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MODERN FREEZING METHODS AND COLD STORE DESIGN 1/

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GENERAL

Man's oldest enemy - hunger - is still to be conquered. A large proportion of the world's population goes to sleep hungry and an even larger proportion suffer from bad malnutrition. Today the situation is growing worse in many parts of the world, due to the lack of rain, where this is most essential. The world's shortage of food can be noticed all over the globe. There are a number of investigations, which all show a catastrophic picture for the years to come.

It is alarming to note that theoretically, the food production is sufficient enough to give all of us a satisfactory diet. Even if the main problems - those of distribution between areas of over production and those of shortage - seem insoluble there is place for great improvement of the existing situation.

In countries which suffer most from food shortage, it is commonly found that wastage of foods is in the order of 25-40%. Locally even higher figures are found. The wastage is to a large extent caused by pests, rodents and climate conditions. A little less than 50% of the food production can be classified as highly perishable products, whereas most foods must be regarded as perishable products. It is essential that those classified as highly perishable products are preserved in an adequate way. In countries with tropical climate, the traditional ways of preservation, sun drying and smoking, very often change the nutritional value of the product in a drastic way. As an example it can be mentioned that during sun drying of fish, infestation from insects is reported to lead to 50% change of the original protein content.

Refrigeration technology has a vital role to play in the struggle to solve those problems. The highly perishable protein rich products should be stored and transported under controlled temperature. Figure 1, clearly illustrates the benefits of low temperature storage and frozen storage for such products.

In the shadow of the energy crisis, which recently hit most countries in the world, it is interesting to note that refrigeration is one of the cheaper methods of food preservation. This provided that the aim of the preservation is to preserve the original quality of the product, with regard to nutritional value and sensory properties. One of the main consuming parts of the preservation when comparing different methods is the packaging material. The energy needed for the packaging material only when processing a 250 gram pack of peas is illustrated in figure 2.

A comparison between canning and freezing taking into account only the special processing operations (figure 3) shows that canning is almost three times more expensive than freezing.

There is very little doubt that refrigeration can offer several advantages in the war against waste. This has also been realized in a number of countries fighting this war. In the first place one has concentrated the application of refrigeration to highly valuable products, intended for export. However, an increase in the use of refrigeration both for chilled and frozen products for domestic use can be noted.

The main problems in the domestic use of refrigeration is that of the infrastructure,mainly lack of distribution and retail equipment. It is therefore essential to make a clear distinction between the use of refrigeration for export and for domestic use in the initial stage of introducing this preservation method.

With regard to the export application, it is essential to meet the quality standards, as well as other standards, set by the importing market demands. This means e.g. that In-Line Individual Quick Freezing (IQF) is essential, as this will give a high quality product, which is more valuable on the export market. This part of the application of refrigeration therefore calls for sophisticated freezing methods.

For the domestic market, where in the initial stage the distribution and marketing of the frozen product are less developed, there is no need for a highly sophisticated freezing method to produce IQF products.

It is furthermore of utmost importance that time is allowed for the planning of the application of refrigeration on new domestic markets. Therefore in short term planning, freezing and frozen storage should be used, in order to prolong the life of the product and to make distribution over longer distances possible. The product may well be sold in a thawed state. It is also evident that the frozen product can be used for further processing like, smoking, drying and canning. The freezing will then ensure a high quality raw material for processing. The main aim to start with is to fight wastage, taking care of and utilizing the protein resources available. During the initial stage there will be time to develop the important infrastructure to a nationwide coverage from the embryos now existing in the more urbanized parts e.g. major cities.

In the following, different types of freezing equipment, as well as some economic fundamentals will be discussed. Also some fundamentals on cold storage lay-out and localization, as well as recent trends in Europe will be covered.

FREEZING METHODS

The development of food freezing during the last 20 years, has shown a need for standards and definitions for frozen foods. Such standards and definitions have been set in a number of countries and work is carried out on an international basis as well.

In the first place, it is essential to distinguish between freezing and frozen storage. Freezing refers to the actual freezing process during which the water content of the product is transferred to ice, the temperature of the product decreasing from ambient to the storage temperature in question. Frozen storage is the storage at the constant temperature chosen.

Frozen food must be subjected to a freezing process specially designed to preserve the quality of the product by minimizing physical, biochemical and microbiological changes both in the freezing process and during subsequent storage. The freezing process should be carried out in such a way that the zone of maximum crystallization (-1 - -5°C) is passed through rapidly and the freezing is completed only when the equilibrium temperature reaches -18°C. The equilibrium temperature or levelling out temperature is the temperature obtained after thermal stabilization has been achieved under adiabatic conditions.

In the early days the freezing process took place in the storage room or in rooms equipped with a surplus of refrigeration capacity. Very soon specially designed equipment was introduced - freezing tunnels. Up till now the freezing process has been carried out batchwise on racks or trolleys. The development of more sophisticated methods in the food processing industry have led to an integration of the freezing process into the production line i.e. In-Line Freezing. This concept has become essential not only from a processing point of view, but also from a quality as well as an economic point of view.

Besides the In-Line Freezing, recent developments have given Individually Quick Frozen products. Individual Quick Freezing (IQF) has given a number of advantages to the industry as well as to the consumer. A number of products are packed prior to freezing. However, this is quite a disadvantage especially when dealing with products with a short harvesting or processing season.

If those products are to be consumer packed after freezing, the necessary capacity of the packaging equipment will have to be very high. In this case products are instead bulk packed in big palletainers or bags. Then packaging into retail packages is done off-season according to sales. There are also other advantages like independence of changes in size of packages and the need for different packages on different markets. A prognosis with regard to the need for different packages on differet markets for a whole year must be regarded as almost impossible.

FREEZING EQUIPMENT

The freezing equipment may be divided into the following groups with regard to the medium of heat transfer:

1. Air - Blast Freezers
2. Metal - Plate Freezers
3. Liquid - Immersion Freezers
4. Boiling Liquid - Liquid Nitrogen -
   Liquid Fluorocarbon Equipment
5. Gas - Carbon Dioxide Freezers

Blast freezers are used for all kinds of products, packed or unpacked, blocks or IQF products; the plate freezers and immersion freezers accept only packed products, and boiling liquid freezers are used mainly for IQF products.

All those methods are today used in the food industry, however, with some concentration of equipment, which can be operated In-Line like automatic tunnels, belt freezers and fluidized bed freezers. In a brief summing up, the following can be said of the basic fundamentals of the different pieces of equipment.

Air

Because air is the most common freezing medium, a large range of equipment designs exists. The following main types can be distinguished:

- Storage Room
- Blast Room
- Stationary Tunnel
- Push Through Tunnel
- Automatic Tunnel
- Belt Freezer
- Fluidized bed Freezer

Even if a storage room should not be considered as freezing equipment, it is sometimes used for this purpose. However, freezing in a storage room involves so many disadvantages that it should be used only in exceptional cases. The freezing is so slow that the quality of almost all products will suffer. If products are already stored in the room, their quality is jeopardized because flavours may be transferred from the warm products to the frozen. Furthermore, the temperature of the already frozen products may rise considerably.

As a storage room is not designed for freezing, the evaporators may frost up so quickly that the total refrigeration capacity is reduced to below what is required to maintain the storage temperature. In total this will result in a more expensive freezing, as compared to freezing utilizing especially designed equipment.

A blast room usually consists of a storage room in which a surplus of air coolers have been installed. The air coolers are equipped with fans, which create some turbulence in the air. As there is no control of the air circulation, the result is a fairly ineffective heat transfer from the surface of the product. Consequently, a blast room should not be used for products with small cross sections as during the slow freezing they will be exposed to excessive dehydration losses.

The stationary freezing tunnel is the simplest type of freezer, which can be designed to produce satisfactory results for the majority of products. It is built up of an insulated enclosure equipped with refrigeration coils and fans, which circulate the air in a controlled way over the products. (Figure 4).

The products are placed on trays, which are then placed into a rack in such a way that an air space is left between every layer of trays. The racks are moved in and out of the tunnel manually. It is important that the racks are placed in such a way that the air cannot bypass them.

The stationary freezing tunnel is an universal instrument as practically all products can be frozen by using this equipment. Whole, sliced or diced vegetables may be frozen in cartons or unpacked in a 30-40 mm thick layer on the trays. The slabs formed when freezing unpacked products are broken in a cluster-buster and a reasonable free flowing product is obtained. Spinach, broccoli, meat patties, fish fillets, prepared foods etc., are usually frozen packed in this type of equipment.

By using different types of racks rather thick packages may be frozen and also whole meat carcases can be handled. It must, however, be observed that when changing from unpacked to packed products or to a thicker package, the freezing time will increase, which means that the capacity of the equipment will decrease. The design and construction of the tunnel is important, in order to obtain as fast freezing as possible and to minimize weight losses.

The flexibility of this type of freezer makes it very suitable during the initial stage of the development of a new frozen food market, as broadly sketched above. However, the flexibility is balanced by high man power requirements and considerable weight losses if improperly used.

A certain degree of mechanization is achieved in a push-through tunnel where the racks are fitted with castors or wheels. The racks or trolleys are usually moved on rails by a pushing mechanism, which is often hydraulic powered. (Figure 5).

This type of freezer has generally the same advantages and disadvantages as the stationary tunnel. However, the labour costs can be decreased, but the flexibility is somewhat less. Products with different freezing times should have separate tracks.

The demand for automatic operation of freezers has led to a great variety of designs of freezing tunnels with a higher degree of mechanization such as:

The sliding tray freezer, travelling tray freezer, carrier freezer and the reciprocating spiral freezer.

Basically the sliding tray freezer consists of one great rack accommodating many big trays on each tier. At one end of the construction there is an elevating mechanism, which lifts entering trays to the top tier, where it is pushed in, forcing all the other trays on this tier to advance one step. The tray at the far end is pushed onto an elevator, which lowers it one tier where this tray is pushed in. Thus on every odd tier the trays will be advancing and on tiers with an even number they will be returning. For each tray that enters all trays will advance one step.

In another version the trays move only on one tier at a time, which gives almost the same result. This version is sometimes equipped with a "plate freezer" arrangement on the first 20-30% of each tier. This eliminates the bulging of packages, but on the other hand it requires more space.

