OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

05485

Distr.
LIMITED

ID/WG.172/14
28 May 1974

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

AFRIFOODS - Regional Consultation on
Promotional and Technical Aspects of
Processing and Packaging Foods for Export

Casablanca, Morocco, 23 - 28 June 1974

METHODS OF FREEZING FISH[1/]

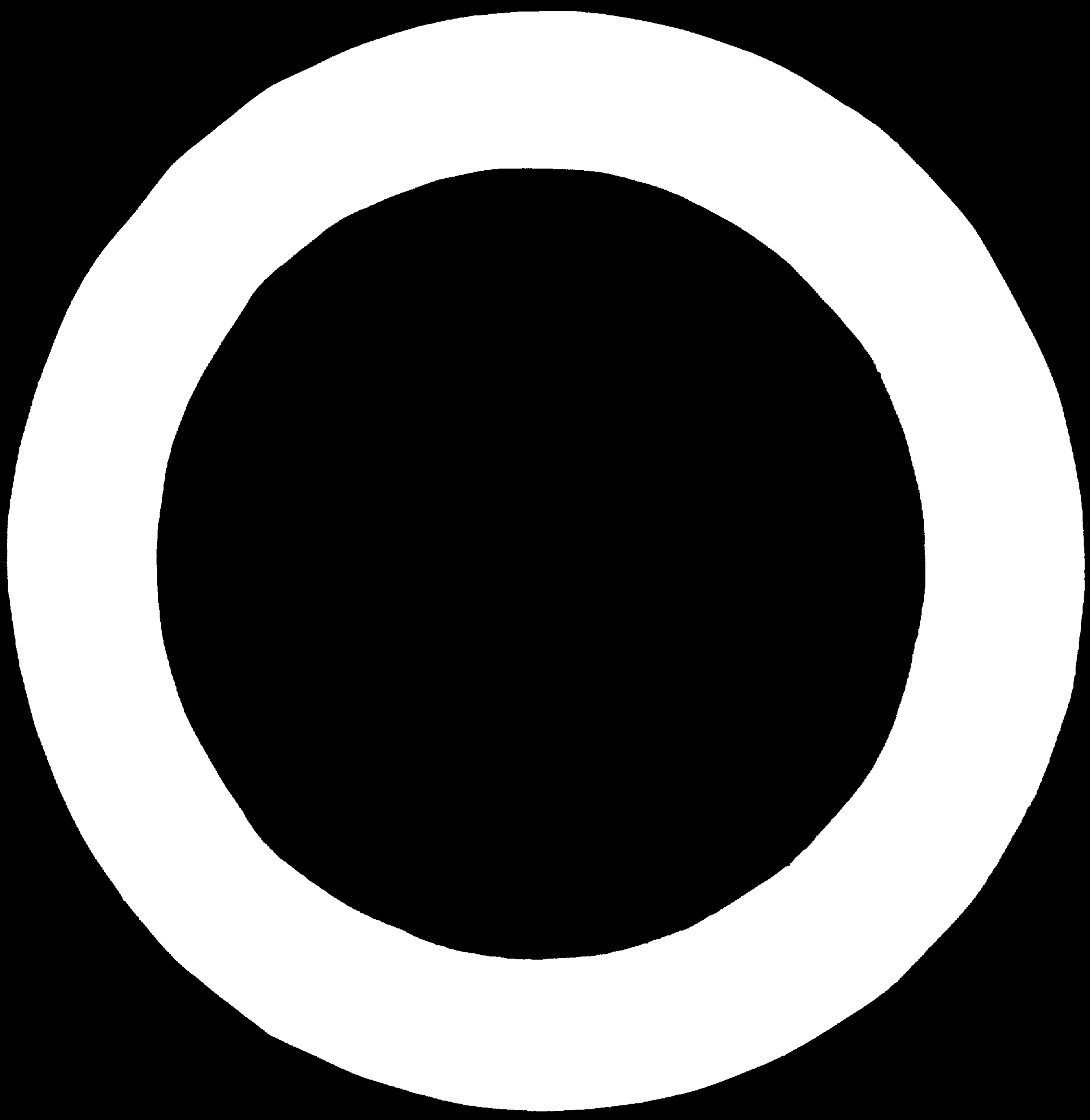
D. W. Everington*

* Director - General Manager, A.P.V. Parafreeze Limited, Thetford, Norfolk, United Kingdom

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has been reproduced without formal editing.

id.74-3891

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.



METHODS OF FREEZING FISH

After catching, the bacteria present in the fish causes spoilage which proceeds rapidly in the temperature range of 10°C. to 20°C. but the deteriorative effect is progressively retarded as the temperature is reduced, and at -9°C. when approximately 91% of the water present in the fish has been turned to ice.

The speed at which the fish is frozen determines the size and distribution of the ice crystals both inside and outside the individual cells. It is well established that cell damage is minimised when the speed of freezing is such that the ice crystal size formed inside the individual cells is small, resulting in a small drip loss on thawing. Slow freezing produces larger ice crystals in the spaces between the cells leading to cell damage, which in turn results in a higher drip loss on thawing. Slow freezing also concentrates the salts and enzymes in solution within the cells, causing the enzymes to become more active which produces undesirable changes in flavour and texture.

During freezing the detrimental effect of bacteriological, chemical and physical changes are acute between the temperature ranges of -1°C. to -5°C., the zone of maximum ice crystallisation (Figure 1) which coincides with the zone of maximum deterioration and, therefore, it is desirable to pass through this zone as quickly as possible. The freezing process should continue further until the centre temperature is reduced to -20°C., at this temperature the surface is generally in the region of -38°C. giving an average temperature throughout of approximately -29°C.

The generally accepted Cold Store temperature required for long term storage is -29°C. and fish frozen to this average temperature will not impose additional heat load on the Cold Store. The absence of a difference in temperature between the surface of the fish and the air in the Cold Store will minimise the deteriorative effect of dehydration.

