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

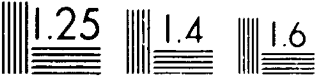
FAIR USE POLICY

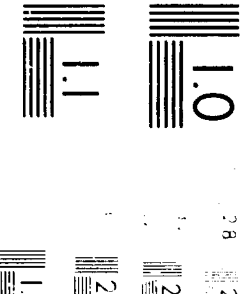
CONTACT

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


1.25
1.4
1.6


1.0
1.1
1.8
2.0
2.2
2.5

10833

Distr.
LIMITED

UNIDO/IO.443
29 July 1981

ENGLISH

UNITED NATIONS INDUSTRIAL
DEVELOPMENT ORGANIZATION

SEMINAR ON INTERNATIONAL CO-OPERATION ON DESIGN,
CONSTRUCTION AND OPERATION OF FRUIT AND VEGETABLE PROCESSING PLANTS AND
COLD STORAGE FACILITIES

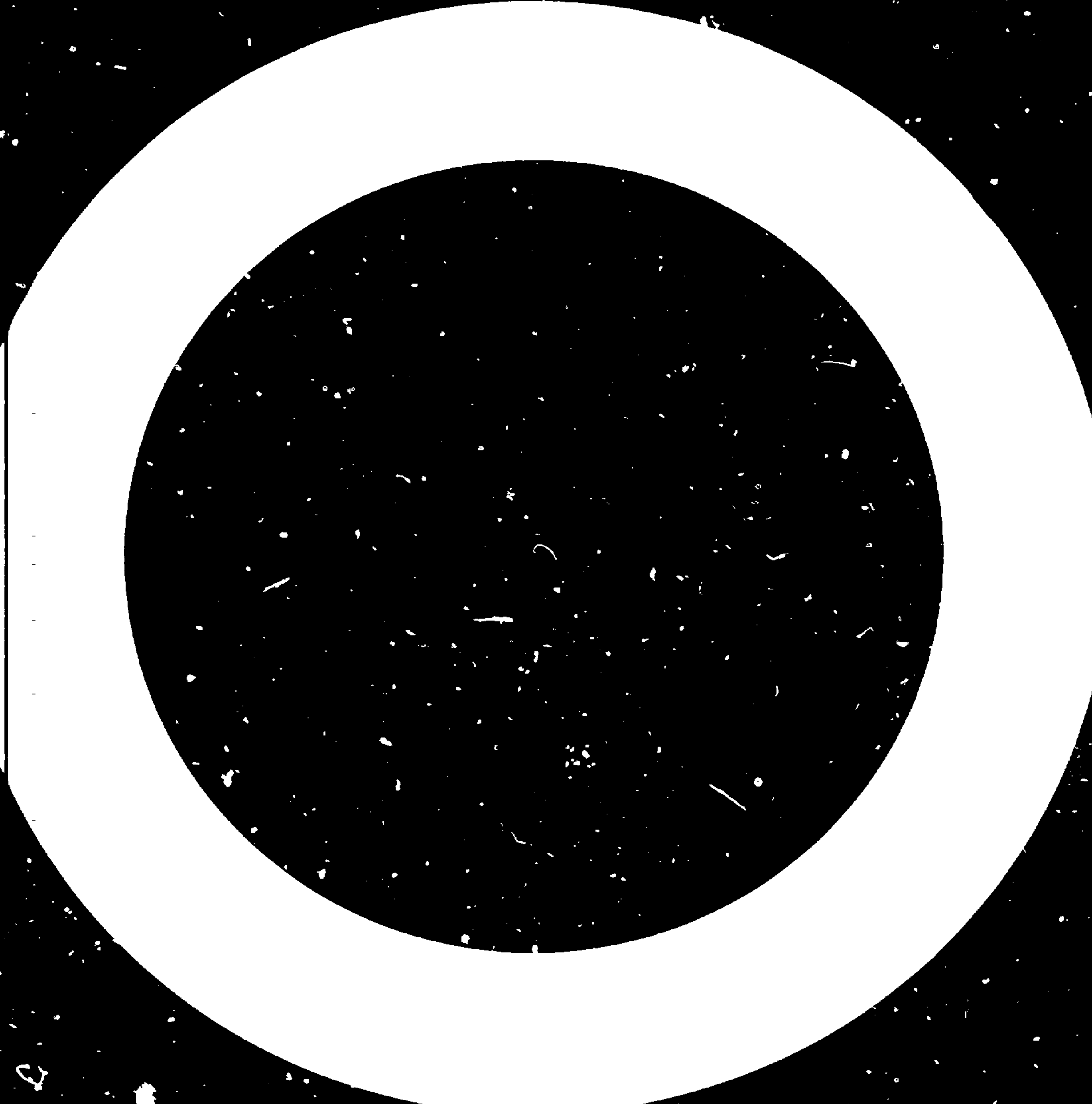
UC/INT/80/115

Trends in design, erection, operation and maintenance of refrigeration plants for processing and storing of fruit, vegetables and food products 1/

T. Gatchilov, M. Lalov and St. Kalev

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO.