All mechanisms are usually hydraulically powered. Outside the freezer enclosure, automatic loading and unloading of the trays may be arranged. Each tray is exposed to considerable mechanical stresses, which limits both width and length. This freezer is therefore suitable for moderate capacities of intermediate size packages only.

In the travelling tray freezer, the trays are connected to two sturdy roller chains at each end. These are arranged to move the trays forward to a set of sprockets, which elevate the trays one tier whilst they maintain their horizontal position. This type is built as large as those previously mentioned, but require more space because the minimum pitch between the tiers is decided by the sprockets which are 200-300 mm dia.

The carrier freezer may be regarded as two push through tunnels on top of each other. In the top section a row of carriers are pushed forward whilst they are returned in the lower section. At both ends there are elevating mechanisms. A carrier is similar to a book case, with shelf levels. When it is indexed up at the loading end of the freezer, the product on one shelf at the time is pushed off the shelf onto a discharge conveyor. When the carrier is indexed up next time, this shelf is in level with the loading belt from which new products are transferred to the carrier. (Figure 6). The carriers may be desgined for almost any pitch between the tiers and for any length and width. This allows maximum compactness. The loading and unloading may be manual or fully automatic. In the latter case speeds around 200 packages a minute are achieved, which represents the highest capacities presently used.

The conveying element in the reciprocating spiral freezer consists of two parallel sets of rails. The one set is fixed. In between there is a set of movable rails. The products rest initially on the fixed set. The movable set lifts the product clear of the fixed set, advances one stroke, descends to leave the products resting on the fixed set again and then returns to the initial position.

Both sets are arranged to form a big spiral, the fixed set supported from an external steel structure and the movable set fitted to a central cylinder. This provides a reciprocating motion around the vertical axis as well as up and down.

The infeed can be arranged very simply for a range of carton sizes, provided the utilization of the conveyor area is limited. Small items must be placed on trays, which are to be loaded, unloaded and transferred from outfeed to infeed separately.

As the total product load is accelerated and decelerated for each stroke, a relatively slow motion is necessitated. The freezer is mainly suitable for intermediate and large package sizes.

Those automatic freezer designs are primarily intended for packed products. Attempts to freeze unpacked fish fillets, meat patties etc., individually on the trays invariably have been only moderately successful, because of a number of problems.

The products will stick to the trays, causing damage and weight losses if products are removed mechanically. An alternative is to heat the trays to release the products, which requires complicated equipment and causes reduced capacity. Furthermore the trays must be washed after removal of the frozen product if acceptable hygienic conditions are to be obtained. The handling of the trays from outfeed to infeed of the freezer is costly whether it is manual or automatic.

There are some principal advantages of automatic air blast freezers, as compared to automatic plate freezers, which are usually the alternative. Products of different thickness may be frozen either simultaneously or in immediate succession after each other. Furthermore the product shape does not need to be square.

The first belt freezers basically consisted of a mesh belt conveyor in a blast room, which satisfied the need for a continuous product flow In-Line Freezing. In addition to the disadvantage of the poor heat transfer in a blast room, many mechanical problems also arose.

Modern belt freezers normally utilize vertical air flow forcing the air through the product layer, which creates good contact with all product particles. A condition is, however, that the product is evenly distributed over the whole belt area. Where the product layer is thin or non-existent, there is less resistance to the air, which will concentrate to these areas and by-pass the thicker product layer. This phenomeon is called "chanelling" and may result in poorly frozen products. Therefore it must be avoided by careful even spreading of the product across the total belt width under all operating conditions.

The single belt freezer, the multi-tier belt freezer and the spiral belt freezer are the main groups of belt freezers in use today.

The simplest type is the single belt freezer consisting of a single belt exposed to an updraft of air. It is suited for relatively dry or deep fried products, which do not tend to freeze to each other and form clumps, e.g. fish sticks, french fried potatoes and bakery products. Wet products tend to form clumps and ice buildsup, which jeopardizes the belt life.

For large through-puts the single belt freezer will require very large floor space. This is reduced by building several tiers above each other. This arrangement has another advantage in that the product, after being surface frozen on the first belt, may be stacked in a rather deep bed on the lower belts. Thus the total belt area required is reduced. (Figure 7).

This type of freezer is suitable for IQF of deep fried fish sticks, fish portions, bakery products etc., whilst the longer freezing times for packed products in most cases make them uneconomical to freeze. This is of course even more pronounced for single belt freezers.

By stacking up to 30 tiers of the belt above each other, a minimum of floor space is occupied by the freezer. (Figure 8). In the most advanced designs of the spiral belt freezer , a special belt is used, which is wound around one or more drums. The belt is supported by rails and driven by the friction against the rotating drum. The belt is continuous, which means it runs outside the enclosure at the infeed and outfeed ends of the freezer. This is an advantage as product transfer points are the most likely causes of problems. Here the products are placed on the belt outside the freezer where it can be supervised and will stay on the same spot until leaving the freezer. As there is just one belt, this can be continuously cleaned during the freezing process.

The flexibility of the belt allows for more than one in- and outfeed using the same belt and furthermore in- and outfeed may be arranged in any direction wanted.

Both unpacked and packed products are frozen. Typical products are meat patties, fish cakes, fish fillets, bakery products, all of which may be frozen raw or cooked. This freezer gives a very large flexibility with regard to the product range to be handled.

Fluidization occurs when particles of fairly uniform shape and size are subjected to an upward air stream. (Figure 9).

At a certain air velocity, the particles will float in the air stream each one separated from the other, but surrounded by air and free to move.

In this state the mass of particles can be compared to a fluid. If it is held in a container, which is fed on one end and the other end is lower, the mass (fluid) will move towards the lower end, as long as more products are added. The product is frozen and simultaneously conveyed by the same air without the aid of mechanical conveyor. (Figure 10).

The use of the fluidization principles, gives a number of advantages in comparison with the use of a belt freezer. The product is always truly individually quick frozen (IQF). This applies also to products with a tendency to stick together e.g. french style green beans, sliced carrots and sliced cucumbers. The freezer is totally independent of fluctuations in load. If partly loaded, the air distribution can be the same as for a full load, i.e. no hazard of chanelling. If overloaded no products flow on to the floor.

The reliability when freezing wet products is greatly improved because the deep fluidized bed can accept products with more surface water. Consequently, there is no hazard of belt damage if a dewatering screen breaks down temporarily.

The freezer is an In-Line Freezer suitable for vegetables, fruit and berries and also for processed products, such as french fried potatoes, peeled cooked shrimps, diced meat, meat balls,etc.

Metal

In a plate freezer the product is pressed between metal plates. The refrigerant is circulated in channels in the plates, which ensures a very good heat transfer. This reflects in short freezing times, provided the product itself is a good heat conductor, as in the case of fish fillets or chopped spinach. However, it is also necessary that the packages are well filled and that metal trays used are not distorted.

The advantage of good heat transfer at the surface is gradually reduced with increasing thickness of the product. For this reason, the thickness is often limited to a maximum of 50 mm.

The pressure from the plates during the freezing eliminates any "bulging" that may occur in air blast tunnels. Thus the packages will be even and square within close tolerances.

Three main types of plate freezers can be distinguished:namely horizontal plate freezer, automatic plate freezer, and vertical plate freezer.

The Horizontal plate freezer usually has 15-20 plates. (Figure 11). The product is placed on metal trays which are pushed in between the plates manually. This means more handling than is required even for the stationary tunnel. In both cases the product is placed on trays at the end of the packaging line. The trays are loaded in a rack or on a trolley, which is transported to the freezer. In the case of a stationary tunnel, the product is frozen on the rack whilst another reloading is required for the plate freezer.

In order to obtain automatic operation of a horizontal plate freezer, the whole battery of plates are movable up and down in an elevating system. At the level of a loading conveyor the plates are separated. Packages which have been accumulated on the infeed conveyor are pushed in between the plates, thus ~~so~~ discharging a row of frozen packages at the opposite end of the plates. This cycle is repeated until all frozen packages have been replaced. Then the space between the plates is closed and all plates are indexed upwards.

The vertical plate freezer was developed in particular for the purpose of freezing fish at sea. The equipment consists of a number of vertical freezing plates forming partations in a container with an open top. The products are simply fed from the top and the frozen block is discharged either to the side, upwards or down through the bottom. Usually this operation is mechanized. In most cases whole unpacked fish is frozen but also fillets are frozen. The block thickness varies between 50-150 mm.

Liquid

For irregularly shaped products e.g. chicken, good heat transfer can be achieved in an Immersion Freezer. This equipment is built up on a tank, containing a cooled brine e.g. a glycol solution. The product is immersed in the brine or sprayed whilst conveyed through the tank.

Immersion freezers are most commonly used for surface (colourset) freezing of poultry. The final freezing is made in a separate blast tunnel or during cold storage. The later alternative, however, involves quality hazards because of slow freezing of the core.

The product must be protected by an absolutely tight thick quality packaging material. The residue of the brine on the package is washed off with water at the exit of the freezer.

High quality products require double handling, which is not required when using modern air blast freezers. These are most common alternatives as they nowadays have been improved to satisfy the special demands with regard to the colour setting of poultry.

Boiling Liquid

Mainly two liquids or freezants are used, Liquid Nitrogen (LN_2) and Liquid Freon Freezant (LFF).

Liquid Nitrogen of -196°C is sprayed into a small single belt freezer. The nitrogen evaporates and is allowed to escape to the atmosphere after the vapours have been used for precooling of the products. (Figure 12).

The low temperature gives a fast freezing, which can be an advantage from a quality point of view for some products, but it may also result in cracking of the product surface if sufficient precautions are not taken.

LN_2 freezers are often used for surface freezing like the immersion freezers. If final freezing is to be carried out, the LN_2 consumption is in the order of 1,2 - 2,0 kg per kg of product, which makes the operation too expensive. In spite of this, the low investment and simple operation makes this freezer economical for small production rates with a utilization of less than 500 hours/year.

The Freon freezant is a specially purified dichlordifluormethane, which has a boiling point of -30°C. The equipment consists of a container into which the product is fed and dropped in a flowing stream of freezant. (Figure 13). Due to the extremely good heat transfer the surface is frozen instantaneously so the product may be stacked on a horizontal freezing belt, where it is sprayed with freezant until completely frozen. A discharge conveyor brings the product up and out of the freezer.