In order to introduce a quality standard The Ministry of Food in Great Britain defined that the term "Quick Freezing" should only be applied to operations in which the fish is reduced in temperature from 0°C. to -5°C., in not more than two hours, the fish then being left in the freezer to be further reduced in temperature to -20°C.

Heat is removed, in the case of conventional freezers, by the use of refrigerated plates brought into direct contact with the fish or by blowing refrigerated air across its exposed surface.

The freezing time will be governed by thickness and the temperature difference between the centre of the fish and the refrigerating medium. When transferring heat by convection with the use of air, the heat flow from the fish must pass through a thin stagnant layer of air surrounding the surface, known as the "Boundary Layer". The resistance of this layer is reduced by creating effective surface turbulence, but even so this resistance is still significant in determining the freezing time.

When Plate Freezing the heat transfer surface is brought into direct contact with the fish, and the heat is transferred by conduction, thereby eliminating the effects of the "Boundary Layer" and consequently faster freezing times are obtained (Figure 2)

The temperature at which the plates or the air is maintained is governed by the evaporating temperature of the refrigerant and in the case of most conventional systems the economic evaporating temperature is in the region of -37°C. to -40°C. In any particular freezer for a given thickness of fish the freezing time can be reduced by the use of a lower evaporating temperature, which in turn will increase the out put from the Freezer. Unfortunately the use of a lower evaporating temperature increases the capital and running costs of the refrigerating plant, and this increase becomes disproportionate compared to the benifits obtained.

A well designed conventional freezer is capable of freezing well within the described quality limits, for example a Vertical Plate Freezer will freeze 107 mm. thick whole fish blocks from +5°C. to -20°C. in 170 minutes, the time taken to pass through the zone of maximum crystallisation however is 65 minutes. When freezing 170 gram fish fillets in an efficient Air Blast Tunnel the time taken is only 11 minutes.

PLATE FREEZERS:

This type of freezer is one of the most commonly used in the Fishing Industry. It is used for freezing rectangular blocks of whole or filleted fish, and for shell fish in trays or cartons. Block thicknesses normally vary in the range of 50 mm to 110 mm.

The modern Plate Freezers use ported plates, manufactured from aluminium alloy (Figure 3). Liquid refrigerant on entry to the plate passes through a small cross sectional area but as the refrigerant absorbes heat a proportion of the liquid changes to a gas and this change increases the volume of the refrigerant flowing. The passes in the plate are therefore expanded so that the cross sectional area available to flow is increased. The effect of this is to reduce the resistance to flow, thereby reducing the pressure drop across the plate, resulting in limiting the temperature rise of the refrigerant. In order to obtain efficient heat transfer the inside ports must be kept thoroughly wetted by ensuring the presence of an adequate proportion of the liquid always being available at the inside surface of the ports. In order to obtain this it is necessary to circulate more liquid than would be theoretically required to transfer the heat from the fish. The ratio of the over feed is normally in the region of 8 - 1.

In the early days of Plate Freezer development steel plates were used, and even today these plates are still used. The steel plate consists normally of a refrigerated coil, placed inside a steel box in which a vacuum is pulled in order to maintain contact between the inside surface of the plate and the outside surface of the coil.

With this type of construction the ratio of the outside plate surface to the inside refrigerant swept surface is small, compared to the aluminium ported design and, therefore, it is not capable of absorbing the same rate of heat flux. When freezing fish blocks in the region of 50 - 70 mm. thick the aluminium plate will reduce the overall freezing time compared with the steel plates by approximately 33%

Plate Freezers are capable of applying a hydraulic pressure to the plates in order to produce high density blocks when freezing and, therefore, the design of the plates must be capable of withstanding the stresses involved. The density of a block of fish fillets can approach 1,000 Kgrams per cu. metre, when frozen in a well designed Plate Freezer.

HORIZONTAL PLATE FREEZERS

Horizontal Plate Freezers, as the name suggests, consists of Horizontal Plates arranged in pairs, each pair forming a Station. Fish is loaded into trays, the trays are then slid between the stations. The plates are opened or closed by the use of a hydraulic cylinder situated at the top of a machine After all stations have been filled a hydraulic pressure of approximately .5 Kgrams per sq. metre can be applied across all surfaces, the applied pressure is then approximately doubled due to the initial expansion of the fish when freezing.

(Figure 4) shows a 15 station Horizontal Plate Freezer which can freeze 38 mm. thick fillets at the rate of 20-tons per day. To obtain an operational cycle time it is necessary to add to the freezing time approximately 15 minutes for loading and unloading the freezer, the handling time involved can be minimised by the use of a fork lift truck.

(Figure 5) shows a Package Plate Freezer, which is complete with its refrigeration unit, this is used extensively in areas where the cost of installing remote refrigeration plants is high. This freezer will freeze 37 mm. thick fillets at the rate of 225 Kgrams per hour and four of these freezers, working in a bank, will freeze 900 Kgrams. of fillets per hour, the units being entirely self contained.

VERTICAL PLATE FREEZERS

The advantage in using this type of Freezer (Figure 6) is that it eliminates the need to use trays, the fish being loaded vertically between the plates. The standard size block usually measures 1070 mm. x 535 mm. and the thickness of the blocks vary from 25 mm. to 130 mm.

A 50 mm. thick whole fish block frozen with the heads on will weigh approximately 23 Kgrams. If the heads are removed before freezing the density of the block will increase by 10% and in the case of freezing fillets the increase in density will be approximately 20%.

In order to remove the blocks from the Freezer the Plates are defrosted generally by using hot gas. Shoes, which held the fish during freezing, are then lifted clear of the freezing plants in order that the blocks can be unloaded and placed on to a pallet or a conveyor.

Vertical Plate Freezers are produced with stations ranging from 5 to 30. A 26 station freezer will hold 1.2 tons of fish fillets 100 mm. thick, and will freeze this load in 3 hours. The circuit diagram (Figure 7) illustrates the piping arrangement required for refrigerating and defrosting a number of Vertical Plate Freezers.

