RECOMMENDATIONS OF THE IIR ON THE QUICK-FROZEN-FOODS COLD CHAIN:
QUICK-FREEZER DESIGN AND CONSTRUCTION,
COLD STORES, TRANSPORT, RETAIL.

INTRODUCTION

Quick-frozen foods are of paramount importance in our diet today:
Annual consumptions per capita are very high in some countries: United States: 54.9 kg/capita.yr; Denmark: 50.2 kg/capita.yr; United Kingdom: 44.2 kg/capita.yr; Sweden: 34.9 kg/capita.yr; France: 33.5 kg/capita.yr; Japan: 15.2 kg/capita.yr (CFCE, 1997).

Quick-frozen foods owe their existence to permanent and continuous refrigeration. This file presents the recommendations that all stakeholders in the frozen foods cold chain should apply during freezing, storage, transport and retail sale.

These recommendations were prepared by an IIR working party set up in October 2000 with as mandate the preparation of the Codex Draft Revised Code of Practice for the Processing and Handling of Quick Frozen Foods. This mandate was assigned to the IIR by the Commission of the Codex Alimentarius.

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The four sections of these recommendations were validated by the Working Party. However, these sections were not retained as part of the Draft Code of Practice proposed for adoption at Step 5 by the Codex Commission at its session of July 2001 because of their length and their technical content. Considering the high technical value of these documents, the IIR, in agreement with the Joint FAO/WHO Food Standards Programme of the Codex Alimentarius, and in agreement with the Chairman of the Working Party, decided to publish the recommendations on its Web site.
1 - QUICK FREEZER DESIGN AND CONSTRUCTION

In the quick-freezing process, the freezing time depends on the temperature of the freezing medium, the heat transfer coefficient, and size and shape of the product. The equipment for quick freezing may be divided into four groups according to the medium of heat transfer:

– Air blast freezers
– Plate freezers
– Cryogenic freezers
– Immersion freezers

1.1 AIR BLAST FREEZERS

Various types of air blast freezers are used including tunnel freezers, belt freezers, fluidised bed freezers, and spiral freezers. These all function by circulating cold air, often below –30°C, at high velocity above and around the product.

The most common type is the tunnel freezer (stationary or continuous) where products are placed on racks with air space between the layers. The heat transfer coefficient increases with increasing air velocity, but this also means higher energy consumption. The stacking is important so that air circulation is not impaired.

Fluidised bed freezers suspend smaller sized foods, e.g. peas, prawns, in a blast of cold air. Heat transfer is faster by this method, and results in individually quick-frozen (hereinafter designated as IQF) foods.

1.2 PLATE FREEZERS

Direct contact freezers transfer heat to the product by conduction. Direct contact freezers include plate freezers, band freezers and drum freezers. The product is either pressed between hollow metal plates (horizontal or vertical) with the refrigerant running through them, or between two bands with the refrigerant circulating on the outside, or frozen on the outside of a drum with refrigerant inside. There should be good contact between product and freezing plate, making as short a freezing time as possible when the product has a limited thickness.

1.3 CRYOGENIC FREEZERS

Cryogenic freezers spray a cold refrigerated medium directly on the food, and normally use liquid nitrogen at –196°C or carbon dioxide. In some cases the product is immersed directly into liquid nitrogen for a brief period. Very short freezing times can be achieved, making it possible to produce IQF products of a high quality.

1.4 IMMERSION FREEZERS

High heat transfer and hence more rapid freezing times are obtained by immersing the food in a liquid freezing medium. The freezing medium may be glycol (propylene glycol) salt, sugar solutions, or alcohol solutions. In most cases the product must be protected during immersion by a sealed packaging.

1.5 TEMPERATURE MONITORING

It is difficult to monitor air temperatures during the freezing process. Monitoring can be achieved by use of small robust temperature recorders. Food simulants with thermal properties similar to the food can also be used.
2 - COLD STORES

The general design of a cold store should take into account the volume of frozen storage required and the amount of heat to be removed during operation in order to provide a suitable storage temperature. Cold stores are often designed not only to store quick-frozen foods but also to reduce temperature during thermal stabilisation of the product. They should not be used for carrying out a quick-freezing process.

2.1  COLD STORE REFRIGERATION

The refrigeration system must be adequate to provide sufficient capacity on days of peak activity under adverse climatic conditions (summer, strong wind, etc.). Most cold stores have forced air circulation in order to maintain the stipulated temperature throughout the cold store under all conditions without generating high air velocities in the cold store.