On contact with the product, freezant evaporates. The vapours are recovered by condensation on the surface of refrigerated coils. Due to the large difference in density between air and freezant vapour, the later remains in the container with only marginal losses to the atmosphere.

This freezer is used for products like corn, beans, shrimps, and berries. Also products like meat patties and fish fillets may be frozen if sprayed already on the infeed belt, instead of being dropped into flowing freezant.

A positive separation of even slightly sticky particles when dropped into the freezant, is one of the main advantages. Another is the very rapid freezing as the product may be exposed to freezant spray with programmed intervals. It is possible to freeze faster than with LN_2, as product cracking limits the freezing rate in the later case. Due to the instantaneously freezing of the surface, there is no measureable weight loss, due to dehydration. The operational costs are close to those of air blast freezers, because the freezant is recovered.

Gas

Also other gases than air (and liquid nitrogen) are used for freezing. Only recently the carbon dioxide (CO_2) freezer has been further developed.

The freezer can be considered a development of a liquid nitrogen freezer. Instead of liquid nitrogen, liquid carbon dioxide is used as freezant, which is injected directly into the freezing chamber. Due to its extremely low evaporation temperature at atmospheric pressure, liquid nitrogen cannot in practice be contained in pressure vessels so a certain loss occurs during distribution and storage. Over and above what is consumed in the freezer around 30% is required to cover these losses. The corresponding loss is very low for carbon dioxide because it can be contained in vessels at moderate pressure.

The main difference is, however, that carbon dioxide can be recovered and recondensed in a compression cycle. (Figure 14). This has made large installations economically possible. In order to avoid mixing in of air a slight positive pressure is maintained in the freezer chamber, which means that there is a continuous loss of freezant vapours, through product entry and exit openings. Thus the total recovery normally is limited to 80% of the total amount of carbon dioxide circulated.

Another important difference is that carbon dioxide does not exist as a liquid, but only as a solid gas or a gas at atmospheric pressure. Consequently, the advantages of high heat transfer due to direct contact between the liquid freezant and the product cannot be achieved.

ECONOMICS

Freezing equipment is at the same time the most expensive and the least expensive link of the modern processing chain. Quite often the freezer represents the largest investment in a modern line, whilst its operating cost usually is in the order of only 3-5% of the total. This means that savings that can be made in any other processing step often cut away the total freezing cost. It is natural therefore that the attention of management is concentrated on such parts of the process once the freezer is installed. The freezer is given undivided attention only before the investment. Often the main topic is: "How to make it cheaper". Very often this results in the choice of equipment, which is quite primitive in design.

In figure 15, it is clearly shown how important it is not to fall into this trap. In the diagram the variation in total freezing cost with the number of hours it is utilized per year is illustrated. In the freezing costs, the investment of the freezer and engine room, all power, labour and maintenance costs are included. The weight loss of the product is shown separately. These costs are also compared with the cost for packaging products. Of course the packaging cost may vary within wide limits, but normally it is several times greater than the total freezing cost.

One essential factor when choosing freezing equipment is that of weight loss, which occur during freezing. Figure 15 also shows that the weight loss during the freezing process may be almost of the same order, as the cost of operating the freezer. This applies to a cheap product like peas. It is of course even more important for expensive products like meat and sea food.

Product losses may be divided into the following categories:

Wastage, mechanical losses

Degrading

Dehydration

Wastage refers to products dropped to the floor, sticking to conveyor belts, juice dripping etc., all of which are very specific for each plant. Usually one only needs to walk along a processing line and watch carefully to establish the cause of such losses. A modern freezer should have almost no losses of this category.

The second category refers to damage to product, breakage and similar, which renders the product unsaleable at a top quality price or it will require cost for reprocessing. This is usually carefully recorded and analysed in each plant and therefore does not require further comment.

It is primarily the third category that has caused confusion. The evaporation of water vapours from products during freezing cannot be seen. It becomes evident as frost on evaporator surfaces but this may equally well be caused by excessive ventilation of warm air into the freezer.

A lot of publication space is and has been used for reports on the new super fast freezing methods, like liquid nitrogen, liquid Freon and carbon dioxide freezing. These are compared to "conventional air blast freezing" and savings in weight losses in the order of 3-7% are often claimed. For most products such claims simply disqualify the comparison of being relevant. Even in the simplest "conventional air blast freezing equipment" the above described batch tunnel, the weight losses should only be in the order of 1-3% if the freezer is properly designed and properly operated. It is particularly the late development towards IQF of hamburgers, fish fillets and similar thin products, which is being carried out in old tunnels, designed for cartoned products that create excessive weight losses.

It should be noted that the still air inside a carton diffusion-tight or not, often creates larger dehydration losses than the unpacked products would have had. However, the frost stays inside the carton. Modern air blast freezers will give a weight loss in the order of 0,5 - 1,5%.

Many of the claims regarding quality improvements and reduced weight losses in a cryogenic freezer can be related to the fact that the modern air blast freezer is of a much more advanced design than the cryogenic freezer. Every laboratory can easily arrange freezing of samples in liquid nitrogen, but there are very few scientific institutions in all of the world that have equipment to be able to simulate the conditions in e.g. a commercial fluidized bed freezer. Also advanced belt freezers offer better heat transfer conditions than those available in most laboratories.

Consequently, there is often no practical interest in comparisons of new freezing methods to "conventional air blast" because this later expression is not usually referring to today's advanced designs.

The ability of a freezer to produce higher product quality, higher product value, is of course, as important as lower product losses. The freezing method may simply be a condition for rendering the product saleable. Throughout the frozen food era, the scientists have stressed the importance of a fast freezing. However, this is again one factor to which a number of misconceptions adhere.

False economy very often impedes wisdom when searching for a cheaper solution to the freezing problem. It must be remembered that in one week only, a modern freezer will produce products of the same value as the total investment for the freezer. Only a few percent decrease in weight loss or increase of the sales price of the product will determine the profit. It is also apparent that one cannot take any risks with regard to the reliability of the freezing equipment or variations in capacity. Even very small differences which cause trouble in production, will compensate for the difference in price between a primitive and an advanced freezer design.

CONCLUSION

The selection of freezing equipment must be done with great attention with regard to the design, way of operation, as well as economics. It must be observed that economics are not only a question of investment, but of operation and maintenance costs. The reliability of the equipment is of utmost importance.

Among the equipment described above, some designs will after further studies crystallize as superior to others. It is, however, important that such an evaluation besides economics and reliability also takes the quality of the finished product into account.

COLD STORES

The general design of a cold store is determined by the requirements of effective and safe handling of merchandized and suitable storage climate for the products.

Cold stores can be divided into production stores and distribution stores, or a combination of both.

It is very important to investigate the initial and future role and desired function of the cold store, before making the lay-out and design. Besides the lay-out and design, localization is an extremely important factor.

With regard to localization the pattern of today's society with an increasing urbanization taking place all over the world, the agricultural parts of the world, in most cases, will be located away from the main large consumption areas. The latter areas are today to an increasing extent more and more industrialized and the increase in environmental conditions do not allow for cattle breeding or other agricultural activities around the large cities.

This has called for the two types of stores - production and distribution stores. It has become a rule to place a bulk store at both ends of the main trunk road i.e. in the area of production as well as in the area of consumption.

Another important factor from a localization point of view is that roads, railroads and sometimes waterways should be close by. The production store does not necessarily have to be next door to the processor. The most important thing is that the products can be transported in and out of the store and that sufficient space is given for the handling of the products at the premises.

The localization of the distribution store maybe more debatable This type of store is normally situated in a rather large city. The question is, if it should be placed within the city or on the periphery of the city. In many harbour cities of the world, a distribution cold store has been placed in the harbour, in order to take care of import and exports as well.

Taking a closer look at such a localization, one can state that in most cases the harbour is a part of the city. This means that the traffic to the harbour has to pass through the city. With the increase in traffic this creates problems and furthermore large vehicles are to an increasing extent forbidden in the inner parts of large cities.

One must also remember that a boat to be unloaded or loaded cannot always be anchored right outside the harbour store. If not, handling will be expensive. The cargo unloaded from the boat will be collected by a fork lift truck, placed on a lorry, which will deliver the goods to the cold store site, where another fork lift truck will unload the lorry. As this is an expensive piece of equipment, a fork-lift truck just unloads the cargo in the yard and another truck has to bring the products into the cold store later on.

The number of lorries and fork lift trucks involved is heavily increased as compared to the ideal situation where the boat is anchored just outside the cold store. Furthermore, the products may suffer from increase in temperature during handling and transit outside the refrigerated area.

The alternative to the harbour store is a store in the periphery of the city. In this case the fork lift truck loads on to a larger, preferably refrigerated, lorry, which takes the frozen products straight out to the store through the city. Depending on distance and time for the transport an insulated vehicle may be used.

Considering in both cases that the lorries spend most of the time standing being loaded or unloaded even a rather small improvement in the efficiency of the handling at a more distant store, will compensate for the few minutes extra it takes to cover the distance. (Figure 16).

In most cases the store will receive and dispatch as much cargo by road and rail as by ship. The harbour localization will be a disadvantage in those cases. (Figure 17). Also another difference between the two localizations will influence the efficiency of the handling and thereby the quality, as well as the economics. This being the lay-out of the store.

The lay-out of the cold store is influenced not only by the size and type of operation but also by the price of the land. In the above example of a harbour store versus a store on the pheriphery of the city, it is likely that the land in the harbour is more expensive than the land outside the city. This will, no doubt, influence the lay-out of the cold store e.g. the area set off for handling will be smaller in the harbour and probably one will go for a multi-storey building. Decisions both of which will influence the efficiency of the cold store in a negative way.

Single storey cold stores have proved to be superior to multi-storied. The normal arrangement is that rooms are built side by side between road and railroad and loading ramps. (Figure 18). Thus all rooms can communicate directly with the loading banks. Extensions are made by adding new rooms sidewise and extending loading banks and traffic yards. The engine room should be placed centrally also after extensions, in order to avoid long pipe runs. Production cold stores or bulk stores are today built in size of 20 000 - 50 000 m^3, but there are some plants in Europe which have reached the size of more than 200 000 m^3. The room size in such bulk stores varies between 800 - 2 000 m^3. In order to keep the investment cost down, the room size should be as big as possible, but fire risks set an upper limit.