AUTOMATIC PLATE FREEZERS

These freezers freeze fish which is filled into cartons or into metal trays. This is essentially an in process line freezer, capable of freezing up to 2-tons of 50 mm. thick fish per hour completely automatically.

Cartons or trays are automatically loaded between stations consisting of two freezer plates, which are held in the open position during loading (Figure 8). When the plate is full the station is indexed upwards and closed, the next station is then ready for loading. This operation continues until all the stations have been filled. The plates then drop to the bottom position and the cycle recommences with the exception that as the cartons are fed into the loading station the cartons already in the station, which have been frozen, are pushed off the plates on to a discharge conveyor.

The use of this Freezer saves the labour required to operate Horizontal or Vertical Batch Plate Freezers.

AIR BLAST SYSTEMS

When it is necessary to individually quick freeze whole fish or fillets an Air Blast Freezer will have an advantage when compared with a Plate Freezing system, because the top plate in a Plate Freezer will not make effective contact with the undulating surface of the fish, whereas air can be blown evenly over all exposed surfaces.

Unfortunately air has the ability to pick up moisture from the surface of the fish, a feature which does not exist in Plate Freezing.

A badly designed Air Blast System using air temperatures in excess of -30°C. will result in producing weight losses which will exceed 3%. However, a well designed system using low air temperatures will restrict the weight loss to the region of 1%.

In cases where the hourly output required to be frozen is small it is possible to place the fish individually in trays and to freeze them in a Horizontal Plate Freezer, thereby reducing weight loss to the absolute minimum.

Air Blast systems normally refrigerate air by the use of a fin coil block, which is known as the evaporator, in which the refrigerant is evaporated at approximately -40°C. Air leaves the coil at approximately 3°C. higher than the evaporating temperature and sufficient volume is circulated in order to restrict the temperature rise across the fish to 5°C. The lower the air temperature is kept the smaller becomes its ability to pick up free water and, therefore, the lower becomes the dehydration effect. In general, economical heat transfer occurs when the velocity of the air is in the region of 4 m. per second.

BATCH TYPE TROLLEY FREEZER

The Freezer (Figure 9) consists of an insulated cabinet in which refrigerated air is blown evenly across the trolleys. The trolleys are manually loaded, prior to freezing, with fish and they are left in the cabinet for a predetermined period after which they are removed and the cycle recommences.

Providing this Freezer has been correctly designed so that it is suitable for freezing fish it is extremely versatile.

As previously mentioned, if too high an evaporating temperature is used within the coil, and the coil surface is too small, this type of freezer can become one of the biggest culprits in producing a high weight loss.

SPIRAL FREEZING SYSTEMS

Spiral Tunnel

This type of tunnel uses a conveyor belt which collapses on its inner edge, enabling it to be wound around a rotating drum. This particular feature enables a conveyor, in the region of 600 m. long, to be used in a single tunnel, and the advantage of this system compared with a straight-line conveyor system are obvious. This is a very versatile freezer capable of freezing thin products having a freezing time of approximately 10 minutes up to thicker products having a freezing time of 3 hours. In the particular system shown in (Figure 10) refrigerated air, at approximately $-35^{o}C$. is blown in a cross-flow across each layer of the spiral, enabling this system to obtain effective coverage of the belt.

When freezing fish fillets it is necessary to thoroughly clean the belt when it is in motion. A three stage washing system is normally fitted which has pre-rinse, detergent wash and final rinse sections. High velocity air is blown over the belt surface at the exit of the washer unit, in order to ensure that the belt is thoroughly dried before the belt returns into the freezing zone.

LIQUID NITROGEN FREEZING

With this method of freezing, the fish is brought into direct contact with the refrigerant and its use will depend upon the cost and availability of potential supplies of liquid nitrogen. With this system it is necessary to install a Liquid Nitrogen Storage Tank which supplies the liquid to the freezing tunnel, the tank being refilled by Road Tankers at regular intervals, depending upon the usage.

In operation the fish is placed on to a variable speed stainless steel conveyor belt, and passes into an insulated tunnel where it immediately comes into contact with the countercurrent flow of the cold gaseous nitrogen, the temperature of which progressively falls to -196^{0}C. directly under the liquid spray (Figure 11). In the case of thin fillets approximately 50% of the product heat is extracted before it reaches the liquid spray, leaving the highest rate of heat transfer to take place in the small area under the spray where half the freezing potential from the liquid nitrogen is utilised.

The advantage of the use of this system is that small shell fish, and thin fish fillets can be frozen in a matter of minutes, thereby, ensuring that high quality is maintained.

COMPARISON OF COSTS

(Figure 12) illustrates the relative operational costs involved between Horizontal Batch Plate Freezers, an Automatic Plate Freezer and a Spiral Air Blast Tunnel, when freezing 1-ton of fish per hour. It has been assumed, in the case of the Plate Freezers, that the fillets have been placed either into cartons or trays having an overall thickness of 25 mm., whereas the Spiral is individually freezing fillets.

COMPARISON OF COSTS continued

For comparison purposes, it has been assumed that no labour is involved in the operation of the Spiral Freezing Tunnel and the Automatic Plate Freezer, but in the case of the Batch Plate Freezer the labour costs involved in loading and unloading have been shown varying from £0.4 , £1.00 and £2.00 per hour. The Batch Plate Freezer base curve shows only costs associated with Capital and Electricity and it can be seen that in Countries where the cost of labour, plus overheads, is below £0.4 per hour that there is no financial advantage, in this particular case, of using a continuous Plate Freezing process.

The running costs of a Liquid Nitrogen Tunnel is higher than conventional systems and these Tunnels are often used for freezing expensive products, where the additional running cost is very small compared with the selling price. Because of the low capital cost involved this method can be economic, depending upon the cost of the nitrogen, when freezing large throughputs for short periods during the year.

