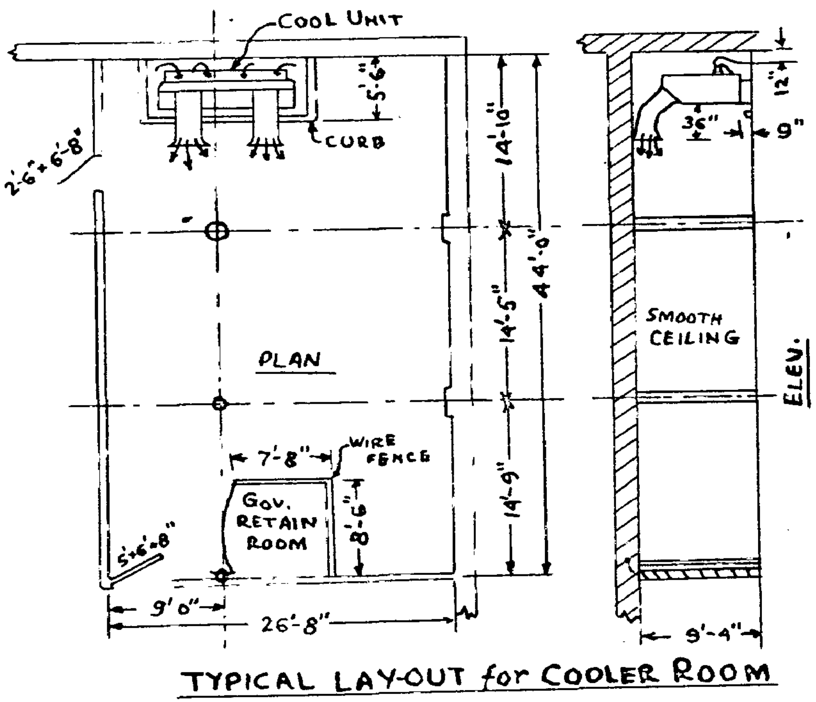


FIG. 7.3

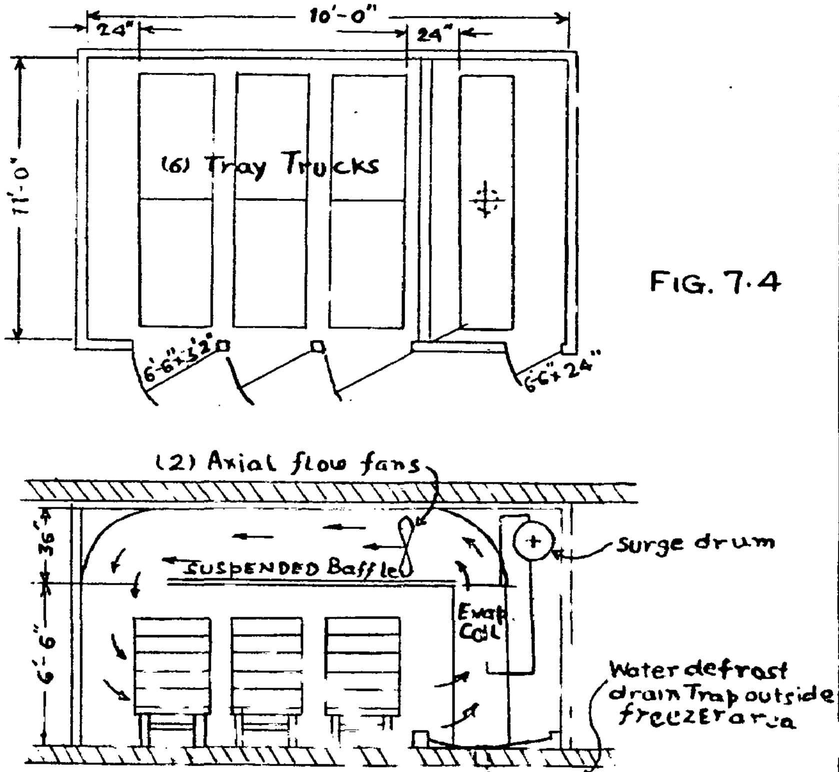


FIG. 7.4

truck (Fig. 7.1&7.2) A typical floor layout may be as shown in Fig.7.3 Refrigeration is supplied by individual unit coolers, dry coil surface of the various types available. 10°F temperature difference between refrigerant and cooler temperature is the desired condition for proper cooler operation. Though this method produces a satisfactory product but the shrink is very high.