V.81-28026



CONTENTS

Figures

I. GENERAL TRENDS

Despite the importance of refrigeration to the food industry, it is estimated that even today only 25 to 30 per cent of all perishable foodstuffs undergo cold processing during their production. As a result losses — amounting to 20 to 30 per cent on a world scale — are still high. Because of this there has been intense development of refrigeration during the last decade.

In practice the development and the application of refrigeration in the food industry features two main trends:

(a) Accelerated introduction of "technological cold" into the different branches of the food industry. Often this goes hand in hand with other process innovations as a means of achieving optimum technological conditions for production of perishable foodstuffs. In this case cold is an integral part of the whole technological process and has to fulfill its specific requirements;

(b) Systematic restructuring of the food industry and the whole cold chain of a given country around the idea of refrigeration. On the basis of the individual elements of the cold chains in some countries, stable or variable cold chains can be linked on a world basis, thus opening up the possibility for intensive international exchange of food products.

The fact that the food industry can undertake cold processing and subsequent storing at the appropriate low temperature in continuously increasing amounts is due to:

(a) Refrigeration processing and storage of the foodstuffs emerging as the best protection against spoiling - preserving simultaneously and to the greatest extent the food products' initial natural properties and qualities;

(b) Cooling and freezing being less expensive in terms of energy consumption than other known methods for storing food products.

In some countries the food industry relies on specialized enterprises both for cold processing (preparation, cooling and freezing) a wide range of perishable food products, and also for their subsequent long-term storage at low temperatures and appropriate humidities. In countries with developed refrigeration economies, the range of the frozen food products already numbers more than 500 different kinds; this number doubles every five years. Frozen food products, in fact, have shown the biggest growth of all branches of the food industry in the past decade.

For example, between 1973 and 1977, the consumption of frozen foods in the Federal Republic of Germany increased by 50 per cent, reaching 368,700 tons in 1977. Consumption increased again to reach 406,000 tons in 1978. Almost 25 per cent of all foodstuffs available in the United States of America in 1978 were frozen foods. The future evolution of the main kinds of frozen foods in that market is presented in the table.

Frozen food production in the United States
(thousands of tons)

Year	Fruit	Vegetables	Ready-cooked foods	Fruit syrups	Total
1970	387	1 946	1 770	860	4 963
1974	343	2 455	1 506	1 000	5 304
1980	400	3 193	2 500	1 200	7 293
1985	400	6 360	10 000	1 800	18 560

In general two trends are evident in world markets:

(a) Production of frozen foods is actively promoted in countries having a developed canning industry;

(b) Frozen vegetables and frozen ready-cooked foods dominate the frozen foods range structure.

The forecasts show this second trend will continue in the future. In most of the developed countries, production of frozen vegetables is considerably higher than that of frozen fruit, often accounting for 70 to 80 per cent of output.

On the other hand, the range of these products is limited to a few basic varieties (e.g., spinach, peas, French beans) required by caterers. However, for some time past, production of frozen vegetable mixtures and frozen onion slices and pieces - replacing dried onion - has been increasing also.

In the last few years production of processed potatoes has shown substantial increases. For example, in 1975, 49 per cent of the United States crop was processed; in 1980 it was forecast to increase up to 76 per cent. This trend, reflected in production increases of 15 to 30 per cent per year, could also be observed in many other countries. It is also typical that approximately 50 per cent of all processed potatoes in the United States found their way into the many varieties of frozen products.

For many years now, centralized production of ready-cooked foods on an industrial basis has been carried out world-wide. In many countries (Austria, Bulgaria, Czechoslovakia, Germany, Federal Republic of, Japan, Poland, Sweden, Union of Soviet Socialist Republics, United States) the leading role in this already belongs to frozen ready-cooked foods and is forecast this trend will intensify still further. Developed West European countries, in particular, are experiencing very high production growths in these foods (10 to 20 per cent per year) and they are accompanied by a considerable broadening of the range of products offered. Similarly in the United States, some 50 per cent of all ready-cooked foods are frozen.

To achieve the goals appropriate to a particular country, the food industry should include in its structure different kinds of refrigeration plant that allow the establishment of a complete closed cold chain. The following main types of refrigeration systems - differing in volume, storage capacity etc. - can be distinguished:

Preparatory refrigerators. For initial cold processing of food products and usually located in the area where the raw product originates.

Industrial refrigerators. To supply the cold requirements of food industry enterprises, including short-term product storage.

Basic refrigerators. For long-term storage of the food products from the preceding two refrigerators. Usually located in consumer areas.

Transit refrigerators. For short-term storage and accumulation of food products during transfer from one type of refrigerated transport to another. Located at large transport centres such as sea ports and river harbours, railway functions.

Distribution refrigerators. For regular supply of large consumption centres requiring food products at all seasons of the year. Established at user centres.

Commercial refrigerators. For short-term storage of the perishable foodstuffs in commercial networks and catering establishments.