The running cost advantage which Plate Freezers have over the Air Blast Freezer is due to the efficiency with which the heat can be conducted straight to the refrigerant without the use of air. In an Air Blast System the heat equivalent of the fan horse power can contribute approximately an additional 25% to the heat load of the fish. In order to maintain the same surface temperature of the

COMPARISON OF COSTS continued

fish when freezing the Air Blast system must evaporate 5°C. lower than the refrigerant in the Plate Freezing System, which increase the swept volume of the refrigeration plant required.

All the Freezers which have been described are capable of freezing well within the prescribed quality limits, and the choice of any particular freezer will depend upon whether the fish is to be frozen in block form or individually, the hourly output required, the availability and cost of suitable labour, together with the number of operational hours per year.

Figure 1

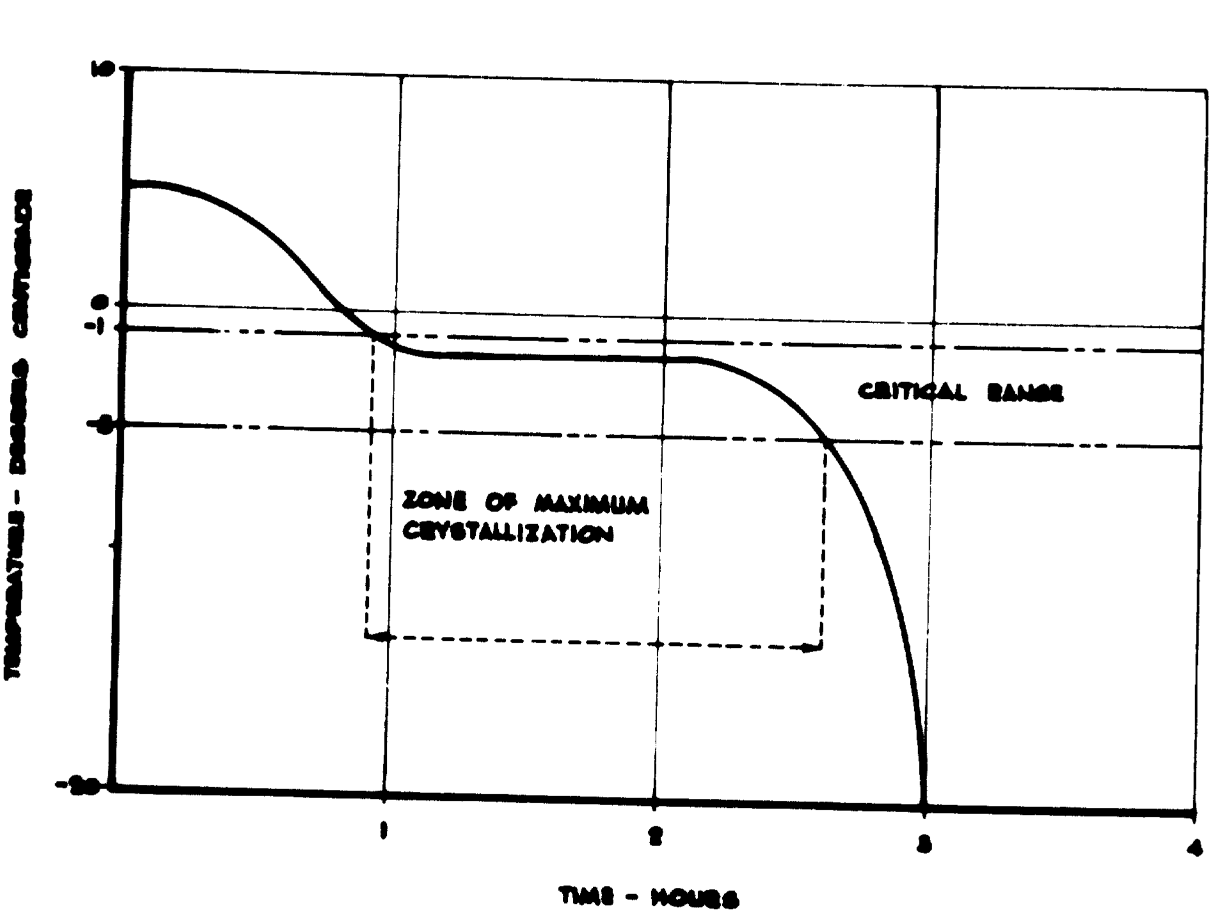


Figure 2

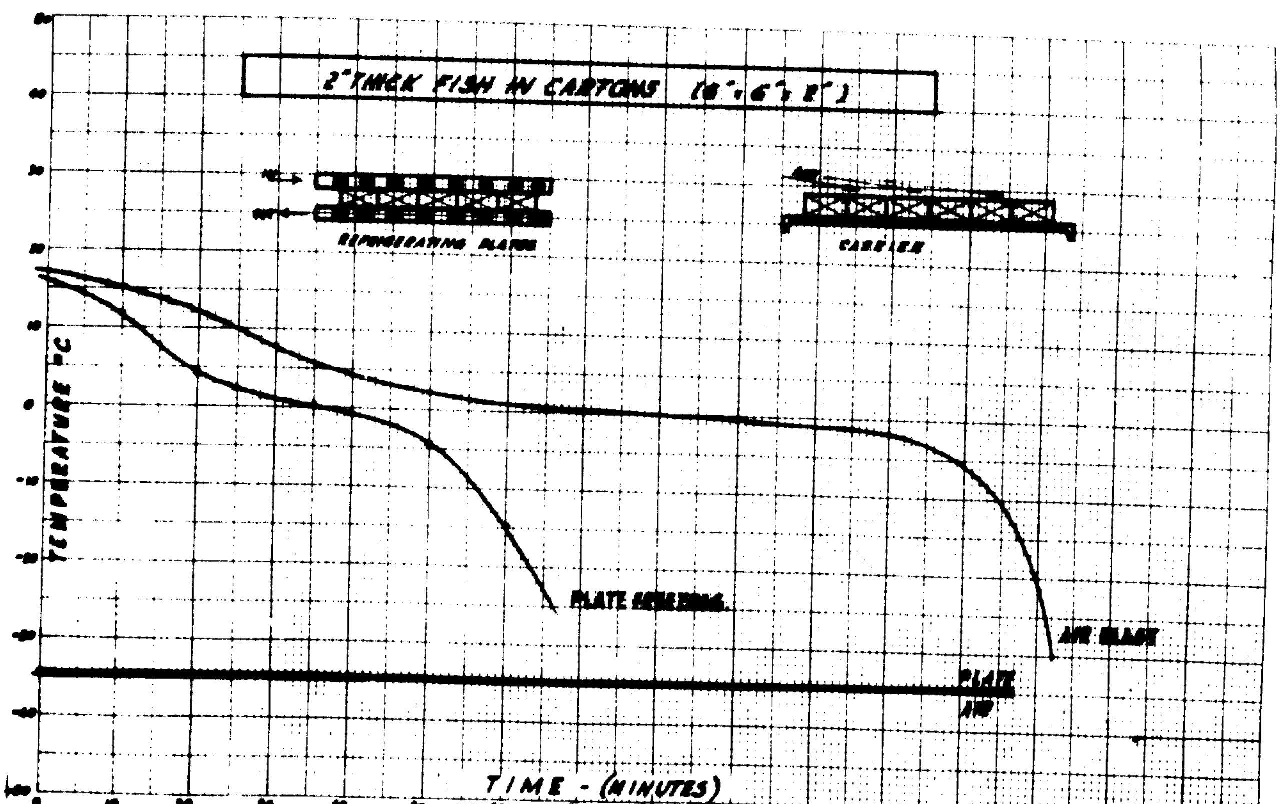
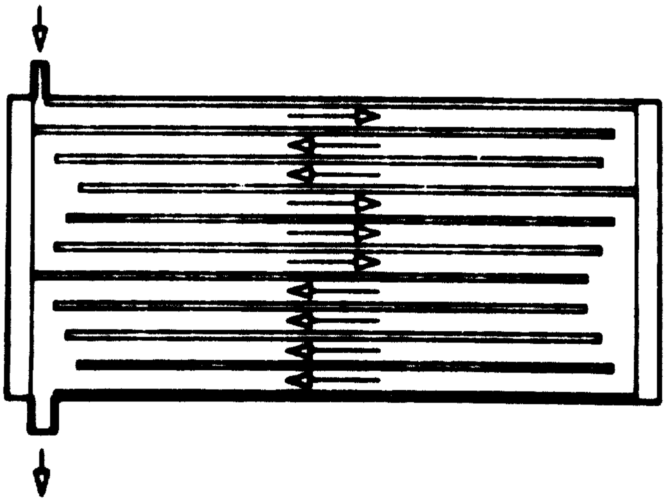


Figure 3



EXPANDING PASS PLATE SYSTEM.