(ii) Quick chilling

This is used for chilling trimmings and employs lower temperature (-5°F) and higher air velocity (800 - 1000 fpm) than the previous method. Care is exercised in the design of quick-chilling cabinet to provide for refrigeration load imposed by the hot products (Fig. 7.4). Prime surface evaporators with hot gas defrosting may satisfactorily freeze it to 32 - 36°F in normally half an hour. In addition of time saving this has an advantage of shrinkage reduction as given by the comparative statement in the table 7.1 below-

Table 7.1

Product	Average shrinkage in %	
	Method No. 1	Method No. 2
Beef, Hog Livers	6	2
Beef, Hog Hearts	6	2
Beef, Hog Cheek meat	3	1
Beef, Hog Kidneys	2½	1
Hog melts	2	½
Beef, Hog Brains	3½	2
Beef, Hog Tongues	4½	1

2. Frozen Meat.

Several method of freezing have been tried such as plate-freezing blast-freezing, stiff-air-freezing and coil shelf freezing. Plate freezing (at -30°F), although very rapid, results in almost complete loss of surface meat colour and appearance. Similar effect is noted with blast freezing between metal plates at -15°F. In still-air-freezing at 0°F no fracture of surface is caused but at the same time original red colour is lost giving rise to very dark coloured meat surface due to slower rates of freezing. Improvements have been suggested[70] in these methods. In plate freezing if two package are placed to make one packing (only during freezing) better surface results are obtained because the display surfaces are thus in centre and are last to freeze. In air blast freezing positioning the meat pieces at the same place from where they were cut and then allowing to cool result in better surface finish and colour.

7.07 REFRIGERATION LOAD

As suggested by L.E. Joslin[72] refrigerating effect may be computed by the formula

$$H_r = W_m (t_1 - t_2) S + W_t (t_1 - t_2) \times \cdot 12 + H_w + H_i + H_m$$

Where,

H_r = Refrigeration Load BTU/Hr.

W_m = Lbs of meat per hour

t_1 = Average initial temperature

t_2 = Average final temperature

S = Specific heat above freezing

W_t = Weight of meat truck per hour

.12 = Specific heat of steel if trucks are used for chilling

H_w = Heat gain per hour through walls etc. and is obtained from Table 2, Page 2, Chapter 13 A.S.R.E. Data Book (Design) 1957-58. It is given for each thickness and temperature difference (outside temperature minus refrigerator temperature). The formula is

$$H_w = \frac{(\text{Heat gain/sq ft/day}) \times \text{Area}}{24} = \text{BTU/Hr}$$

H_i = Heat gain per hour through infilteration and is given by the formula

$$H_i = \frac{(\text{No of air changes/day}) \times \text{room capacity} \times \text{heat gain/cft}}{24} = \text{BTU/Hr}$$

Where,

*Table 6, Page 8, Chapter 13 A.S.R.E. Data Book (Design) 1957-58 gives air changes due to infilteration for given room capacity.

Table 9, Page 3, Chapter 13 A.S.R.E. Data Book (Design) 1957-58 gives heat gain per cubic ft. for given storage temperature and % relative humidity of outside air.

H_m = Heat gain per hour through mechanical equipment and lighting.

Problem.

It is required to chill eight truck loads of meat from a maximum temperature of 105°F to 38°F in two hours. One truck weighs 480 lbs. empty; one truck holds 600 lbs. of meat. Walls, ceiling and floor are insulated with 6 inch of insulation and temperature difference through the walls is 45°F. Room temperature is to be held at 0°F with an outside air temperature of 90°F and 70% relative humidity. It is given that:-

Specific heat(S)	= .75 BTU/lb.
Room capacity	= 2000 cft.
Area of walls	= 980 sq.ft.
Motor	= 6 Horse power
Electric light	= 200 watts.

W_b	$= \frac{8 \times 6000}{8}$	= 6000 lb/hr.
$t_1 - t_2$	= 105 − 32	= 73°F
W_s	$= \frac{8 \times 600}{8}$	= 1200 lb/hr.
H_w	$= \frac{40 \text{ BTU/sq.ft} \times 950}{24}$	= 1600 BTU/hr.
H_l	$= \frac{1.40 \times 2000 \times 12}{24}$	= 1400
H_m	= 8 x 2500 + 50 x 0.4	= 20,020
$W_b(t_1-t_2)c$	= 6000 x 73 x 0.78	= 340,000
$W_s(t_1-t_2)x.12$	= 1200 x 73 x 0.12	= 10,500
H_T	= total	=305,000
*safety factor	= 10% of H_T	= 3,600
Refrigeration load	= Grand total	=400,000 BTU/hr. = 34 tons.