Also from a handling point of view a room can be too large. The storage height varies from 7,25 m up to 9,25 m, the latter figure is achieved thanks to be improved lifting capacity of modern fork lift trucks.

Distribution stores are normally built to the size of 500 - 10 000 m^3. The turn-over rate is normally high, which has great influence on room sizes, storage height and lay-out. In order to keep handling costs down, the storage rooms are sometimes equipped with special pallet racks and break-up arrangements. The trend today in the distribution stores is towards faster product movement, which has made the handling technique more and more important. There are already a number of fully mechanized stores in operation. The technical approach varies from rather simple equipment to fully automated plant utilizing advanced data techniques. However, common for them all is that they must be economically justified. Figure 19, illustrates the variation of operation costs with investment costs and turn-over. Most of the mechanized stores seem to have a turn over of at least 30-40 times a year. It is considered that at least 20 times turn over must be reached before fully mechanized stores should be considered.

The investment cost per cubic metre storage volume decreases with increasing total volume. A store of 50 000 m^3 has half the investment per cubic metre of a store of 5 000 m^3 and more important approximately half the annual operation cost per cubic metre. This means that merchandise should be stored as long as possible in the big stores instead of being spread out in small expensive depots.

It has until recently been common to erect cold stores using traditional building techniques using material of conventional type, bricks and concrete. Today new techniques with light constructions for storage and industrial buildings are used. Almost 90% of the American and 50% of the European new cold stores are built this way.

One example of the light construction building technique using panels as a complete wall element comprising external cladding, vapour barriar, insulation and internal cladding. From a technical point of view, it is a so called sandwich panel, where the external facing and vapour barriar is a special aluminium sheet called Kal-Zip and the internal facing is very light corrugated aluminium sheet. The core is polyurethane foam with very good insulation and strength properties.

The panel can be manufactured in one piece in a length up to 20 metre, with a width of 1,2 metre. This means that all conventional cold stores can be built without horizontal joints. Furthermore the size and light weight of the panels makes it possible to erect faster than with other panel systems. The panel can also be used for external roof insulation without any additional roofing.

There are no wooden frames or other heat bridges and the joints are filled with polyurethane foamed in situe after erection of the panels. This means that the vapour barriar and insulation are continuous and form a complete unbroken envelope around the cold store.

Already ten years ago the first screw compressors were used in Europe for refrigeration applications. The last years an increasing number of those units have gone into operation and a continuous intensive development program in order to make them competitive also for small capacities is going on.

Refrigeration units can today be purchased as packages i.e. package engine room units containing compressors, vessels, controls and electric panels in one unit. After positioning it is only connected to the condenser and the coolers in the storage room. Both these units can also be delivered as package units.

The air coolers must be designed and located so that an even temperature can be maintained throughout the store even under severe conditions and without generating high air velocities in the chambers.

Large evaporator surfaces, air distribution through air ducts or false ceilings normally ensure this. The air coolers should be located so that they are easy to serve and in such a way that they cannot be damaged by product handling. Defrosting is normally carried out automatically with timer or semiautomatically by pressing push buttons when defrosting is desired. This carried out with hot gas or electrical heaters and defrost water is drained away in heated hoses through the wall or pumped up on the roof.

In order to improve safety may control easier and cheaper most modern refrigeration plants are automated. The degree of automation may vary, but normally in the room temperature, compressor capacity, lubrication, cooling water, defrosting pumps, fans, current and voltage of the main supplies are controlled and supervised by central control panel in the engine room.

CONCLUSION

Localization and lay-out are vital points in the investigations to be carried out prior to the building of a cold store.

Modern light industrial constructions utilizing prefabricated panels are to be prefered to traditional building techniques from an economic point of view.

Mechanized stores must work with a very high turn over and should only be considered on highly developed markets.

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MODERN FREEZING METHODS AND COLD STORE DESIGN[1]

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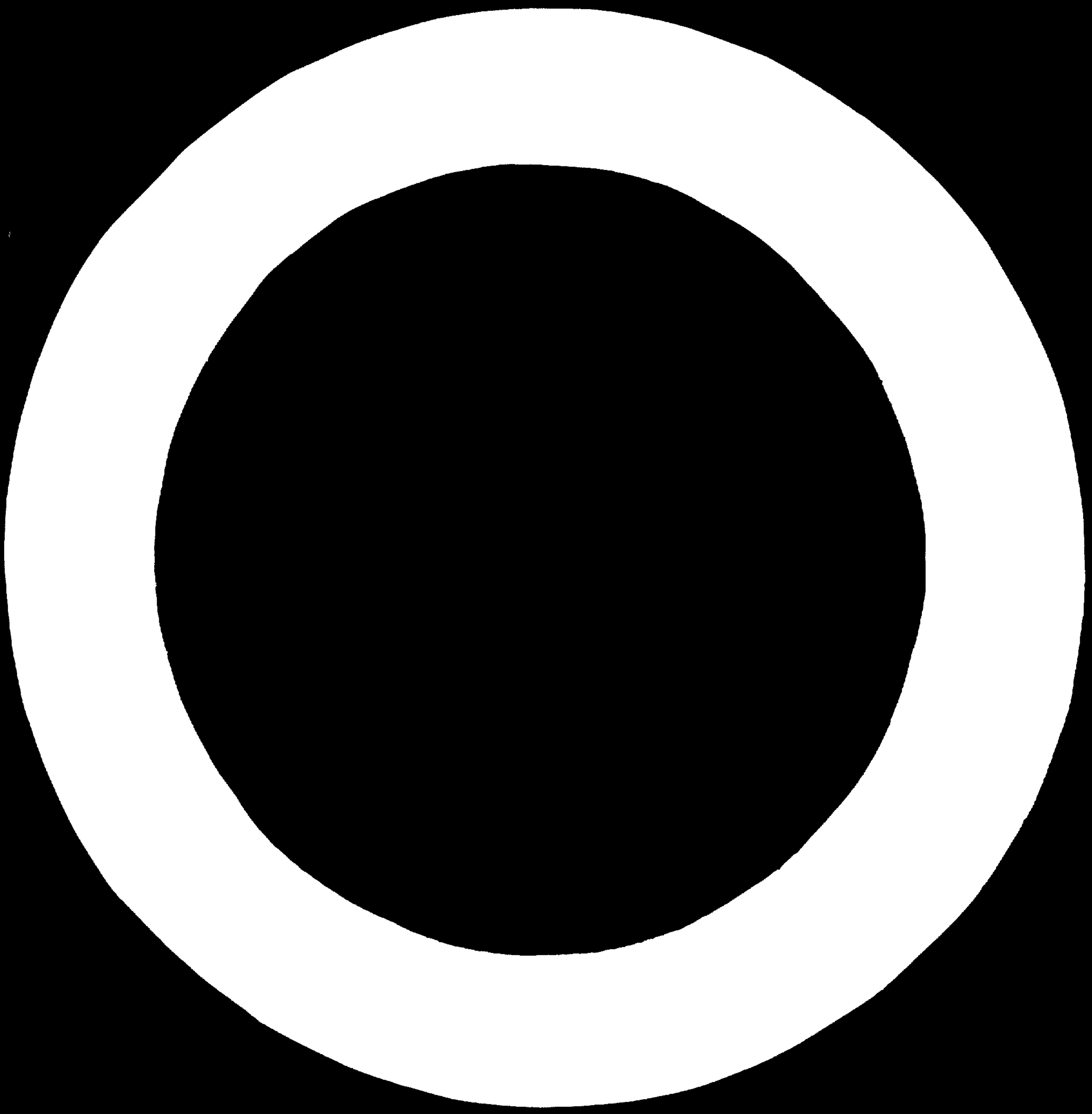