Refrigerated vehicles. Refrigerated wheel-, sea-, river- and air transport. Intended to provide optimum low temperature conditions for transporting perishable foodstuffs [illegible] areas of the above-mentioned stationary refrigerators. The importance of these refrigerated vehicles for establishing and operating a complete cold chain cannot be overestimated.

Household refrigerators. For short-term storage of food products in domestic conditions. Together with catering department refrigerators, acts as the final link in the cold chain.

Three further characteristics of refrigerators may also be noted:

(a) In most cases separate refrigerators accomplish two or more functions due to their ability to perform different operations;

(b) Each refrigerator can be adjusted to maintain one or more temperatures, i.e., food products may be stored under one or more temperatures. At the same time, the number and the relation between the capacities of the different systems depend on the function of the particular refrigerator;

(c) Depending on the type of refrigeration plant, equipment of different types can be installed in it for preliminary preparation of the food products, preceding their cold processing.

Running an enterprise for cold processing and storing of fruit, vegetables and foodstuffs involves five main activities - preliminary research, design, erection, and maintenance and operation.

II. PRELIMINARY RESEARCH

The research stage is the initial and most important activity. On it depend the final structure and effectiveness of the enterprise. It is realized in several sub-stages: technical inquiry, quotation and the working design.

A. The technical inquiry

This initial document is the responsibility of the investor and provides the basis on which quotations and working designs are made. The technical inquiry should therefore reflect the real and prospective raw materials supply, the transport system, the utility supply facilities such as electricity and water, and the manpower available.

The raw materials base should as far as possible be described in detail, specifying the kind of the fruit and vegetables, their quantity and seasonal availability.

If a plant location is defined (at the raw material base or at the point of consumption), data should be provided on the state of the transport system, the type of vehicles, the type of processing and the packaging envisaged.

To determine refrigeration capacity, there should be data referring to:

(a) The seasonal flow of product to be processed, the type of cold processing, the duration of storage at the enterprise and where production will be shipped (within the country or abroad);

(b) Available electric energy; this determines the energy economy and the eventual need for an in-plant diesel generator set;

(c) Available water sources; this influences the type of water pretreatment needed (mechanical, chemical etc.) as well as its efficient utilization;

(d) Available manpower and its costs; this determines the level of the mechanization of the operation.

The above technical and economic data could also be prepared by a separate organization authorized by the investor.

B. The quotation

This is a full elaboration of the project, divided into separate parts: architecture, building, process, refrigeration, heating and ventilation, water supply and sewerage, and electrical requirements. In addition to the technical decisions, each of these parts requires complete specification of the equipment, the erection materials and manpower.

All parts are mutually connected and are co-ordinated. Special attention is given to the final techno-economic section that defines the profitability of the refrigeration enterprise. This part is also worked out by the investor's own experts on the basis of the preliminary project and concerns the basic economic factors:

(a) Commodity production:

(i) To prolong the consumption season at home and abroad;

(ii) To prolong the running period of the processing lines;

(b) Raw materials value and energy requirement. For the electricity, the installed plant capacities and the respective yearly expenses, should be given; for water, the size of the expenditures and the respective annual expenses;

(c) Manpower and wages. The operating staff per shift and average yearly pay; all social charges should be included;

(d) Investment cost. This includes:

(i) Building works necessary for the whole enterprise - including insulation work. To this should be added and the cost of the land, vertical planning and inter-plant roads;

(ii) The machinery and the equipment including their transport and insurance;

(iii) The erection works, including the inter-plant transport, rigging and technical assistance;

(iv) Research and design;

(v) Other expenditures such as interest on credits, insurance and administrative or management expenses;

(e) Production cost. The general economic statement should also evaluate the following:

(i) Plant expenditures, including those for raw materials, energy consumption, labour and depreciation allowances;

(ii) Cold processing cost and the final production cost of the stored product:

(iii) Yearly profit of the refrigeration enterprise; profitability may be calculated as:

$$\frac{\text{annual profit}}{\text{plant expenditures}}$$

(iv) The payback period:

$$\frac{\text{investment}}{\text{annual profit}}$$

The techno-economic section should also show whether the enterprise would be economically advantageous and effective.

The complete quotation is subjected to discussion at a council of experts consisting of the investor's technicians and economists. When solving new problems (such as those concerning process or building questions), it is better if the relevant parts of the project are submitted for written comment to specialists in the field, e.g. an institute or a prominent expert.

Where there are several quotations it is necessary to prepare a techno-economic comparison showing the advantages of each. On the basis of this, the most suitable and efficient offer for the buyer is selected.

C. The working design

The final stage of the design includes all notes for modifications and additions recorded in the council of experts' written statements and the technical appendixes accompanying the signed supply agreement.

The working design is completed with detailed specifications of the proposed machines, equipment and erection materials. The working project must also contain and all instructions for mounting, maintenance and repair of the machinery and equipment as well as the labour protection requirements.