7.00 STORAGE

(a) Temperature

Lot of work has been done as regards producing best flavour and palatability conditions of frozen meat. It has been found that 0°F and in some cases even temperatures upto − 10°F provide best results. Care should be taken that fluctuation in storage temperature is not occurring because

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* In good practice 10–25% safety factor is added to the computed refrigeration load.

this effects development of rancidity about the mean temperature i.e. variation from -20°F to 10°F means an effect corresponding to that at 0°F.

(ii) Life

Life[70,79] of the frozen meat is estimated according to the desired flavour and acceptability at the time of reaching of the product to the consumer. Table 7.8 gives a rough idea of the life of various meat products stored at different temperatures.

Table 7.8 Life of Meat products.

Products		Months		
	10°F	0°F	-10°F	-20°F
Beef	4	6	12	18*
Lamb	3	8	12	18*
Veal	3	4	8	12
Pork	2	4	8	10
Chopped Beef	3	8	8	10
Pork Sausage	1	2	3	4
Beef Liver	2	3	-	-

7.09 DISTRIBUTION

Meat packing business is based on handling, large volume at low cost. The product may be loaded many times in its normal shipping cycle. It may be loaded in cars containing entirely frozen food or mixed car of frozen and fresh food. Transporting temperature suitable is 0°F, and care must be taken to maintain this condition. Besides this, it is necessary to have volume storage facilities at the farther end of distribution line, adequate facilities for distribution (wholesale and retail) as well as adequate home accommodations.

7.10 PROPER HANDLING

This aspect is equally important as freezing and storage and involves the following to be considered -

1. Thawing

Whenever practical frozen meat should be cooked from frozen state. If thawing becomes necessary it should be done at refrigerated temperature. Speed may be accomplished by placing the frozen product under running water but in no case thawing be permitted at elevated temperature because improper thawing results in multiplication of organisms and food spoilage. Also meat loses some of its nutritional value through loss of vitamins, minerals and soluble proteins in the juices.

2. Refreezing

After thawing and holding for some time refreezing is to be done. During this period micro-organisms initially present may multiply to some extent but the process is not much harmful. According to Prof. Thomas Ziegler[78] of Pennsylvania State University " Refreezing meat does not materially affect its quality. This does not mean that one should become careless but it suggests that it is needless to become panicky about using all the meat in a package that has been thawed, if it is more than is needed for that meal. Rewrap it, refreeze it and use it at another time".

This proper handling of frozen meat depend on -

(i) Holding product at 0°F or lower

(ii) Minimising fluctuations in storage temperature

(iii) Avoiding thawing and freezing

(iv) Educating the consumer for proper storage and preparation of frozen foods in the home.

II FISH

7.11 FISHERY PRODUCTS

Refrigeration of fish is about a century old technique. The term fish and fishery products include fish, 'shellfish' and 'crustacea'. From the time they are caught until delivered to the consumer in a proper condition needs careful consideration. For fish as with other frozen food, the same old procedures and techniques for packaging, freezing, storing and handling are adopted with slight modifications.

7.12 PACKAGING

In selecting proper packaging the factors considered are -

(i) the effect of unit package size on freezing and handling requirements

(ii) the protection afforded to the product by the package.

(iii) attractiveness and consumer appeal of the package.

The size and thickness depends upon the rate of heat transfer through the package. It should be thin enough to produce rapid freezing and thick enough to withstand heavy abuse. The size of the package be such that it fits the freezer properly. Besides this, the package should be moisture and oil resistant, fit the product tightly to minimise air space to check moisture entry.

Packaging materials in use for fishery products are paper board cartons with various waterproofing materials such as wax-coating or aluminium foil. The sizes are of capacity 8 oz to 15 or 20 lb. product.

7.23 FISH SPOILAGE AND FREEZING

Certain enzymes that occur naturally in fish and the bacteria which attack the flesh from outside once the fish is dead, cause alteration in physical character, and development of undesirable odours, flavours and sometimes appearance. All this activity is retarded when fish is frozen. During freezing water crystallises out leaving the salts present to be concentrated in the fish. The different concentrations at different temperatures produce different quality of fish hence one should specify the freezing temperature. From 30°F down to -20°F different quantities of water freeze out as shown in table 7.3 which indicates that major portion of water freezes from 30 to 25°F and almost all at -20°F.