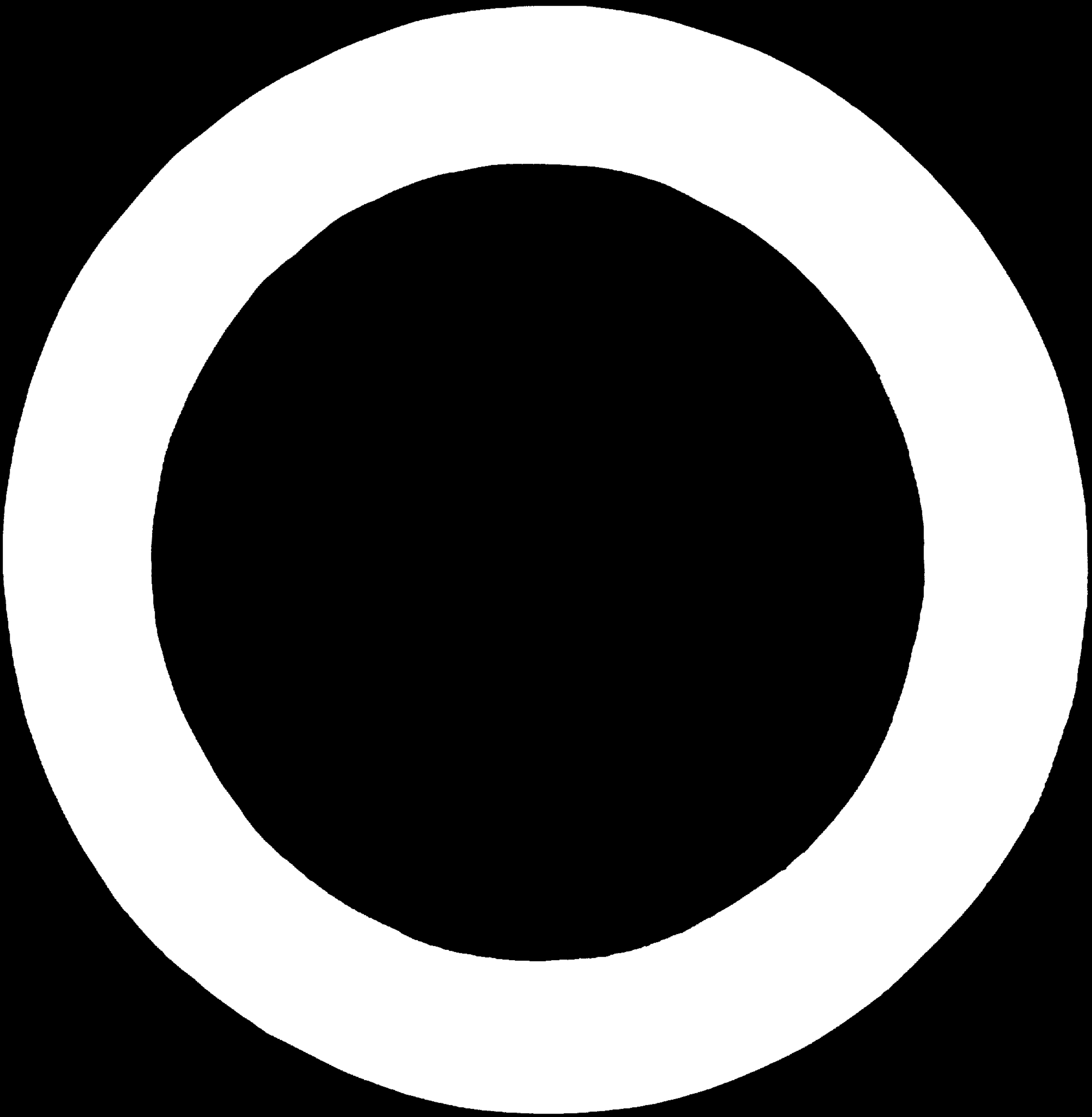

Appendix I

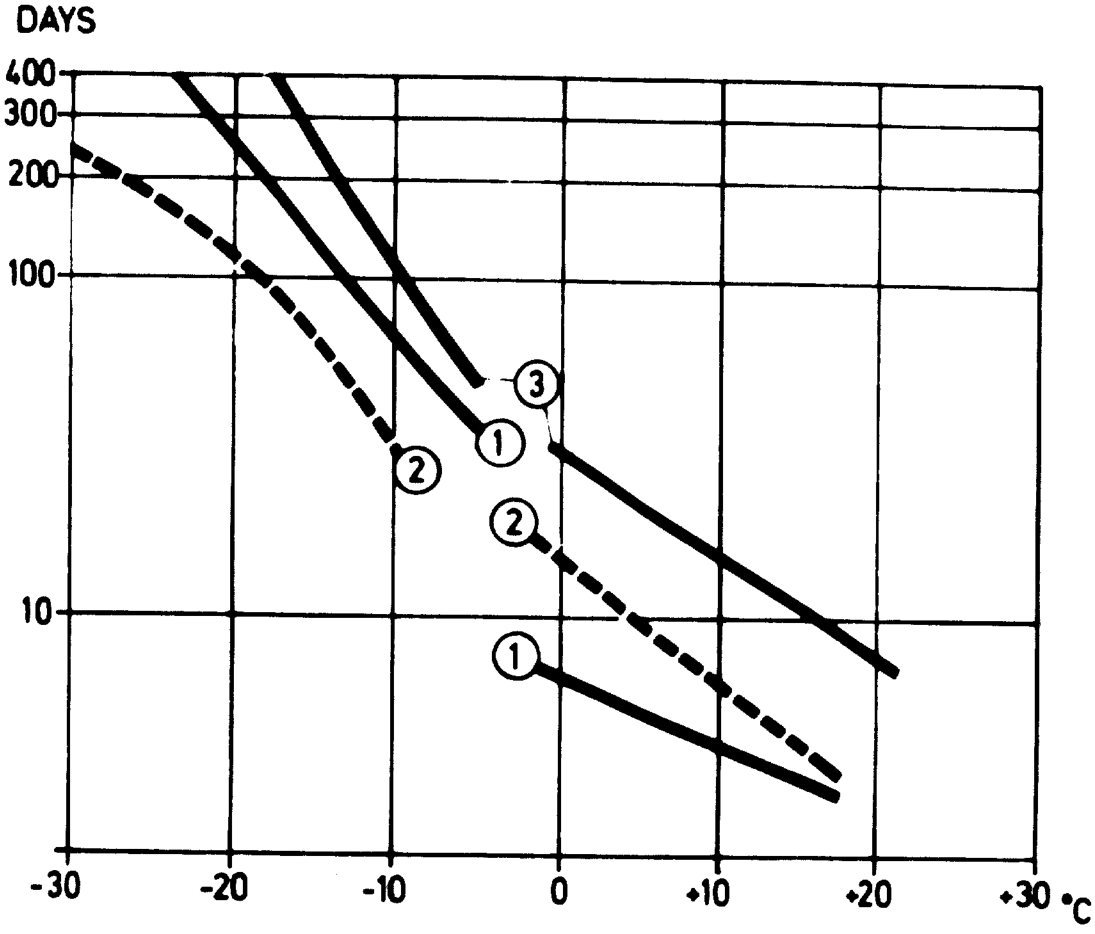

Fig. 1. Storage life for some perishable products

1. Chicken
2. Beef
3. Fish

Packaging material	Energy index
Tin can	7
Glas jar	12
Polyethene laminated paper	3
Polyethene bag	1

Fig. 2. Energy needed for packaging material for a 250 gr pea pack.

Process	Energy index	
	Canning	Freezing
Freezing	-	1
Sterilization	2	-
Cooling	2	-
Packaging	33	13-5
Storage 6 months	0,5	5
Transport 500 km	1	1,1
TOTAL	38,5	20-12

Fig. 3. Energy cost expressed as index for canning and freezing, special processes only.

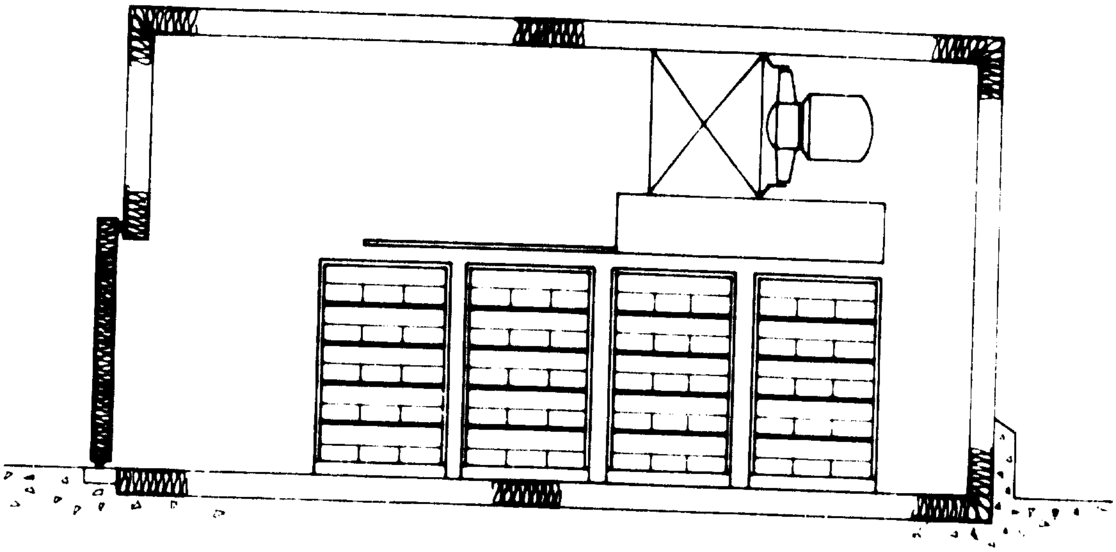

Fig. 4. Stationary freezing tunnel.