Besides this, the working design also contains general operating instructions covering the normal and efficient operation of the plant. Special attention is given to measures for environmental protection.

III. TRENDS IN DESIGN

The design task can be simplified with the assistance of:

(a) Extensive technical information, already collected and classified;

(b) Handing over problem questions to experts having knowledge and experience;

(c) Preliminary study of all conventional equipment and utilization of as many standardized parts for mounting foundations, supports etc. as possible;

(d) Use of computers for calculating certain technical problems;

(e) Use of up-to-date techniques for making copies and photographs.

In designing the structure, the trend is that they should be light and easily mountable. The production premises should be provided without internal columns to allow more efficient and progressive technologies to be introduced in the future. A metal framework - galvanized or treated with anticorrosive coating for protection against high humidity (especially for countries with tropical climates) - is preferable.

The structure should also be designed bearing in mind that its depreciation allowances are significantly smaller than those of the process and erection equipment. Sandwich type panels, consisting of zinc-coated steel sheets on both sides, are preferred for the insulated structures. The panels facing the interior of the refrigeration chamber are additionally covered with a plastic coating selected for resistance to the open foodstuffs passing through the plant. Panel interiors are polyurethane foam, the thickness of which corresponds to the temperature difference. (This is optimally defined with reference to the energy consumption and depreciation allowances for a given plant). The insulation panels must also provide the required vapour resistance.

To reduce the influence of direct radiation from the sun, i.e. to reduce energy consumption (especially in southern countries), external cladding of the refrigeration building roof and walls is foreseen. By this measure, natural air circulation in the intermediate space between the cladding and the panels eliminates the additional heat gain from the radiation.

The number of doors for each refrigerating chamber is determined according to its capacity and either the arrangement of the pallets or the transport passages within the chamber. To ensure free traffic flow in the corridors and easy handling, sliding doors with open areas - giving ample clearance for transport vehicles, is preferred. To reduce cold losses, such doors should be automatically as well as manually operated, and provided with air curtains.

The trend in the number and size of the refrigerating chambers is in the direction of consolidation in order to achieve good load factors.

The main trends in process design are to maximize mechanization of the loading-unloading area and to maximize utilization not only of the refrigerated area but also of the refrigerated volume. As a result it is advisable to extend the height of refrigerating chambers, which for each separate project has to be determined with reference to the means of transport used.

Another clear tendency in the design of refrigeration installations is to provide small capacity cold stores with their own cooling, but giving larger ones a centralized refrigeration system.

In the first case each of the refrigerating chambers is cooled by a separate packaged air cooling unit. Using a modular principle cold stores can thus be built up with capacities ranging from 60 to 3,200 tons (figure I). Air cooling units operate with freon as refrigerant and are often provided with air cooled condensers. An example is shown in figure II.

The modular principle can also be used for refrigerating chambers with centralized cooling. This permits cold stores with capacities up to 16,000 tons (figure III). The refrigerant here is ammonia (R 717), which, as shown in the following table, is the refrigerant with the best thermodynamic properties.

Refrigerant	Volumetric cooling capacity[a/] ($kcal/m^3$)
Ammonia R717	517.6
Freon R12	305.6
Freon R22	494.0
Freon R502	512.3

a/ $t_o/t_c = -15/+30^\circ C$.

Following better safeguards against leaks at flange connexions and fittings, use of ammonia, the least expensive refrigerant, is now preferred.

The evaporating temperatures (i.e., the number of cooling cycles) should comply with the operating requirements. Preferred technical conditions are those that reduce foodstuff losses during storage and that give small temperature