Figure 4

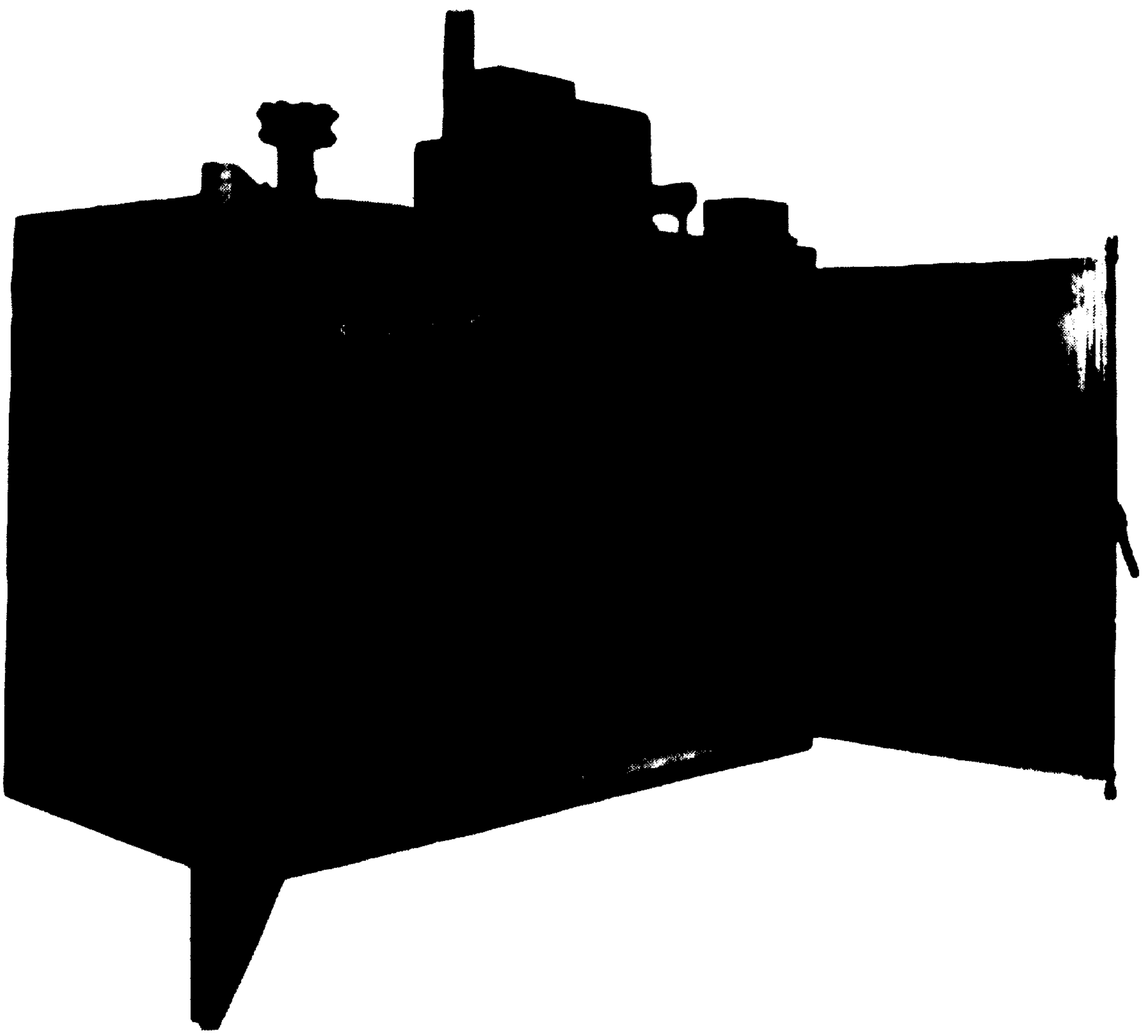


Figure 5

Figure 6

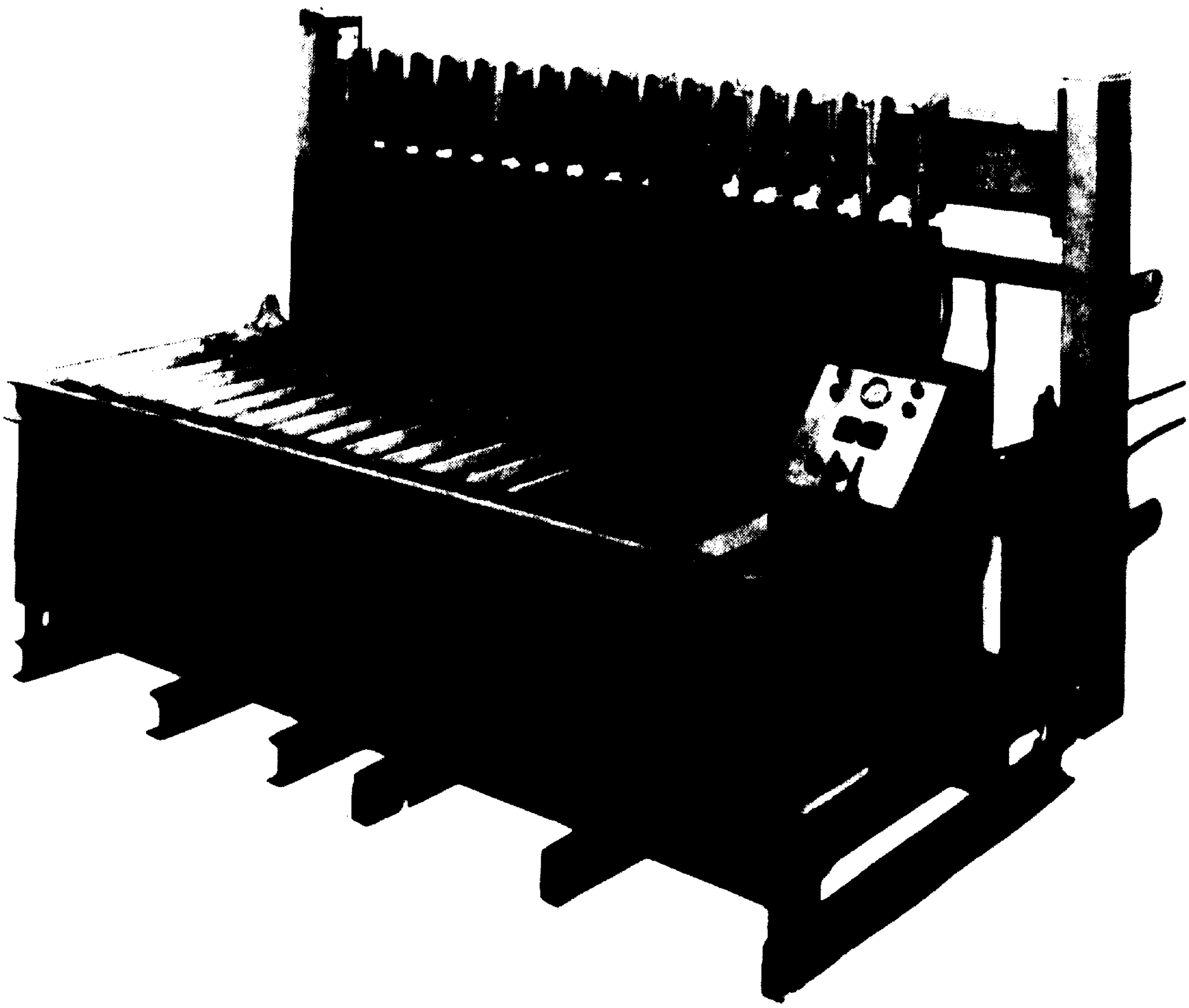