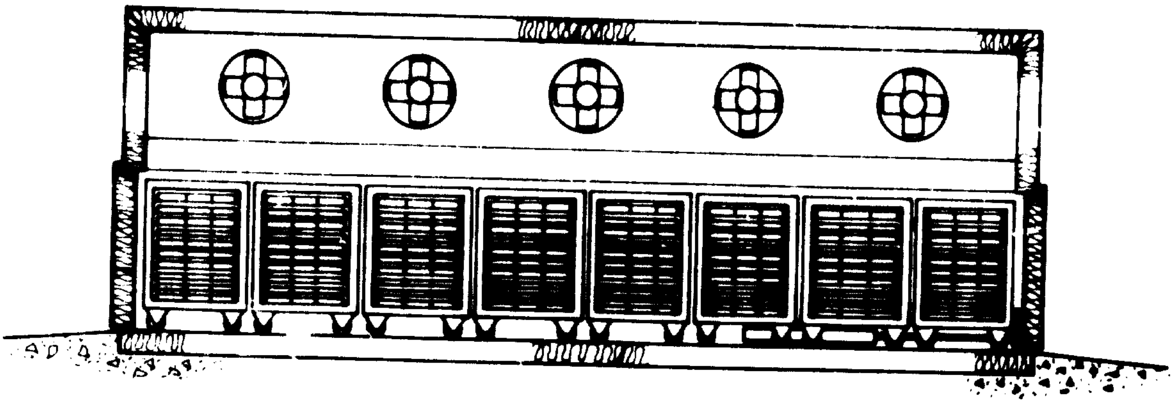

Fig. 5. Push Through Tunnel

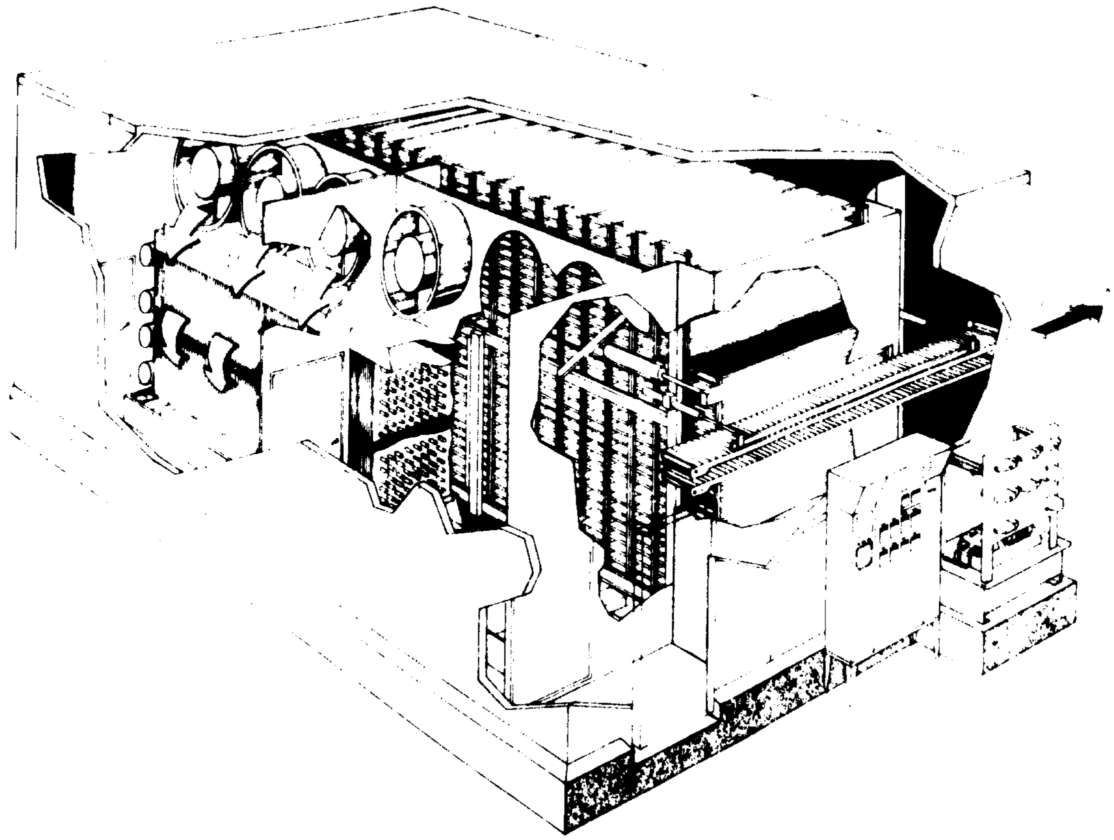

Fig. 6. Carrier freezer

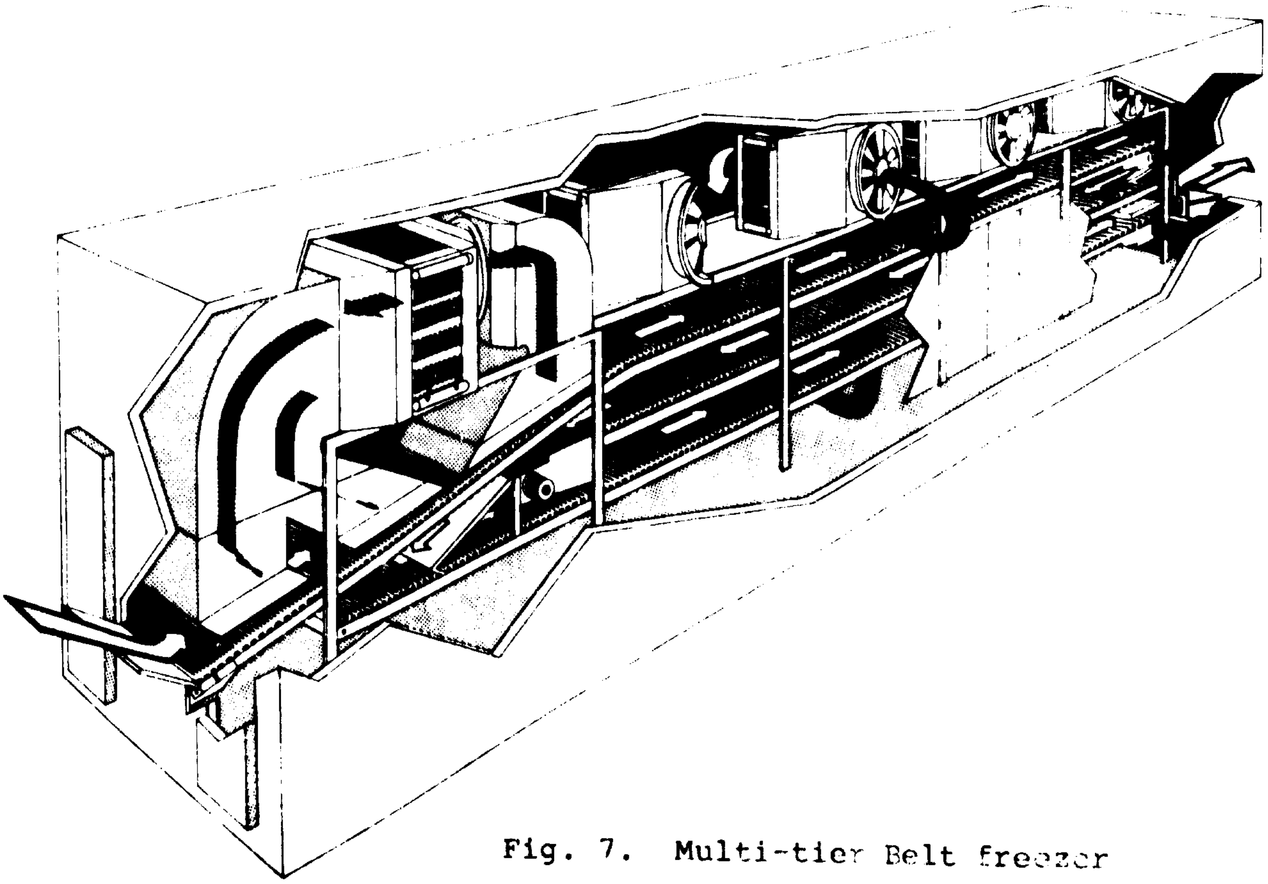

Fig. 7. Multi-tier Belt freezer

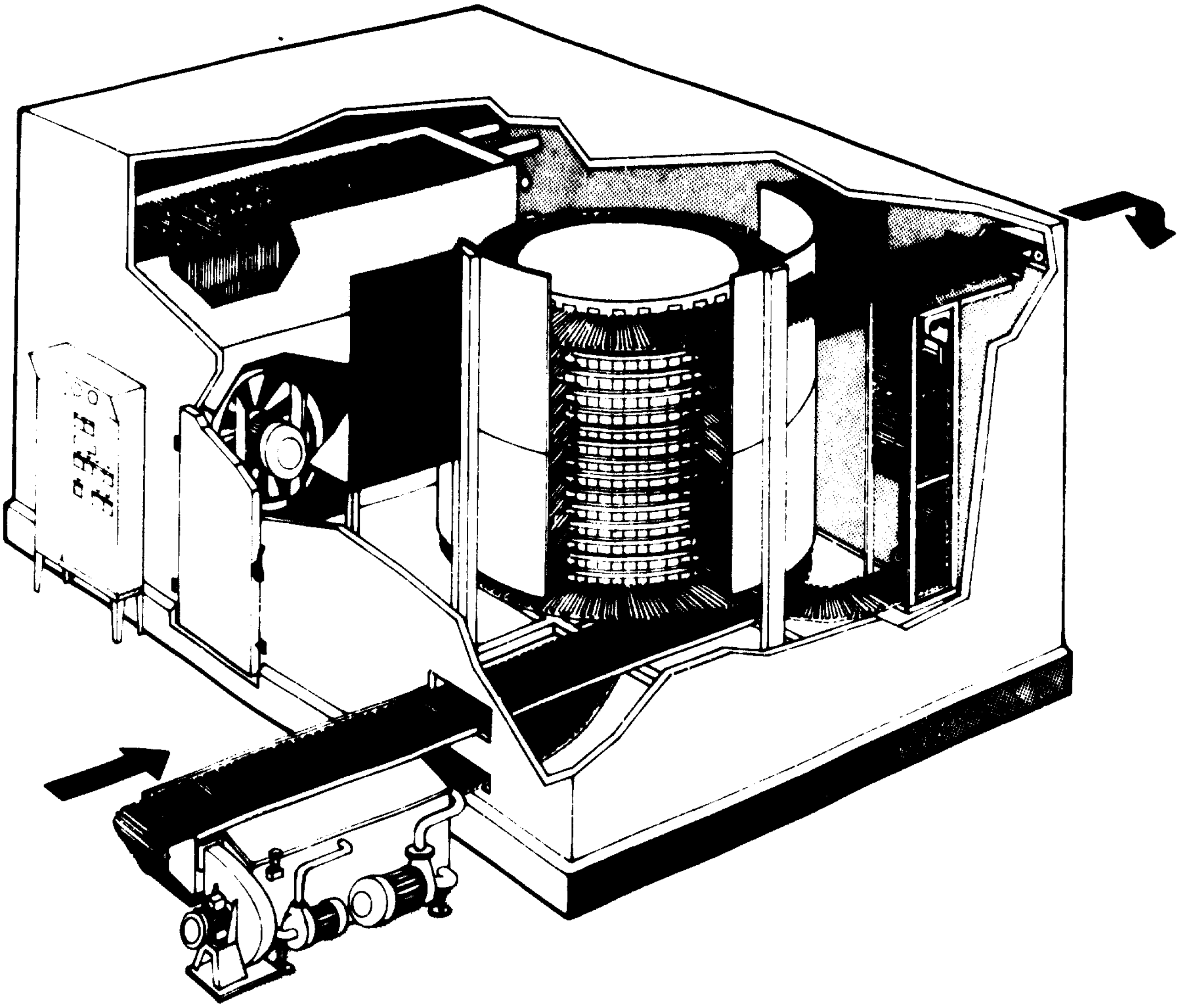

Fig. 8. Spiral Belt Freezer

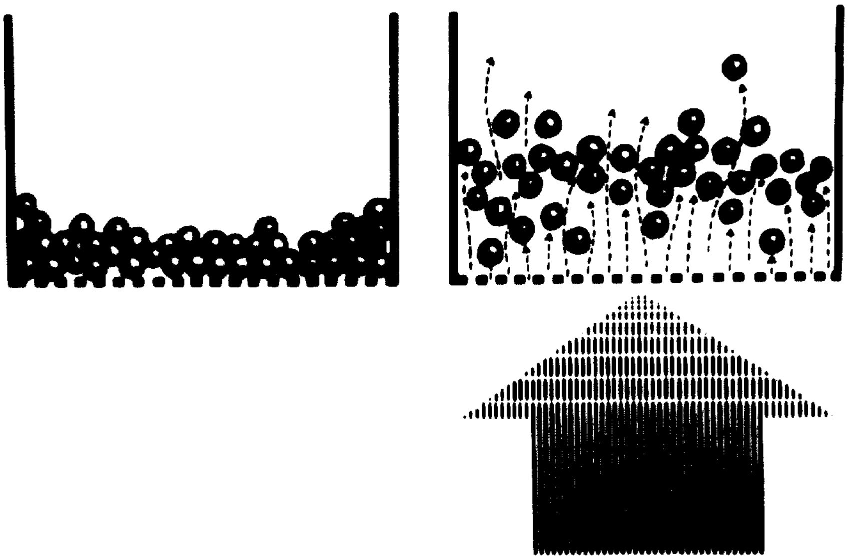

Fig. 9. Fluidization Principle.