Figure I. Cold stores with separate cooling system

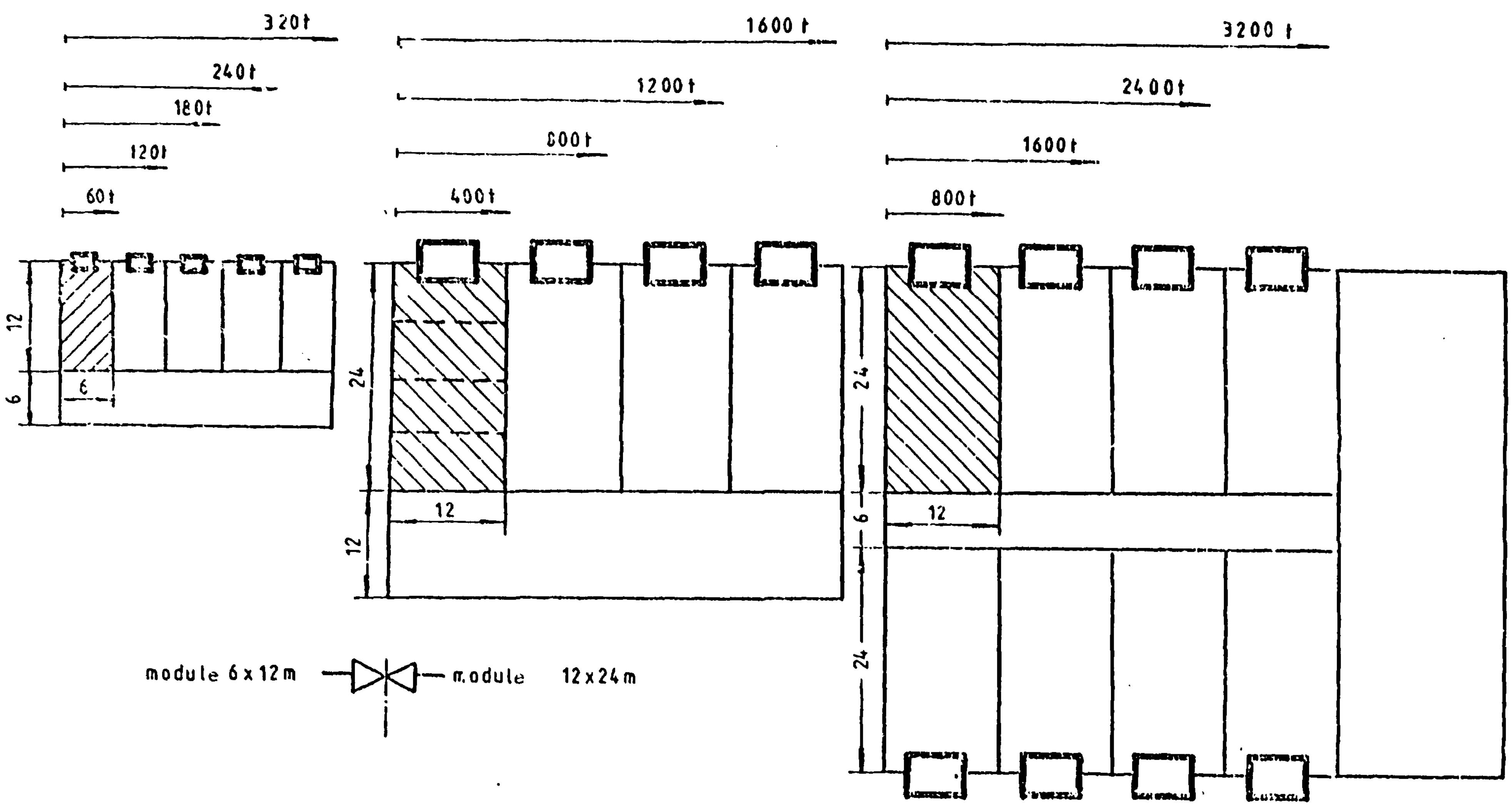


Figure II. Refrigerating chamber provided with separate air cooling unit

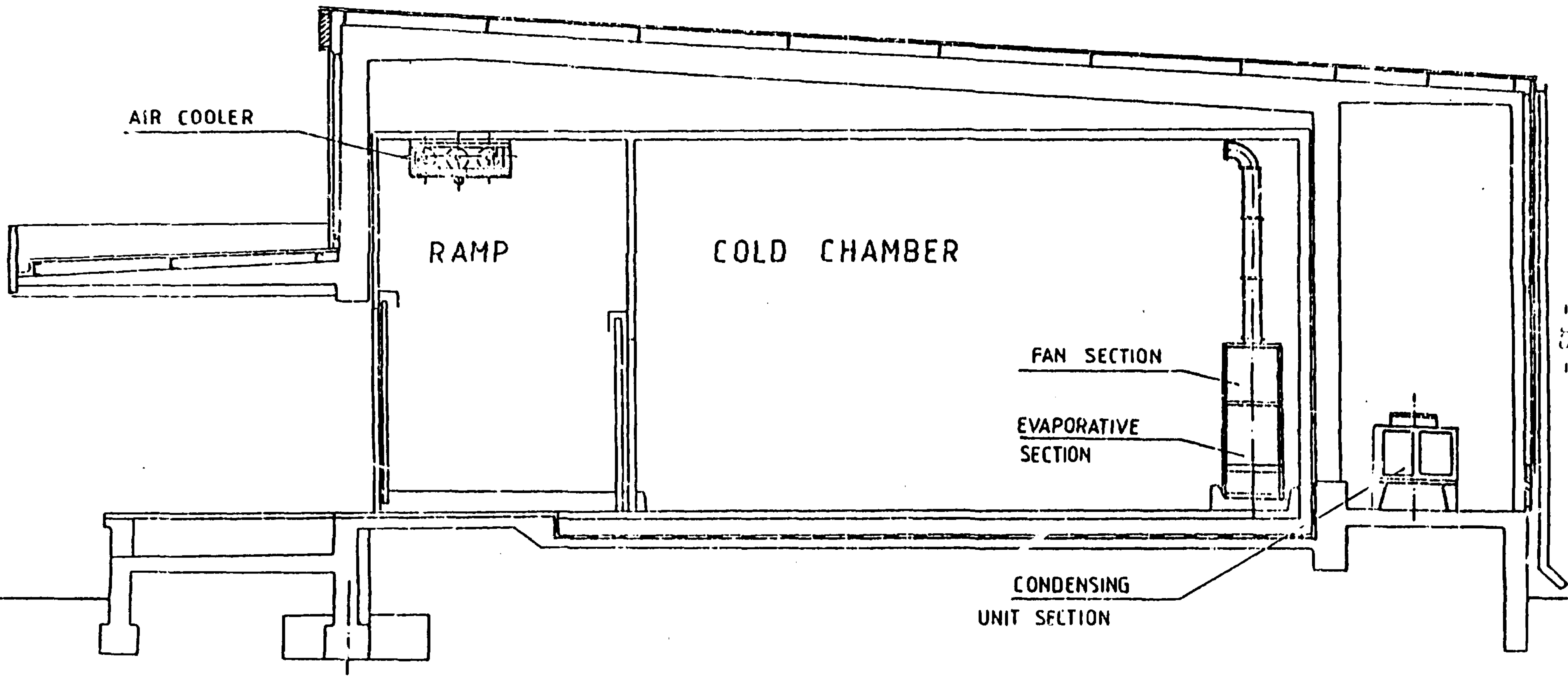
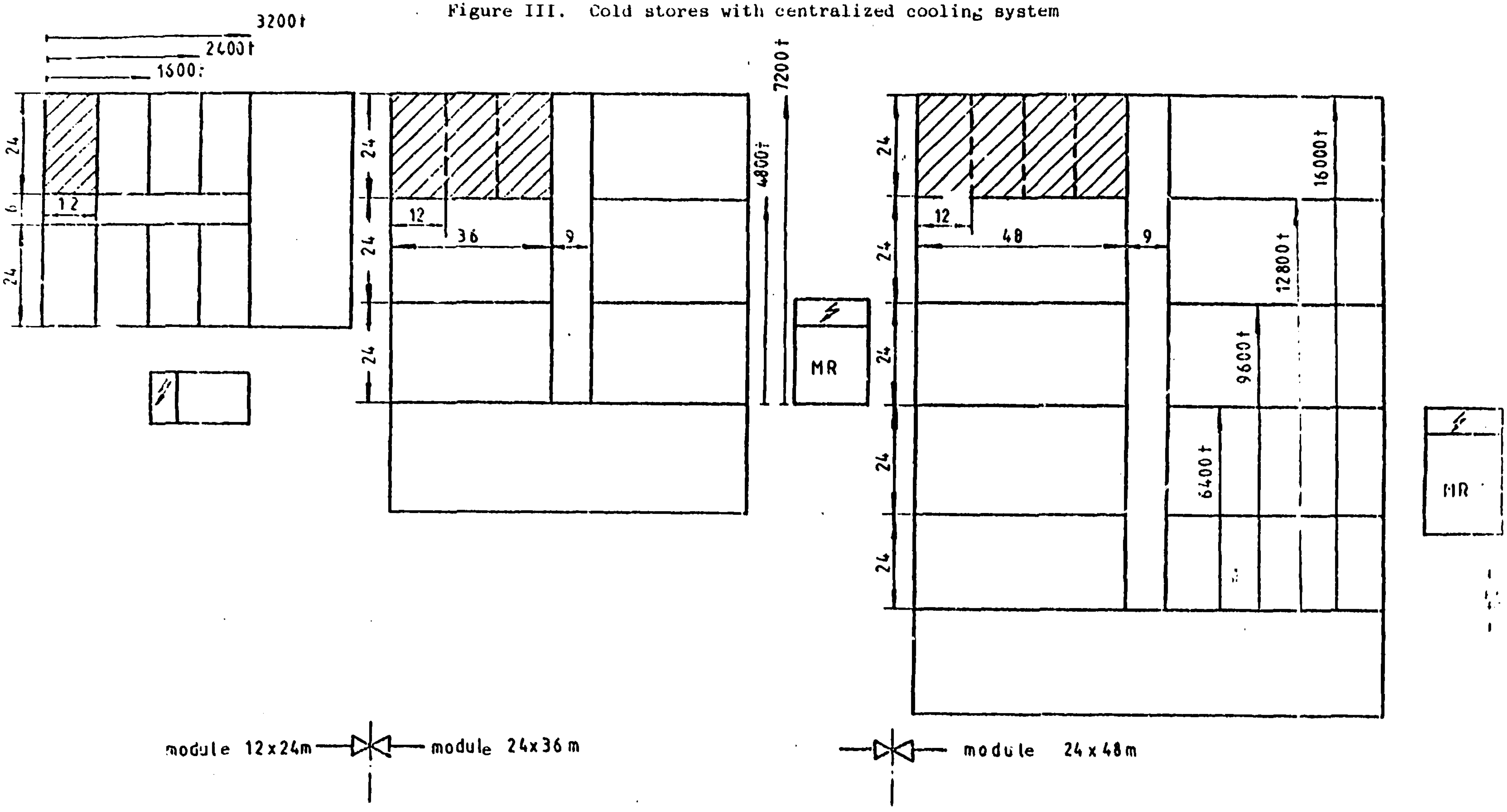


Figure III. Cold stores with centralized cooling system



differences, e.g. with increased area of evaporative surface. The increased initial investment costs (depreciation allowances) are offset by the reduced cost of the stored products (reduced losses) and by the reduced operating energy concumption: every 1°C reduces electric power consumption by about 4 per cent.