Figure 7

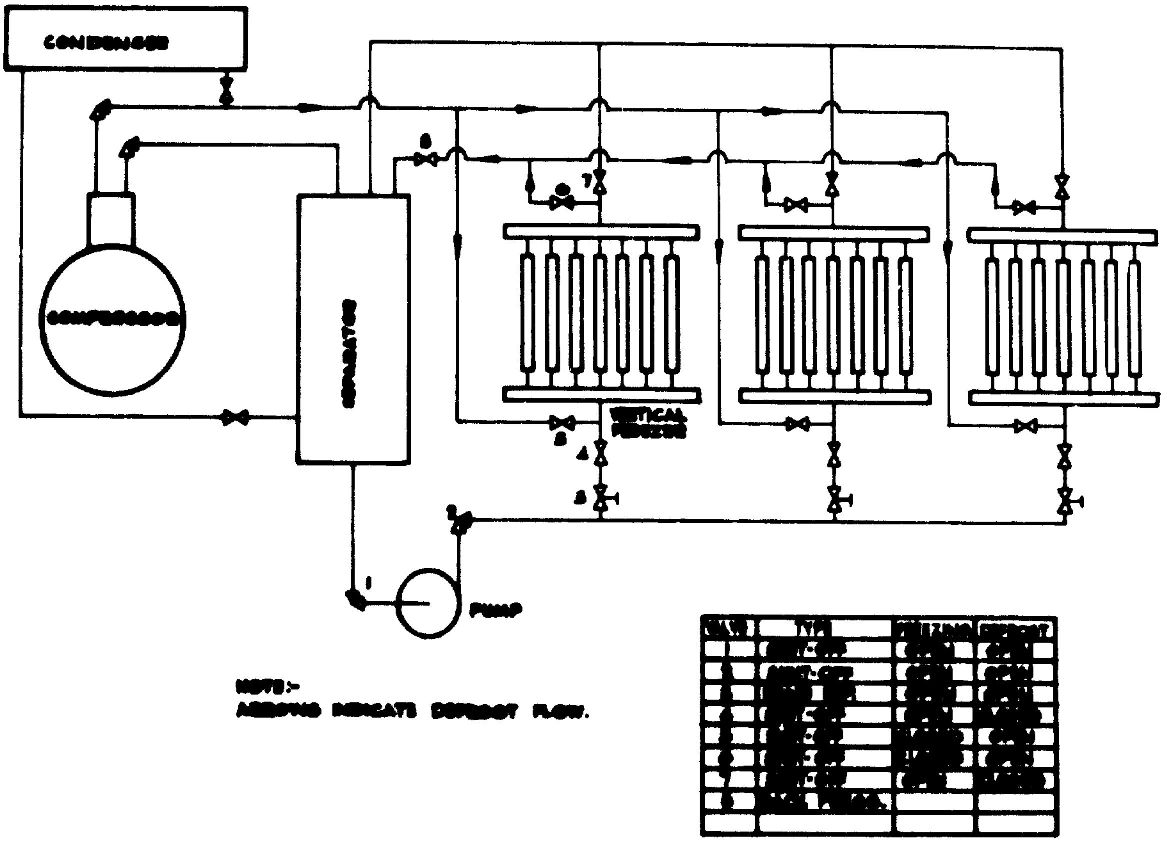
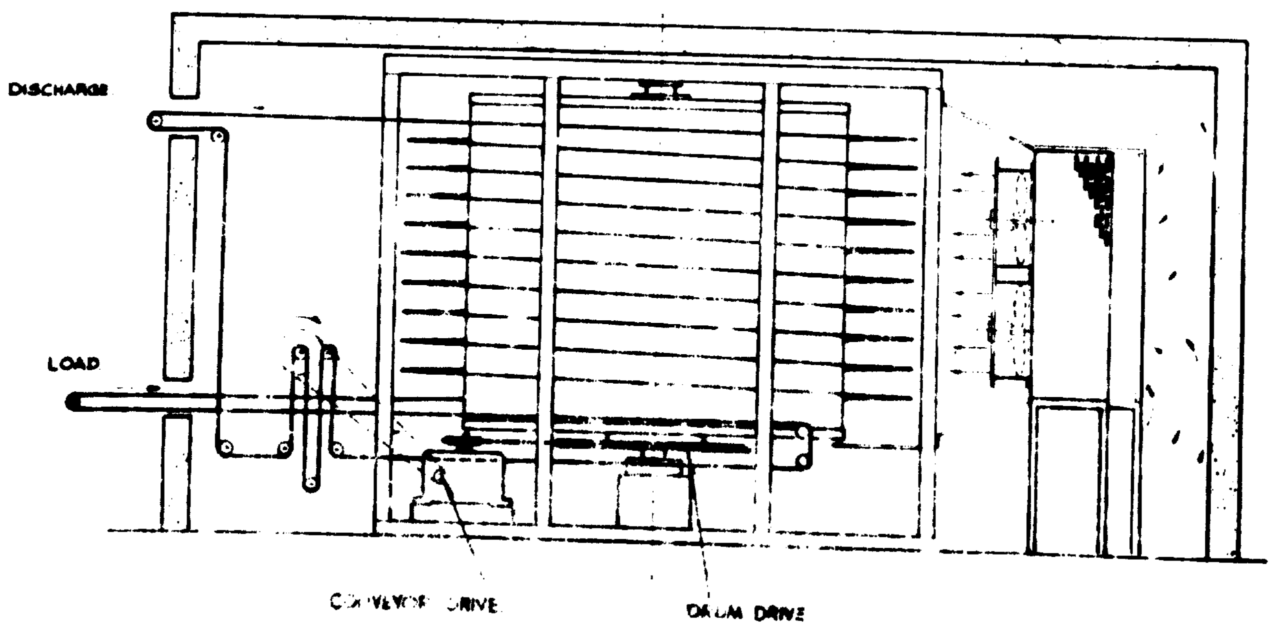