Table 7.3

Temperature °F	30	20	15	- 5	-10	-20
Proportion of water frozen (%)	69	83	91	93.5	95	97.0

It has been established that quick freezing of fish has the following advantages -

(i) It chills the product rapidly preventing bacterial spoilage

(ii) Facilitates rapid handling of large quantities of product.

(iii) Makes utilisation of conveyors and automatic devices practicable, thus materially reducing handling cost.

(iv) Promotes maximum utilization of freezer space.

(v) Produces a packaged product of uniform appearance, with a minimum of voids or bulges.

7.24 FREEZING METHODS

These fishery products may be frozen in any of the following types of freezers as described below -

(i) Shelf Freezer

This is used for freezing round fish as salmon and halibut and panned fish. Ammonia F_{12} or chilled brine is circulated in coils to provide necessary refrigeration. For proper freezing the temperature of the shelf coils is kept between -20 and -40°F and the fish are placed on shelves in single layer.

(ii) Blast Freezer

An addition of fan to promote heat transfer is the main feature of this freezer. Air velocity is kept between 800 and 2000 fpm and conveyors are used to move the fish continuously through the blast room or tunnel. This is used for packaged fish fillets and scallops and may be used for round and shellfish.

(iii) Plate Freezer

Freezing is accomplished by refrigerant flowing through connected passage ways in the horizontal movable plates stacked. Vertically within an insulated cabinet. This is used for freezing packaged fishery products such as fillets, steaks, shrimp, fish blocks and scallops. This method provides a rapid and efficient freezing.

(iv) Immersion Freezer

As already discussed in chapter 2 this method provides rapid handling and is suited for freezing fish such as shrimp, haddock and cod tuna and halibut. Each requires a special technique. This freezing medium now contains glucose and salt in water.

(v) A new method

(Proton Method)[70] Round fish or fish fillets are frozen in a jellied mass having a freezing point below that of fish. The fluid filled in the freezer cell is a salt solution to which addition of sodium alginate, certain salts and diluted acid is done and the mixture after certain time turns to a jelly which after freezing forms a layer over fish. Thus this method eliminates the problem of glazing (discussed in article 7.13)

7.1 LOAD CALCULATION.

Total refrigeration for fish freezing consists of two parts

(i) Refrigerator load

(ii) Product load

The former is calculated by the usual method, as indicated in Chapter 18 A.S.R.E. Data Book (Design) 1957-58 and the latter is given by

$$Q = W\left[c(t_1 - t_2) + h_{ig} + c_i(t_2 - t_3)\right]$$

Where,

Q = heat removed (BTU)
W = weight of product (lb)
c = specific heat above freezing (B/Lb/F)
c_i = Specific heat below freezing (B/Lb/F)
h_{ig} = latent heat of fusion (B/Lb)
t_1 = initial temperature of product
t_2 = temperature at which latent heat is removed from product
t_3 = final temperature of frozen product (F)

The values of c, c_1, h_{if}, t_f and time for freezing for various types may be obtained from the tables 7.6 and 7.9.

Table 7.6

Fish	Water content %	Average freezing Pt. °F t_f	c	c_1	hif
Whole fish					
Haddock, cod	78	28	0.82	0.43	112
Halibut	75	28	0.80	0.43	108
Tuna	70	28	0.76	0.41	100
Salmon	64	28	0.71	0.39	92
Fish Fillets or Steaks					
Haddock, cod	80	28	0.86	0.44	115
Hake, whiting	82	28	0.86	0.45	118
Pollock	79	28	0.83	0.44	113
Shell fish					
Scallop	80	28	0.84	0.44	115
Shrimp	83	28	0.86	0.45	119

Table 7.5

Thickness of fish	Approximate round weight of fish (lb.)	Freezing time (minute)	
		10°F	0°F
2½	1 – 2½	55	35
2	2½ – 3½	83	53
2½	3 – 5	123	90
3	4½ – 7½	170	110
3½	7 – 10	320	145
4	9 – 12	420	205

Problem

It is required to cool 2000 lb of Salmon fish (Table 7.4) having thickness 2½" and approximate weight of fish as 6 lb per package. The cooling is to be done from 40°F to 0°F. Calculate product load –

From table 7.4, $C = .76$
$C_1 = 0.41$
$h_{if} = 98$

From table 7.5, time = 90 minutes

$Q = 2000 \left[.76 \; (40 - 28) + 98 + .41 \; (28 - 0) \right]$ = 222300 BTU

$q = \frac{Q}{hour} = \frac{222300}{90/60}$ = 167000 BTU h = 13.9 tons

Adding 25% for heat leakage and other losses
product load = 13.9 x 1.25 = <u>17.4 tons</u>

7.16 STORAGE AND QUALITY

Fishery products undergo changes in flavour, appearance and texture during storage. Proper storage temperature and maintaining good quality depends upon the following factors -

a. Temperature

During storage above 0°F it is observed that even the freshest quality fish is liable to be subjected to bacterial and enzymic action, oxidation, drying of surface and denaturation of proteins resulting in bad texture. All this is retarded by lower temperature, the lower is the temperature the longer is the life as shown in table 7.6 .