The maximum heat load depends on the following factors:

- maximum and average quantity of each product to be received per day;
- temperature at which each product will be received;
- maximum number of operators and trucks working in the cold store at any one time;
- maximum number of door openings per hour;
- maximum quantity to be dispatched at any one time;
- maximum ambient temperature (and climatic conditions) likely to be experienced.


2.2  COLD STORE CONSTRUCTION

The cold store walls, doors, floor and ceiling should be suitably insulated in order to reduce energy consumption, and help to maintain product temperature. It is important that water vapour does not pass through the insulation, as the resulting ice formation in the insulation would cause severe damage to the effectiveness of the insulation and eventually a risk of structural failure. The insulation should include a fire-retardant additive or be fire-resistant.

The insulation of the doors should be comparable with the cold store wall insulation. The doors should be as small as possible, and they should open into temperature controlled rooms/zones. Door openings may contribute significantly to the heat load, and can give rise to an increased frequency of defrosting. Therefore, door openings and their duration should be controlled. This can be achieved by using automatic doors which open and close quickly after the passage of a truck. Other means of reducing losses are by installing additional equipment such as air curtains, flexible doors or plastic strip curtains, and areas such as airlocks, platforms and corridors to provide protection from climatic conditions.

At least one emergency exit is strongly recommended and is included in legislation in many countries. Emergency exits should be kept clear, both inside and outside, and should not be locked without provision to open the door from the inside. An audible warning and/or a light warning signal system should be provided, operable from inside the cold store.

The floor must be sufficiently strong to support the considerable weight of the frozen product stored. Normal construction requires an insulated layer beneath the floor, and a vapour barrier below that. Ice formation in the soil under the cold store should be prevented to eliminate frost heave, which may cause the floor to rise considerably and make it necessary to close the cold store during repair and replacement. In order to avoid this situation it is recommended to incorporate temperature sensors in the base slab to enable monitoring of under-floor temperatures.

In most modern cold stores walls and ceiling are panels, e.g. plastic coated steel bonded to an insulated core. Protective rails should be provided to protect the walls from physical damage by pallets, and ensure vertical air movement.

The lighting in cold stores must be sufficient for truck drivers and others concerned with handling of the quick-frozen food. Lighting will add to the radiant heat load, and lamps with a very high lighting/power ratio are recommended.
2.3 **STACKING**

Stacking of product is designed to make the best use of available space without affecting air circulation in the cold store. It is important to leave sufficient space between the foods and the walls, e.g. 20-30 cm, and between the top of the stacks and the ceiling, e.g. 70 cm to 100 cm, and also between the foods and the floor (10 cm to 20 cm). Quick-frozen food positioned near the doors should be protected from the effects of external air ingress and frost build-up.

2.4 **MAINTENANCE**

Maintenance is important in order to maintain product temperature and the efficiency of the cold store. Condensers, both air- and water-cooled, should be regularly cleaned. The cooler defrost drains should be kept clean. Regular servicing of the system, e.g. once a year, by qualified technicians should be carried out.

Regular checks of the structural fabric should be undertaken, and the integrity of water vapour barrier checked.

Heaters around doors should be checked; a simple hand touch should register slight warmth. Failure is seen as frost appearing.

2.5 **AIR TEMPERATURE MONITORING**

Sensors should be placed in the chamber in the warmest positions, and the recorders can be placed more conveniently outside the cold store or in control offices. The sensors should be located high up and well away from the cooler fans and well away from the entry and exit doors, to avoid exaggeratedly low temperatures or wide fluctuations. Small stores (less than 500 m\(^3\)) may need only one sensor, whereas, those less than 30,000 m\(^3\) will require two sensors. Stores that are between 30,000 m\(^3\) and 60,000 m\(^3\) will require 4 sensors, and those above 60,000 m\(^3\) will require 6 sensors.
3 - TRANSPORT

The transport of quick-frozen food can involve carriage by road, rail, sea or air or combinations thereof. Normally thermally insulated compartments or containers equipped with a refrigeration system for maintaining the temperature of quick-frozen food are employed. They are not designed to reduce the temperature of the product. The product should therefore be at the correct temperature at the time of loading.

3.1 TRANSPORT EQUIPMENT

Different types of transport equipment exist. Long distance transport, such as international transport and transport between large cold stores is typically carried out in semi-trailers, containers, or railway wagons. Local distribution, i.e. transport between cold store and retailers or institutional outlets is normally carried out in smaller vehicles with insulated compartments.