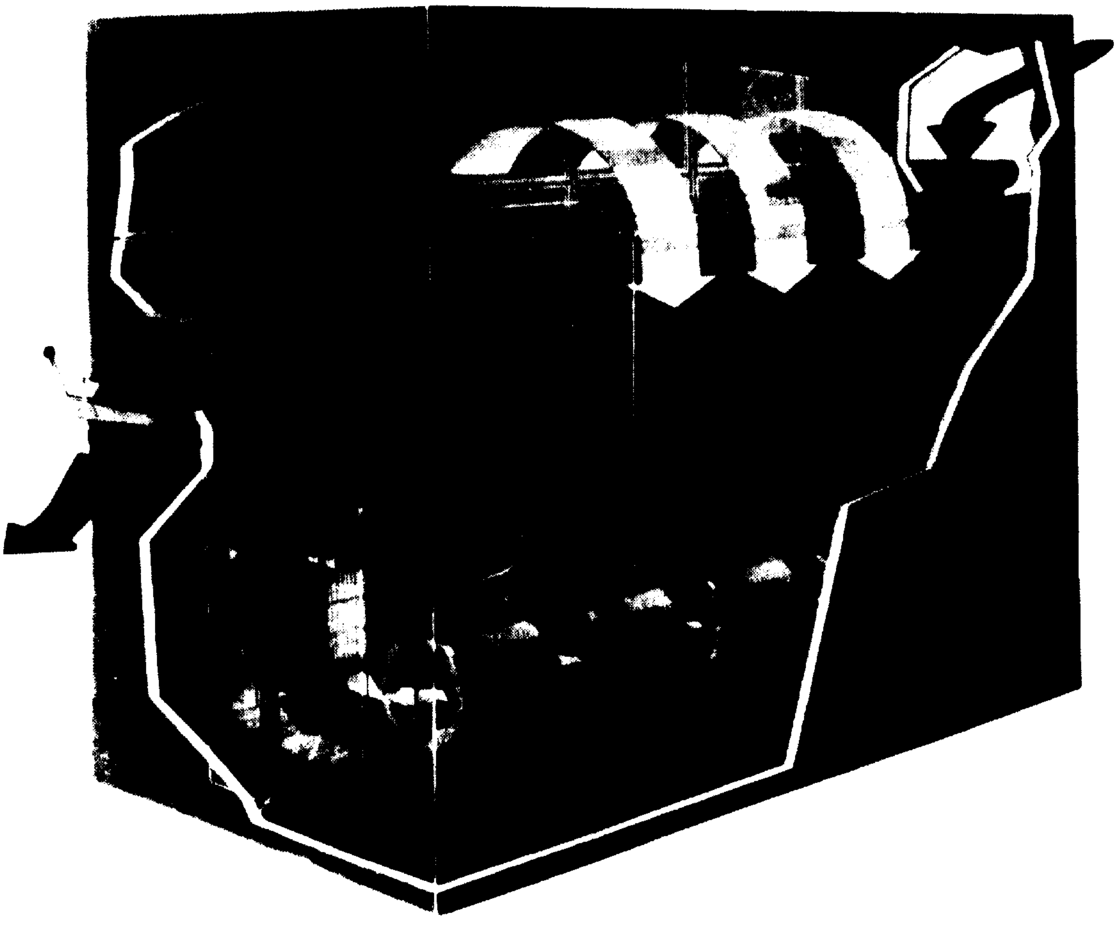

Fig. 10. Fluidized Bed Freezer

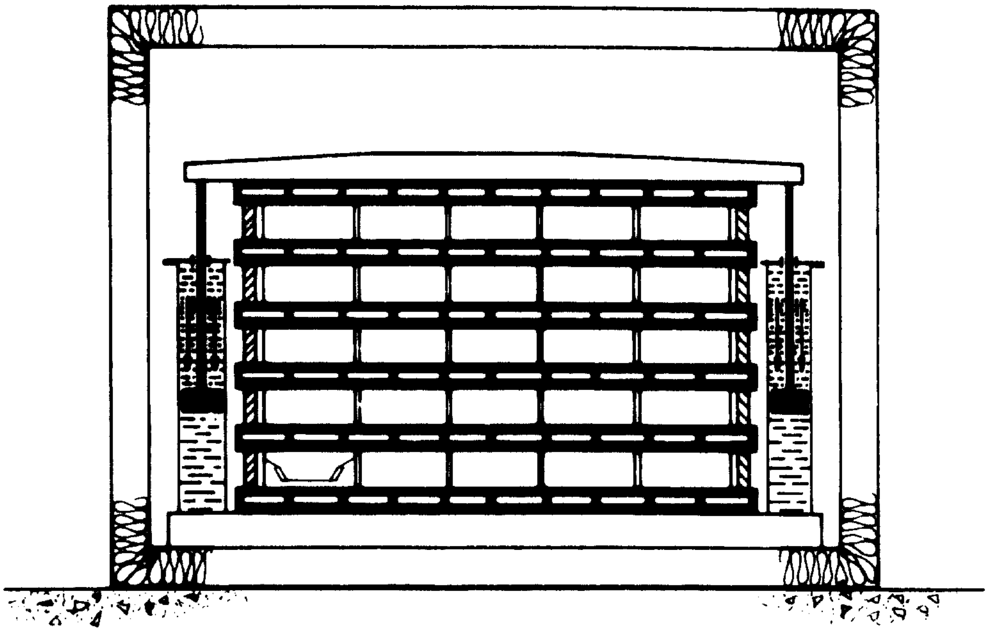

Fig. 11. Horizontal Plate Freezer, Principle.

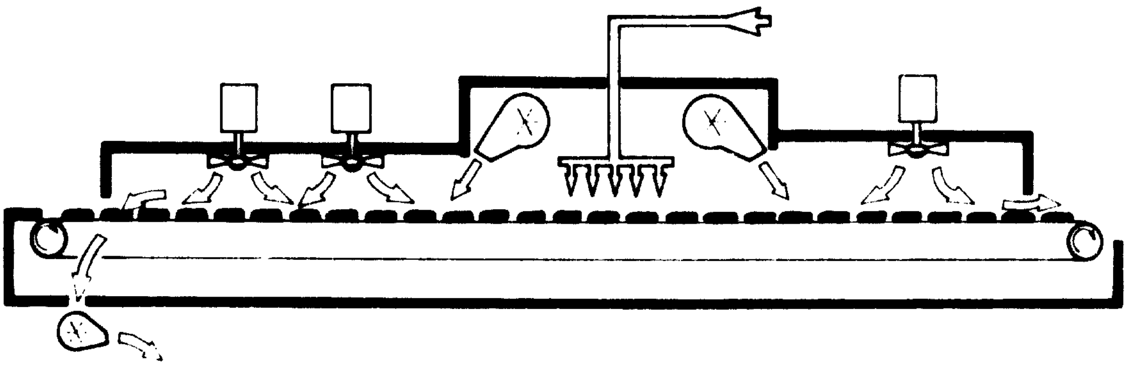

Fig. 12. Liquid Nitrogen Freezer, Principle.

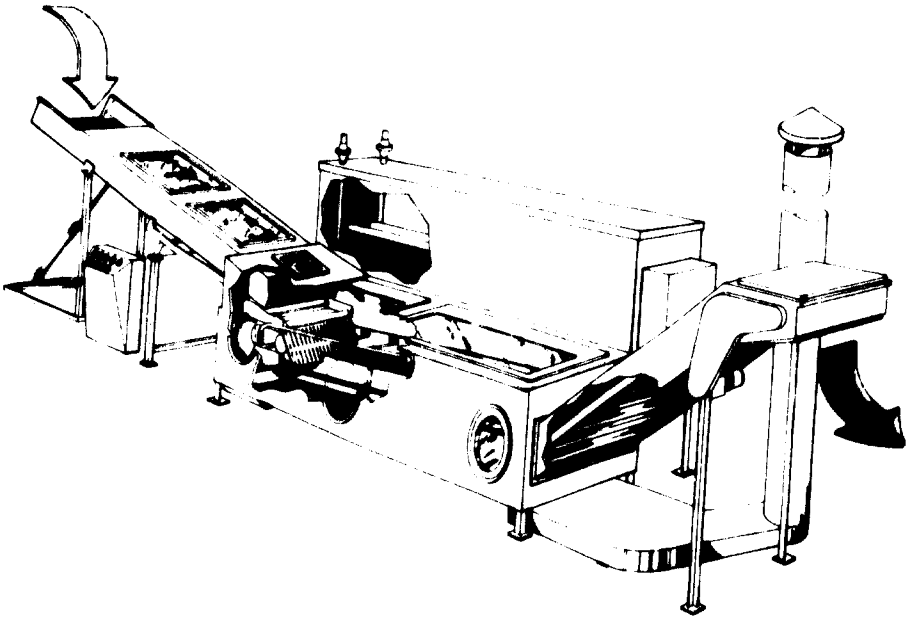

Fig. 13. Liquid Freon Freezer, Principle.

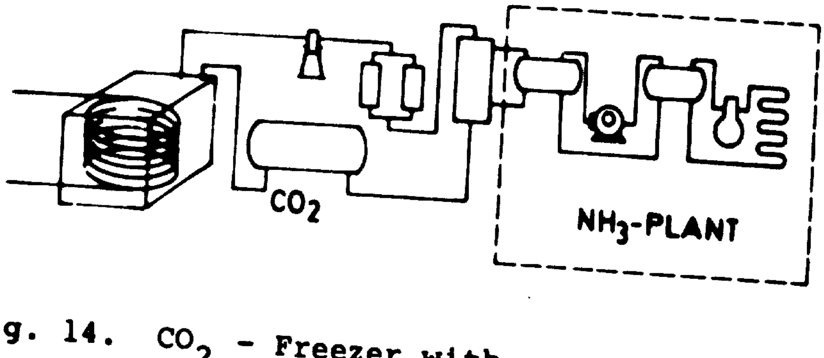

Fig. 14. CO_2 - Freezer with recovery system.