7.6

Type of fish	Life in months At various temperature of storage		
	15°F	-5°F	-20°F
White fish	2	4	8
Herrings	1	3	6
Smoke cured white fish	2	5	7
Kippers	1	3	4

b. Humidity

A high humidity in cold storage room is a desirable feature to check evaporation of moisture from the product. A larger temperature difference between room cooling coils (-15°F) and room temperature (0°F) means lower relative humidity, but this has to be kept due to practical consideration. Therefore, to maintain larger humidity a jacketed type cold storage room may be used to obtain humidities over 90%.

9. Packaging and Glazing.

Even at the lowest and most favourable temperature of storage it is necessary to protect fish by packaging and glazing; the former protecting product dehydration and subsequent quality loss. Glazing is a process by which the frozen fish is covered with a skin of ice by dipping it several times in water or by spraying it with water. It provides an envelope that fits more tightly than any wrapper and is comparatively slowly penetrated by oxygen, thus retarding development of rancidity in fish. Table 7.7 shows the approximate length of time a water glaze may be expected to remain on fish in cold storage.

° Table 7.7 Time required for ice glaze to evaporate from surface of the fish.

Fish	Weight prior to glazing g	Weight of glaze g	Weight of glaze in % by weight of fish	Duration of glaze (Days)
Mackerel	624	59	10.0	20
Haddock	906	140	15.3	88
Cod	2250	208	9.0	23
Flounder	530	64	12.0	20
Eel	590	61	10.0	16
Pollock	6570	728	11.1	38

° Published in A.S.R.E. Application Data 10.12, Vol. I, 1960.

4. Raw Materials.

It has been observed that if the materials are of the freshest quality there is virtually no deterioration due to cold storage.

5. Thawing

Thawing has little effect on quality in normal condition but in the zone of maximum deterioration (20 to 25°F) it is harmful.

6. Storage Life.

Storage life of fish can be increased if the following procedure is employed -

(i) Using only high quality of fish for freezing

(ii) Using proper packaging

(iii) Freezing immediately after processing or packaging.

(iv) Glazing prior to packaging.

(v) Putting fish in cold storage immediately after freezing.

(vi) Storing at 0°F or lower temperature

(vii) Renewing glaze during storage.

Life for few species is given in table 7.6.

Table 7.6 Storage condition and storage life for frozen fish.

Fish	Recommended protection	Storage life in months at 0°F
Chum, pink salmon	Ice glazing before packaging	4 - 6
Mackerel, sea herring		
Pollock, smelt	"	5 - 6
Tuna	Packaging	4 - 6
Flounders, halibut, whiting, shrimp	"	7 - 10
Haddock, Cod, Hake	"	Over 10

7.27 DISTRIBUTION

Frozen fish are transported in trucks, railroad cars, refrigerated ship, and by air then in small quantity. The modes have already been discussed in detail. A proper quality of fish during transportation and distribution to the consumer can be obtained if the following handling conditions are maintained -

(i) Frozen fish should be transported in carrier with ample capacity to maintain 0°F over long distances.

(ii) Refrigerated carriers should be precooled to 10°F before loading.

(iii) From warehouse frozen fish should be directly loaded in carriers and not allowed to remain outside on the dock.

(iv) Fish temperature should be checked with a dial thermometer before loading.

(v) Proper air-circulation around the product is necessary.

(vi) Refrigerated carrier temperature should be recorded continuously and an alarm system be provided.

(vii) Products when received in at retail store, should be put immediately into a 0°F storage room.

(viii) Display case temperature should not exceed 0°F, not be over loaded above frost line, and should be provided with alarm system.

These proper handling practices are of as much importance as the methods of packaging, freezing and proper storage and if kept in view may lead to good quality product and the development of frozen fish market.