In the refrigerating chambers for storing fruit, vegetables and other food products, the tendency is to provide also the necessary mechanical appliances for maintaining relative humidity and the other optimum conditions needed to ensure long-term qualitative storage in addition to the equipment to maintain low temperatures.

It is also advisable for the production premises to be air-conditioned or at least temperature controlled, both from a process and a comfort point of view.

The problem of how many and what type of refrigerating compressors turns on the need to ensure process continuity. The individual cooling capacity of the compressors can be optimized in accordance with available work time (16 hours/day), operation under full load, and the number of cycles per hour. Refrigeration compressors should at all times be protected against unallowably high condensing and low suction pressures, poor lubrication, overheating of of the hot vapours and electrical faults. Compressors should also be provided with a means for easy starting and automatic capacity regulation.

The latest requirements for evaporators used in refrigeration chambers means they should be designed with forced air circulation. It is advisable that the evaporator fans be operable at two speeds. This allows switching in accordance with the process demand and/or storage of fruit, vegetables and other foodstuffs. The air coolers should be compact, with fin spacing optimized for the temperature of the air in the refrigeration chamber but adjustable for automatic defrosting with hot refrigerant vapours.

The choice of condenser type should be determined bearing in mind the world-wide energy crisis and the general lack of industrial water supply. It is preferable to use a condenser with as small as possible water consumption and with the possibility for applying the heat-pump principle allowing use of waste heat of condensation. One use of this heat of condensation, given a suitable heat exchanger, is hot water for domestic and process heating. In this realization the coefficient of transformation $\left(\frac{\text{energy received}}{\text{energy input}}\right)$ is more than double that of a refrigeration system only.

The heat-pump process, moreover, is fully automatic and it has good performance and high economic efficiency.

In a modern refrigeration plant, electrical installations include: lighting, power, emergency light system, telephone exchange, earthing, lightning conductors, fire warning, emergency "man in refrigerator" and remote temperature control.

Control measuring instruments and automatic devices for providing normal operation of the refrigeration system and all other installations are also needed. These instruments and devices ensure:

(a) Automatic protection against emergency situations;

(b) Automatic control of temperatures, relative humidities, pressures, liquid levels, cooling capacity etc.;

(c) Display of all parameters;

(d) Recording of temperatures or remote temperature control using suitable measurement and recording devices.

IV. ERECTION REQUIREMENTS

The modern trend in erecting of refrigerating plants involves quick and inexpensive construction.

The quick erection obligation requires priority in utilizing prefabricated elements needed for: building construction, insulating panels and roof and wall cladding.

Only trained specialists should work on the building site. This shortens the erection period and reduces the number of the working personnel many times.

Only single-storey refrigeration plants are generally erected. This gives the highest efficiency in relation to investment, the building and the operating conditions.

Low cost building construction can be realized by building on the modular principle. This permits catering for larger throughputs by adding further modules.

Many refrigerating plants are built under turn-key delivery terms. This avoids the investor having to negotiate with many suppliers, and he is still provided with a full guarantee by the general contractor.

V. MAINTENANCE

Cold processing and storage of food products in a given refrigerator can only be achieved when its main components - the insulated refrigeration building, the refrigerating installation itself and the process equipment - operate properly. Efficient processing thus depends on efficient maintenance.

Technical maintenance

Maintenance aims at keeping all machines and equipment of the refrigeration plant in good working order. The required temperature and humidity conditions can only be guaranteed if the state of insulation is continuously monitored and in the event of failures, measures are taken in good time. Special attention must be given to keeping the doors, process equipment and transport facilities in good working order. They should not be allowed to become sources of additional heat gains, due to which the temperature-humidity conditions would deteriorate.

The heat exchangers must be regularly inspected and cleaned of any contamination.

The refrigeration system should also be constantly inspected and even the smallest leakage attended to immediately.

Control instrumentation should always be kept in order and regularly submitted for checking to the appropriate authorities.

Most complicated and yet among the most important are the requirements for maintaining compressors. To ensure reliable and safe operation, running repairs should be carried out to remove any faults and damage. Scheduled overhaul repairs are generally performed at a time most suitable for the refrigeration system, when the latter is less loaded.

The technical equipment intended for transportation, sorting, mechanical and thermal processing and packaging of food products is very varied and because of this should be controlled and maintained every day. After the close of the season, it should be subject to scheduled overhaul and repair.

It is also very important that technically obsolete and worn out equipment be replaced in good time.