Fluidized Bed Freezer

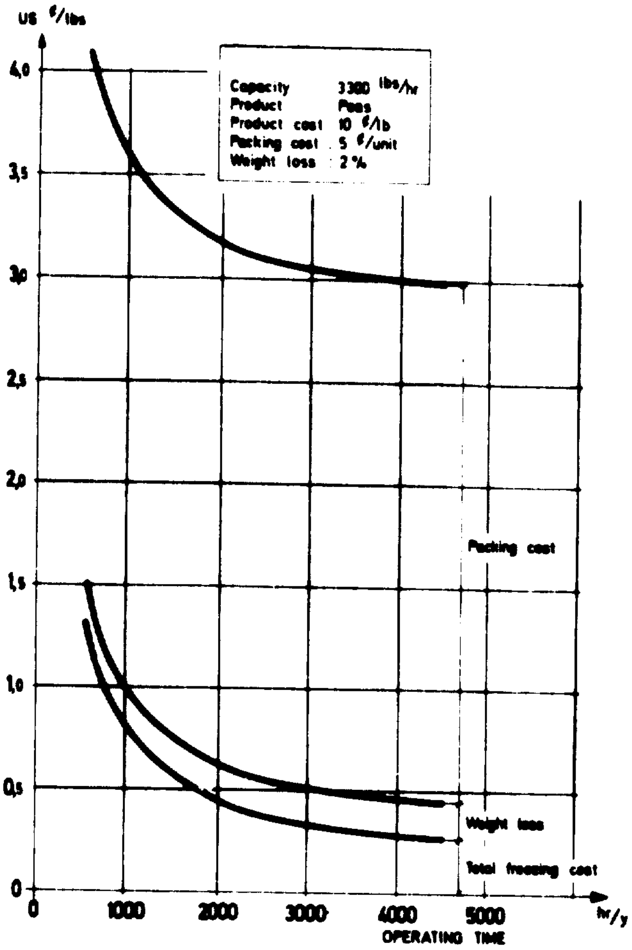

Fig. 15. Cost relationship.

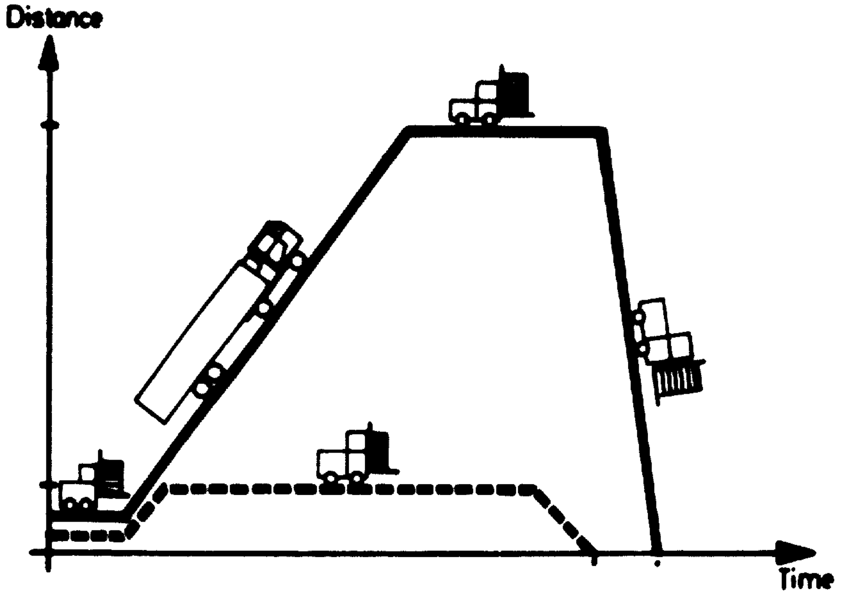

Fig. 16. Transport and handling time for harbour store (---) and distant store (——).

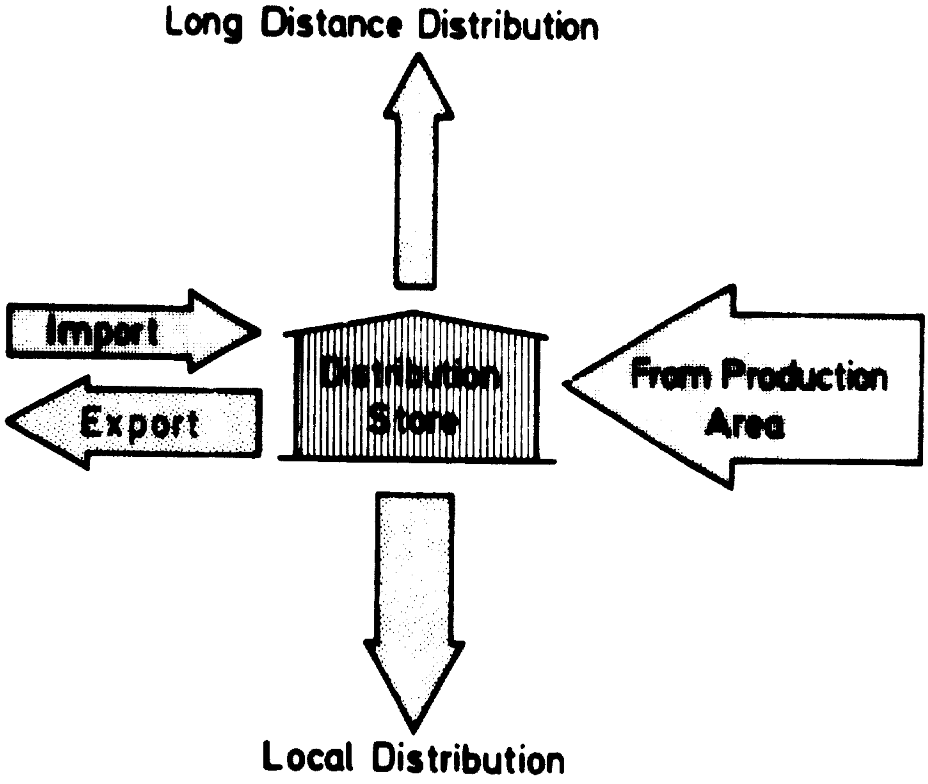

Fig. 17. Product flow for Distribution Store.

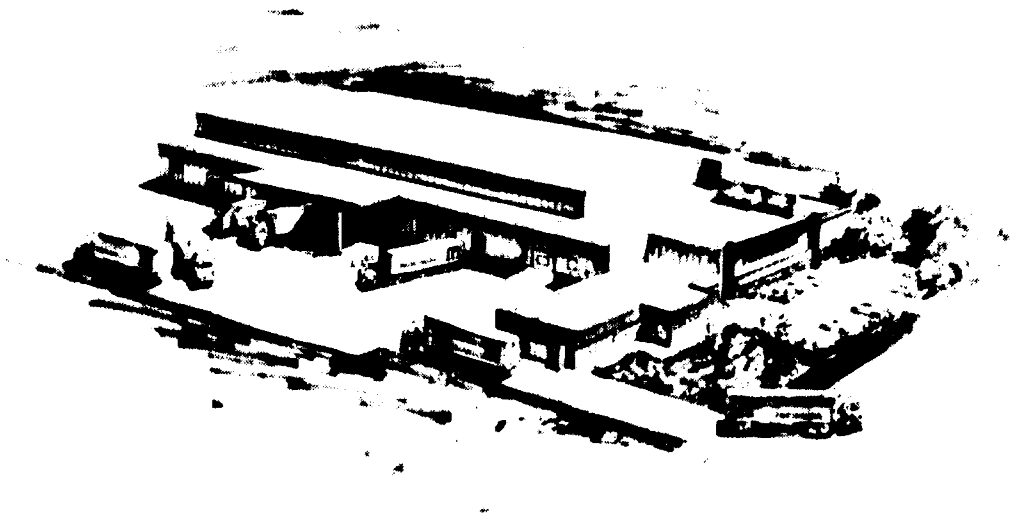

Fig. 18. Lay-out of modern single storey cold store.

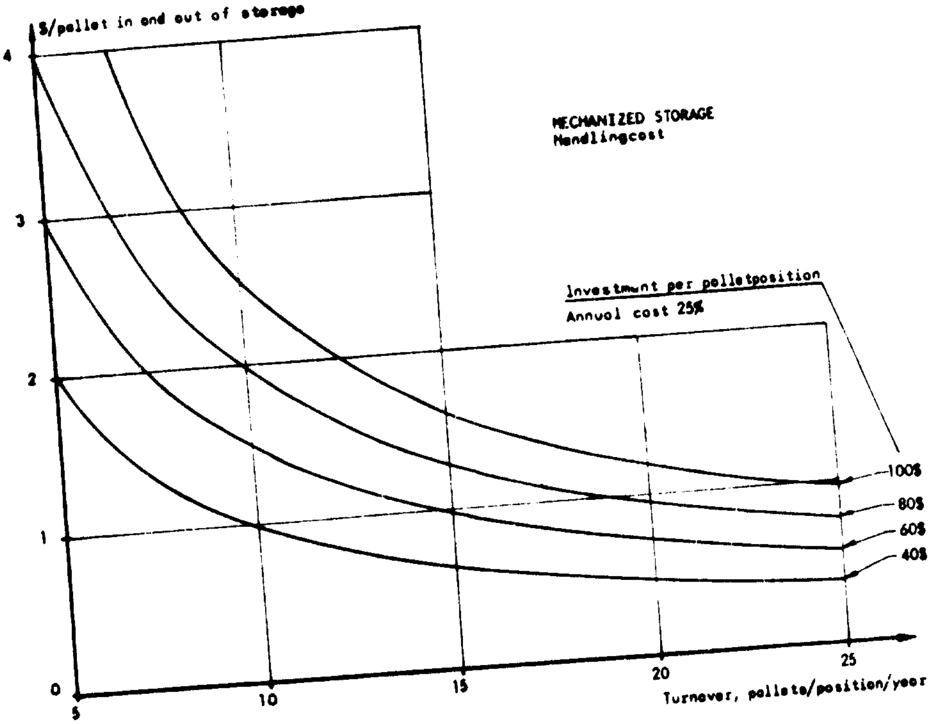

Fig. 19. Variation of operation costs with investment cost and turn over for automatic cold store.

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