BIBLIOGRAPHY

CHAPTER-1

1. Woolrich, W.R. & Bartlett L.H.; Freezer Storage, Section XVI, P[illegible], Hand book of Refrigerating Engineering, Third Edition 19[illegible]
2. Nectrol, J.F. & Prote, J.G.; Food Preservation, p. 1[illegible], House-hold Electric Refrigeration.
3. Gunther, R.C.; Principles of Cold Storage, Chapter 24, p. [illegible], Refrigeration, Air Conditioning and Cold Storage, First Edition 1957.
4. Proctor, B.E. & Phillips, A.W. ; Micro-Biological Aspects of Frozen Precooked Foods; Refrigerating Engineering , Vol. 5[illegible], p. [illegible], 1947.
5. Althouse & Turnquist; Frozen Food Refrigerators, Chapter [illegible], p. [illegible]-[illegible]; Modern Refrigeration & Air Conditioning, 1950.
6. Nickerson, J.T.R. & Proctor, B.E.; Micro-Biology of Frozen Foods Chapter [illegible]; A.S.R.E. Air Conditioning Refrigeration Data Book(Application) Vol.I, 19[illegible].

CHAPTER - 2

7. Woolrich, W.R. & Bartlett, L.H.; Quick Freezing of Foods, Section XVII, p.[illegible]-[illegible], Hand Book of Refrigerating Engineering, Third Edition 19[illegible].

8. Evans, C.F.; Theories & Methods of Freezing, Chapter 12, A.S.R.E., Air Conditioning Refrigeration Data Book (Application) Vol. I, 19[illegible].

9. Moll & Williams; Chapter 28 (Other applications) p. [illegible], Mechanical Refrigeration Fifth Edition 19[illegible].

10. Griffiths, E.; The Freezing of Food, Chapter VII p.[illegible]; Refrigeration - Principles & Practice, First Edition 1951.

11. Tressler D.K.; Methods & Apparatus for commercial freezing, Chapter VI p.67 - 76; Some Aspects of Food Refrigeration & Freezing, United Nations Food and Agricultural Organization, Washington November, 1949.

12. Mock, G.W. & Green, V.R.H.; Evaluating Food Freezing Methods; Refrigerating Engineering, Vol. 5[illegible], p. [illegible] - [illegible], 496 May, 19[illegible].

CHAPTER - 3

13. Tressler, D.K.; Construction of Cold Store Plants, Chapter 4 p.[illegible] - [illegible], Some Aspects of Food Refrigeration & Freezing, United Nations Food and Agricultural Organization, Washington November, 1949.

14. Ewell, A.W.; Ozone and its application in food preservation; Refrigerating Engineering, Vol. [illegible], p.[illegible], September, 19[illegible].

15. Tressler, D.K.; Refrigerating Machinery, Chapter 3, p. [illegible] - [illegible] Some Aspects of Food Refrigeration & Freezing, U.N. Food & Agricultural Organization, Washington November, 1949.

16. Thermal Insulation and Water Vapour Barriers, Part III Design Data Chapter 12, p.10, A.S.R.E., Air Conditioning and Refrigeration Data Book (Design) 1957-58.

17. Christensen, P.B., Haynes, D.O.; Materials Handling in Multi-Story Cold Storage Warehouses; Refrigerating Engineering, Vol. 56, p. 520 - 22, 538, December 1948.

18. Hunters, C.; Moisture in Walls of Cold Storage Rooms; Refrigerating Engineering Vol. 57, p.795-808 August, 1949.

19. Phero, U.L. ; Refrigeration for Military Cold Storage Plants; Refrigerating Engineering, Vol. 60, p.591-595, June, 1952.

20. Jones W.L. & Riddell, R.R., Insulating a mammoth Cold Storage Plant; Refrigerating Engineering Vol. 60, p. 846-47, August 1952.

21. McCoy, D.C. & Smith, J.A.; Locker Plants Chapter 20 A.S.R.E. Air-Conditioning & Refrigeration Data Book (Application) Vol. I 1950.

22. Trescoler, D.H.; Home Freezers present & Future, Refrigerating Engineering, Vol. 57, p.247-50, March 1949.

23. Domestic Refrigerator Conference, June 1950, Present and Future Insulations for Household units; Refrigerating Engineering Vol. 58, p.867-68, September 1950.

24. Cmalk, J.R.; Refrigeration in the Food Store Part II - Refrigeration Units & Cabinet Design, Refrigerating Engineering, Vol. 60, p. 962-960, 1008 September 1952.

25. McCoy, C.S.; Household Refrigerators and Freezers Part I - Refrigerators Chapter 23, A.S.R.E., Air Conditioning & Refrigeration Data Book (Design) 1957-58

56. Mc Geachen, E.G. & Fisher M.G.; Freezer Alarm Performance, Refrigerating Engineering, Vol. 58, p.334-336, April 1950.