The vehicle or container manufacturer is responsible for the construction of the vehicle body and the design of the refrigeration system. The user of the vehicle or container is responsible for:

- supervision of product temperatures at the moment of loading;
- method of stowing packages in the vehicle to protect the cargo against heat entering from outside;
- operation of the refrigerating unit during transit, including the correct thermostat setting;
- the method of unloading at the point of arrival (particularly the frequency and duration of door openings);
- proper maintenance of the insulated body and the refrigeration system.


3.1.1 Trucks, Trailers

Road vehicles for long distance transport are usually at least 10 meters long and equipped with mechanical refrigeration. The ATP agreement (1) requires transport of chilled and frozen foods crossing the international borders in Europe to attain a certain standard for the insulation and refrigeration unit. Transport vehicles meeting the standard are issued with a certificate. Vehicles are classified on the basis of results from tests carried out at ATP test stations. ATP specifies standards for maximum K coefficient (2) of the insulated body (for transport of quick-frozen foods the K coefficient must be 0.4 W/m²K or lower), air tightness, and air temperatures to be maintained in the compartment. There is also a minimum requirement for the refrigeration capacity of the fitted unit.

3.1.2 Distribution Vehicles

Distribution vehicles are loaded at the cold store and deliver to shops, stores etc. Delivery vehicles may have mechanical, eutectic plate or cryogenic refrigeration.

Local distribution often involves a number of door openings, making it difficult to maintain the necessary temperature conditions. In many distribution vehicles, plastic strip curtains are fitted in the door openings in order to reduce the amount of warm air coming into the cargo space during door openings.

3.1.3 Containers

Containers are used for long distance transport, especially when a sea voyage is included. The ISO thermal container standard (ISO 1496 II) has thermal requirements, which are very similar to the ATP standards (3).

The refrigeration unit in mechanically refrigerated containers is similar to the unit in mechanically refrigerated vehicles. The air circulation is different, being from bottom to top. Generally the standard of temperature control is higher in containers, due to the needs associated with longer journey times.

Adequate space, e.g. at least 10 cm, must be left between the top of the load and the ceiling for air to return to the refrigeration unit. Normally a red load line is indicated, and the load should be kept below this line.

Unloaded space over the (T-bar) floor between the end of the load and the rear doors should be blocked in order to maintain air pressure under the load.
3.1.4 Railway Wagons
In principle, these are designed and constructed in a similar way to refrigerated trailers.

3.1.5 Insulated Boxes or Insulated Vehicles
For transport or distribution not lasting more than a few hours, depending on ambient temperatures etc., it may be acceptable to use insulated boxes or vehicles without a refrigeration system. The K coefficient should be about the same as for trailers.

3.1.6 Air Freight
During air freight insulated containers should be used.

3.2 Transport Refrigeration
The transport vehicle must be equipped with adequate refrigeration capacity and air delivery system to continuously maintain product temperatures of $-18^\circ C$ or colder in the anticipated operating conditions.

3.2.1 Mechanical Refrigeration
The refrigeration unit is most frequently mounted at the front of the compartment. In most vehicles, the cold air is blown from the refrigeration unit, above the load to the back end, so-called top-air delivery. It is very important that the cold air from the refrigeration unit has a sufficient velocity to carry it all the way to the rear of the vehicle. The use of air ducts improves air delivery to the rear end and improves even air distribution.

It is equally important that the air circulation is not blocked. The cold air should be allowed to come behind the load, e.g. by providing a 5 cm space between the rear doors and the load. Also, the cold air should be allowed to circulate down the sides of the load, and under the load, e.g. by using pallets beneath the cargo. There should be an arrangement at the front, e.g. a solid bulkhead, to allow the air to return to the refrigeration unit.

Bottom air-delivery is normally used in containers, i.e. the cold air from the refrigeration unit is blown into the T-bar floor under and up through the cargo. The air returns to the unit over the top of the load.

The temperature sensor used for temperature control (thermostat) is automatically changed between air supply and air return depending on the set point. For quick-frozen foods, air return control is used, and air supply temperatures will be colder than the set point.

As discussed for road vehicles it is important not to block the air circulation.

3.2.2 Eutectic Plates
Eutectic plates contain a "brine", which is a solution of water and various chemicals (approved by the authorities) such as salts or glycols. The brine should be non-toxic and preferably also non-corrosive. The melting point of the brine is $-30^\circ C$ or below. A refrigerating circuit is used to lower the temperature of the brine and to solidify it during the night.