Figure 8

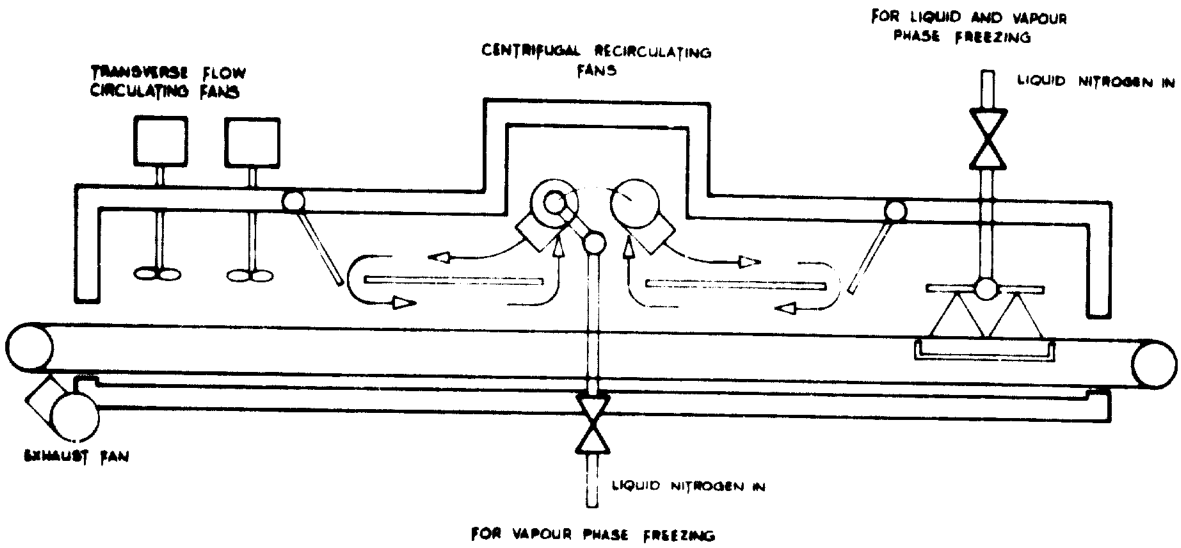
Figure 9

Figure 10



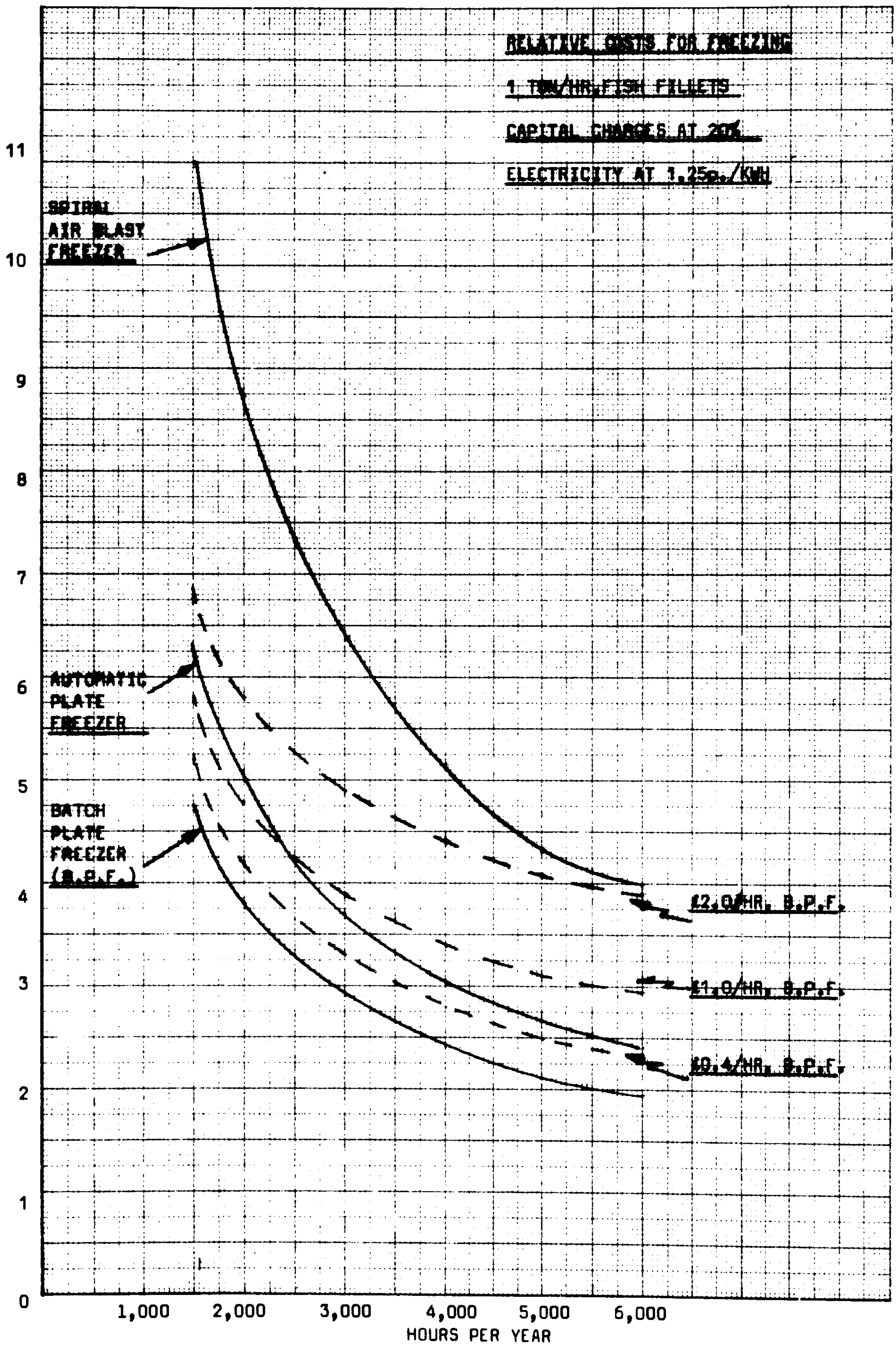
SPIRAL FREEZING TUNNEL

Figure 11



LIQUID NITROGEN TUNNEL

Figure 12


RELATIVE COSTS FOR FREEZING
1 TON/HR. FISH FILLETS
CAPITAL CHARGES AT 20%
ELECTRICITY AT 1.25p./KWH
SPIRAL AIR BLAST FREEZER
AUTOMATIC PLATE FREEZER
BATCH PLATE FREEZER (B.P.F.)
£2.0/HR. B.P.F.
£1.0/HR. B.P.F.
£0.4/HR. B.P.F.
0
1
2
3
4
5
6
7
8
9
10
11
1,000
2,000
3,000
4,000
5,000
6,000
HOURS PER YEAR

74.10 .1