57. Emmel, C.D. & Stoddard, E.S., Methods of Improving Food Preservation in Home Refrigerators, Vol. 65, p.39-43, Refrigerating Engineering, June 1957.

58. Cooper, L.M.S.; Upright and Chest Type Home Freezers; Refrigerating Engineering, Vol. 62, p. 966-972, September 1955.

CHAPTER - 6

59. Osborne, H.A., Refrigeration of Prepackaged Fresh Fruit & Vegetables Refrigerating Engineering, Vol. 61, p.742, July 1953.

60. Rear, J.C.; Precooling, Chapter 31, A.S.R.E., Air Conditioning & Refrigeration, Data Book (Application) Vol. 1, 1950.

61. Woolrich, W.R. & Bartlett, L.H.; Refrigeration of Meat, Fish & Poultry; Hand Book of Refrigerating Engineering, Section XII, p. 536-620, Third Edition, 1948.

62. Woodroof, J.G. & Roback, M.; Protective packaging of frozen foods Refrigerating Engineering, Vol 62, p. 43 - 45, Feb. 1954.

63. Griffiths. E.; Packaging Materials & Packages for Frozen Foods; Refrigeration Principles & Practice, Chapter X, p. 194-200

64. Trescolon, D.K.; Packaging Materials & Machinery Chapter V, p. 70 - 80, Some Aspects of Food Refrigeration & Freezing; Food & Agriculture Organization of U.N., Washington November 1950.

65. Woodroof, J.G. & DuPree, W; Frozen Food containers and Container Materials; Refrigerating Engineering Vol. 45 p.78-81 1943

56. Gorman, E.A.; Produce protection in Rail Transit, Refrigerating Engineering, Vol. 58, p.668-78 July 1950.

57. Sainsbury, G.F.; Improved Fruit Cooling Methods, Refrigerating Engineering, p.436 May 1951.

58. Nichol, E.R.; Refrigeration Design Considerations below -20°F, Refrigerating Engineering, Vol. 59, p.558 June 1951.

CHAPTER - 9

59. Peterson, W.E.; Refrigeration of Delivery Vehicles; Refrigerating Engineering Vol. 59, No. 4, p.331, April 1951.

60. Redit, W.H.; Refrigerated Truck Transport Problems; Refrigerating Engineering, Vol. 61, No. 5, p.526, May, 1953.

61. Phillips, C.M.; Trucks & Trailers, Chapter 32, A.S.R.E. Air Conditioning and Refrigeration Data Book (Application) Vol. 1 1950.

62. Tomlinson, O.H.; Electric Powered Mobile Refrigeration Gaining Momentum, Refrigerating Engineering, Vol 63, No. 11, p.60, Nov. 1955.

63. Green, M.D.; How to Truck Frozen Foods; Refrigerating Engineering, Vol. 64, No. 11, p.44 Nov. 1956.

64. Pollock, H; Unique Refrigerated Van Pays for itself in two years; Refrigerating Engineering, Vol. 64, No. 12, p.50, December 1956

65. Kirk-Patrick, N.J.; Specialized Refrigeration Equipment Meets Trucks Demands; Refrigerating Engineering Vol. 65 No. 9, p.53, September, 1957.

66. Griffiths, E.G.; Refrigerated Land Transport, Refrigeration Principles
& Practice Chapter XVII, p.334.
& Practice Chapter XVII p.334.

87. Eby, S.W. & Collister, R.L.; Insulation in Refrigerated Transportation Body Design, Refrigerating Engineering, Vol. 63 p.50, July 1955.

88. Kratzer, R.W.; Truck Refrigeration; Refrigerating Engineering, Vol. 50, No. 4 p.324 October 1945.

89. Albert, F.; Truck Trailer Refrigeration; Refrigerating Engineering Vol. 55 No. 1, p.31, January 1948.

90. Colbert, Lentz, Rooke; Effect of Bunker Ice Salt Concentration on Temperature, Refrigerating Engineering, Vol. 59, No. 10, p.968 - 69, October 1951.

91. Anderson, C.E.; Railway Refrigerator Cars; Chapter 38, A.S.R.E. Air Conditioning & Refrigeration, Data Book (Application) Vol. 1, 1959.

92. Tewksbury, R.D.; & Kelly, J.H.; 1952 Picture for Rail Road Refrigerator Cars, Vol. 60 p.263, March 1952.

93 Tewksbury, R.D.; Rail Transportation of Perishable Food Stuffs; Refrigerating Engineering, p.33 Vol. 61, January 1953.