The eutectic plates are mounted on the vehicle walls and ceiling, and during distribution the brine melts, providing the refrigerating effect necessary to maintain the required temperature.

Eutectic plates are widely used in local distribution.

3.2.3 Cryogenic Refrigeration
Cryogenic refrigeration systems, also called total loss systems, use liquid nitrogen or liquid or solid carbon dioxide as the refrigerant sprayed into the chamber from a reservoir.

3.3 Stacking
Quick-frozen foods do not generate heat and should be loaded tightly together, i.e. stacked in a block, with the cold air flowing above, below and beside the cargo. It may be necessary to use spacers against walls that are not equipped with vertically perforated side stowing bars. The cargo should be secured to prevent vibrations, shifting, etc. Bracing, e.g. at the rear doors, is often used.

3.4 MAINTENANCE

It is important to check that the refrigeration system is functioning properly. This includes regular servicing. For containers, a pre-trip inspection should be carried out before every loading. For other equipment, the thermometer and the temperature recorder should be checked and compared to the thermostat setting.

During transport and distribution, especially during loading and unloading, damage can occur which will lead to holes and leaks, in the walls, doors, floor and ceiling. Such damage can let in outside heat, moisture, dirt etc. and should be repaired as soon as possible. Moisture will reduce the effectiveness of the insulation (by increasing the K coefficient). Breaks in the surface of the wall and floor will permit accumulation of dirt and micro-organisms, and are difficult to clean. This makes it necessary to inspect the internal and external walls frequently.

Operation and the conditions of the doors, ventilation openings, and provisions for load locking and bracing should be checked.

Air tightness should be checked, especially around door seals. This may be done by inspection from inside with doors closed, looking for entry of light.

3.5 TEMPERATURE MONITORING AND CONTROL

Measurement of the return air temperature to the cooling unit will give a good indication of the load temperature, provided adequate air flow is achieved throughout the length of the vehicle. For longer vehicles (above 6 m) air ducting is recommended to ensure sufficient cold air reaches the rear of the vehicle. In a long vehicle, two sensors are recommended to be fitted in the compartment: one measures the return air temperature, and the other is placed two thirds to three quarters the length of the vehicle mounted in the ceiling ducts. The difference between these two temperatures should be an indication of how well the refrigeration is functioning. If the difference is large or variable it may be indicating insufficient pre-cooling, incorrect stowage of pallets, or unnecessary delay in closing the doors. The recorder can be placed in the vehicle cabin or mounted on the outside usually near the refrigeration controls.

A non-destructive (surface) temperature measurement should be taken of the product being loaded into the vehicle and a record made on the documents.

A product temperature measurement is required if there appears to be a problem. If it is necessary to measure product temperatures during transport whilst the vehicle is loaded, samples should be selected from the top and bottom of the consignment adjacent to the opening edge of each door or pair of doors.

Similarly, if product temperature measurement is necessary, it should be done when the vehicle is unloaded, or when the cargo is placed in refrigerated environments in the same way as in the vehicle. Four samples should be selected from amongst the following points:
Sampling positions for a loaded vehicle

- top and bottom of the consignment adjacent to the opening edge of the doors;
- top and far corners of the consignment (as far from the refrigeration unit as possible);
- centre of the consignment;
- centre of the front surface of the consignment (as close to the refrigeration unit as possible);
- top and bottom corners of the front surface of the consignment (as close as possible to the air return inlet).

When samples are selected a non-destructive temperature measurement should be carried out first. In some countries a total tolerance of 2.8°C should be applied (2°C for limitations of methodology and 0.8°C tolerance for the system) before deciding whether a destructive measurement is necessary.

3.6 Transfer Points

Transfer points can be the weakest link in the cold chain if care and attention is not paid to moving quick-frozen foods as rapidly as possible from cold store to vehicle, or from vehicle to holding store, or from holding store to cabinets. Often, transfer of responsibility (ownership) occurs at the same time.
Quick-frozen foods should not be left for any significant length of time to ambient temperature and humidity. It is recommended to use a temperature controlled area (dock, loading and unloading platform) for all external handling of quick-frozen foods. Procedures should be established for dispatching loads and for immediate storage of food upon arrival, in order to minimize exposure to humidity, elevated temperatures or other adverse conditions. It should be ensured that all personnel are following such procedures. It is recommended to check the temperature of quick-frozen food that is received or dispatched, and to retain a record of these measurements for as long as is legally or commercially appropriate.