94. Lentz, C.P. & Cook, W.H.; Transport & Storage of Perishables in Canada, Refrigerating Engineering, Vol. 61, No. 2, p.160, February 1953.

95. Mechanically Cooled Cars Introduce New Era for Low temperature perishables; Refrigerating Engineering, Vol. 61, No. 11 p. 1200, November 1953.

96. Penner, K.V.; Mechanical Refrigeration Versus Ice for Rail Road Shipment, Refrigerating Engineering, Vol.62 No.7, p.43 July/54

57. Henney, C.F. & McCoy, D.C.; Mechanical Refrigeration for Rail Road Refrigeration Cars, Vol. 62, p. 8, October 1954.

58. Elfving, T.M., Moisture Problems in low temperature, Rail Road Transportation, Refrigerating Engineering Vol. 63, No. 6 p.40, June 1955.

59. Aitken, G.R., Marine Refrigeration from the Operators Point of View Refrigerating Engineering, Vol. 62, p.51, May 1954.

60. Cook, W.H. & Reeves, T.A.; War time Refrigeration of Foods for Transportation at Sea, Refrigerating Engineering Vol. 44, p.378, 1943.

61. Hoelling, L.L.; Merchant Ships, Chapter 24, A.S.R.E., Air Conditioning and Refrigeration Data Book (Application) Vol. I 1959.

62. Griffiths, E.G.; Marine Refrigeration, Chapter XVIII, Refrigeration Principles & Practice, p.323

63. Claypool, L.L.; Kasmire, L.L., Perkins, W.T. & Mayer, W.N.; How to ship perishables by Air Vol. 60, p.337, April 1952.

64. Claypool, L.L.; Air Shipment of Fruits & Vegetables, Vol 60, p.480 Refrigerating Engineering, May 1952.

65. Reilly, W.H.; Air Transport, Chapter 37, A.S.R.E. Air Conditioning & Refrigeration Data Book (Application) Vol I 1959.

66. , Jacob [illegible], How to Handle precooked Frozen Food – Frozen Food Conference Part XIX , Vol 6[illegible], p.[illegible], 19[illegible].

CHAPTER – [illegible]

67. Tressler, D.K., Some Aspects of Food Freezing, United Nations Food & Agricultural Organization, Washington, November 1950 Chapter 12

68. [illegible] & [illegible] , Quick Freezing of Foods, Chapter XVII, p.[illegible]

69. Clarence Birdseye, Looking Backwards at Frozen Food, Refrigerating Engineering, Vol. 6[illegible], p.[illegible] Nov, 19[illegible].

CHAPTER – [illegible]

7[illegible]. Robertson, R.J., Preparing Frozen Meats, Refrigerating Engineering, Vol. [illegible], p.77[illegible], August, 19[illegible].

7[illegible]. [illegible], G.H., How to Handle Frozen Meats, Frozen Food Conference Part XXI, Refrigerating Engineering, Vol.[illegible], p.[illegible], Oct. 19[illegible].

7[illegible]. Jordan, L.R., Chilling & Freezing Poultry Meats, Vol [illegible], p.[illegible], Refrigerating Engineering, September 19[illegible].

7[illegible]. [illegible], [illegible], Meat Products, Chapter 2[illegible], A.S.R.E., Air Conditioning & Refrigeration Data Book (Application) Vol.X 19[illegible].

74. Segal, [illegible]; Load Calculation for Commercial Refrigerators Chapter [illegible] A.S.R.E. Air Conditioning & Refrigeration Data Book (Design) 19[illegible].

75. Butler, C & [illegible], J.[illegible]; Fishery Products, Chapter 24, A.S.R.E. Air Conditioning & Refrigeration Data Book (Applications) Vol. I 19[illegible].

76. Griffiths, [illegible]; Fish Freezing, Chapter VIII, Refrigeration Principles & Practice, p114

77. Butler, C., [illegible] J.F. & [illegible], D.O.; Fish Freezing at Sea, Refrigerating Engineering Vol. [illegible], p.[illegible], June 19[illegible].

78. Lorentzen, G.; Fish Freezing Plant in Bergen, Norway, Refrigerating Engineering Vol [illegible], p. [illegible], April 19[illegible].

79. Plank, R; New Fish Freezing Method Improves quality, Refrigerating Engineering Vol. [illegible] p.[illegible], July 19[illegible].

80. Butler, C.; Handling Frozen Sea Food, Frozen Food Conference Vol.[illegible] p.[illegible], August 19[illegible].