Operations (such as casing, order assembly, palletising, etc.) should be carried out in the cold store or in suitably temperature controlled area.


(2) **K coefficient**: the overall coefficient of heat transfer which represents the insulating capacity of the equipment.

4 - RETAIL

The quick-frozen food facilities in retail premises should be designed to maintain a product temperature of –18°C or colder except during defrosting and brief periods during loading.

Quick-frozen foods are displayed in retail cabinets which have to balance presenting the foods clearly and within easy reach with maintaining the quick-frozen food temperature at the prescribed level.

Display cabinets should have a properly marked maximum load line on the cabinet wall, and the foods should never be placed outside the load line.

Display cabinets should be equipped with an accurate thermometer that is easily readable. In open cabinets, the temperature should be measured in the return air, at the load line level, or at the warmest place.

4.1 DISPLAY CABINETS

Display cabinets can be classified as:

- open-top horizontal cabinets (gondolas, chest cabinets);
- open vertical cabinets (multi-decked cabinets);
- vertical cabinets with glass doors;
- horizontal cabinets with movable (sliding) glass or plastic covers.

Some shops use combination cabinets, comprising an open-top cabinet with a glass door cabinet above it.

4.2 REFRIGERATION SYSTEM IN DISPLAY CABINETS

The refrigeration system is mechanical. In large supermarkets there is normally a central refrigeration plant, from which the refrigerant, or the secondary refrigerant, is circulated to the cabinets.

Stand-alone (or self-contained) cabinets have the refrigeration machinery within the cabinet, usually in the base. Power supply and a drainage system are the only connections necessary.

4.3 FACTORS INFLUENCING TEMPERATURE IN DISPLAY CABINETS

The temperature of quick-frozen food in retail cabinets is influenced by several factors, apart from the temperature and velocity (and distribution) of the circulated cold air.

Heat radiation from the walls, ceiling and lighting can cause temperatures in the exposed packages (packages in the upper and outer layers) that are 5-10°C warmer than in unexposed packages. This is especially a problem in open-top horizontal cabinets, but is also important in the other cabinets.

Infiltration by warm air into the cabinet is very important in open cabinets. The air curtains should reduce the infiltration, but especially in vertical cabinets there is a considerable air infiltration. This is also the case in open vertical cabinets with glass doors, when the doors are open.

Night cover: the use of night covers outside opening hours is recommended as they may reduce product temperatures and reduce the energy consumption.

Conduction: heat will be conducted through cabinets walls. As these are insulated, the heat introduced by conduction is normally of limited importance.

Other factors: heat from lighting, defrosting, de-misting in glass door cabinets, electrical heaters in the rim around the top of open-top horizontal cabinets, etc. can raise the temperature in quick-frozen food cabinets.

Positioning the cabinet: proper positioning in the store has a marked effect on the performance of the cabinet, and may have a marked effect on the temperature conditions in the cabinet. Cabinets must be placed away from direct sunshine, draughts (from doors, windows, air conditioning fans), heating sources, etc.

4.4 MAINTENANCE

The cabinet should be inspected daily, especially to ensure that:
- the temperature readings (and possibly recordings) are in the normal range. It is recommended that
  new equipment is fitted with an audible or visual alarm system that will activate should a refrigeration
  failure occur;
- the defrosting system is operating correctly;
- the load is properly arranged, particularly respecting the load limit line.

The cabinet should be kept clean and free of dirt and debris, to maintain refrigeration efficiency and to
reduce the possibility of food contamination. The outside should be cleaned every day.

At appropriate intervals, the refrigeration system should be stopped, and the quick-frozen food
compartment emptied and washed thoroughly. Before reloading the temperature in the compartment must
be back to normal (refrigeration system should be started again).

The refrigeration system should be serviced according to the manufacturers instructions, at least once per
year.

4.5  **Back-up Storage Room**

All shops should have some sort of a back-up storage room for storage of quick-frozen food. Back-up
facilities make it possible to:

- reduce food temperature to the appropriate level, as a brief temperature rise during local distribution is
  allowed in many countries;
- have a reserve of quick-frozen food from which food can be loaded into display cabinets. Thus, the
  back-up should be large enough to store loads immediately upon arrival;
- store quick-frozen foods during breakdown of cabinets, and during cleaning and service of cabinets.

4.6  **Temperature Measurement**

If it is necessary to measure the temperature of quick-frozen foods in retail display cabinets, then one
sample should be selected from each of three locations representative of the warmest points in the
cabinets. The positions will vary with the different types of retail display cabinets used.