VI. PLANT OPERATION

A. Storage of cooled products

With cooled products - as opposed to frozen (see below) - storage is carried out at near zero temperatures but never below the cryoscopic temperature of a given product. This usually ranges from 0°C down to minus 1°C. In this case the preserving effect results from the fact that decreasing product temperature by 10°C reduces the rate of the different chemical and biological processing going on in it by two to three times. Thus the period during which the product remains unspoiled is significantly extended. Products can also be spoiled due to the action of micro-organisms, which at lower temperatures also less actively influence the product. A vital factor for the microbiological processes on the surface of the product is the relative humidity of the air where the product is being stored. The relative humidity should correspond to the temperature, e.g. at high temperature is should be small, while at low temperature, it should be higher. Losses due to evaporation of product moisture depend on the relative humidity value; high humidity is therefore an advantage.

Besides temperature conditions and the duration of storage, specific product properties exert a substantial influence on the system. That is why different products can be stored under cooled conditions for different periods - ranging from a few days or hours (ready-cooked foods, minced meat) up to a few months (some fruit and vegetables, some dairy products). It may be noted that, for their storage under cooled conditions, fruit and vegetables are treated like living organisms. Because of this they should be kept under optimum temperature-humidity conditions, where the temperature varies from 0°C up to 6° or 8°C and relative humidity is within the limits of 80 to 90 per cent.

During the last two decades experiments have been carried out aiming at decreasing the temperature at which the cooled food products, including some fruit, should be stored, e.g. down to 3.4°C below zero. In this case some partial freezing of the products is observed. Due to the fact that the transition from cooled to frozen condition is still not well understood, and to the fact that it is difficult to maintain the above temperature constant, this method has still only limited application.

Some of the basic trends in the storage of cooled food products are as follows:

(a) Only cooled products of high quality are subjected to further cooling and storage. The period covering the time of collecting the product, e.g. harvesting of fruit and vegetables, up to the time when cooling begins, should be as short as possible;

(b) Before being cooled and stored the products are prepared and packaged. For some destinations fruit and vegetables should be packaged separately;

(c) Increasing large-scale use of palletization;

(d) Before being stored the products are cooled down to their storage temperature. Depending on the kind of the product, this might involve intensive or less intensive cooling;

(e) Products are cooled in up-to-date and efficient premises. As noted, fruit and vegetables are considered as living organisms, their cooling for long-term preservation in refrigerating chambers has to be performed slowly to enable them to adapt to the new conditions. To avoid disturbing the temperature-humidity conditions, the quantity of the products imported into the refrigerating chambers each day should not constitute more than 6 to 8 per cent of the chamber capacity;

(f) Many different additional ways to help extend the product storage period are known. These can be divided in two groups:

(i) Where the aim is to suppress the process going on inside the products;

(ii) Where there is additional suppression of the development of microflora.

A typical example of the first group is storage of fruit and vegetables in a modified gas medium (i.e. a controllable atmosphere). Increasing the carbon dioxide content up to 3 to 5 per cent and reducing oxygen content by a similar amount but not less than 2 per cent, helps extend the storage period at reduced losses and gives fruit and vegetables of higher quality.

The ways to suppress development of micro-organisms are more varied: irradiation with ultraviolet rays or radioisotopes, treatment with antiseptics and antibiotics, electroantiseptic treatment, treatment with ionized gas.

Besides preparation of the products for storage, cooling as a technological process may be also performed to create optimum conditions either to meet specific processing requirements for the production of foodstuffs or to achieve pleasant taste in the final product (e.g. cooling of beverages). In its turn, cooling may have two purposes: cooling products for direct consumption and storing of the raw materials and the semi-manufactured articles for further processing.

Despite the comparatively low cost of cooling and the fact that it does not affect the products at all, there remains one main disadvantage - the limited storage life of most products. That is why the second method for food preservation is widely used: freezing.

B. Freezing of foodstuffs

Freezing is achieved when temperatures are gradually decreased down to -20° to -30°C - the majority of the water going from the liquid to the solid state. Since the temperatures here are significantly lower than those during the cooling, they reduce the intensity of the processes going on in the product, without stopping them entirely. At the same time, these temperatures exert an unfavourable influence on micro-organism activity, and at values lower than -12°C, the micro-organisms stop developing entirely. Moreover, a large part of them perish during freezing and subsequent storage. The preserving effect of decreased temperatures is further enhanced by transition of the water from liquid to solid state - a condition which may be regarded as a kind of dehydration of product and therefore depriving the biochemical and microbiological processes of their liquid medium. Due to all these factors frozen and the stored products are protected against spoiling for a prolonged period of time (from 2 to 12 months).

As compared to cooling, the freezing and storage of the frozen foods is a more expensive. Besides this, it negatively influences the structural-mechanical properties of the product compared to other canning methods. Nevertheless, the major extension of the storage period during which the nutritive properties are almost entirely preserved has ensured this method of widespread acceptance. A further factor favouring freezing is the fact that the pecularities of individual products exert less influence compared to cooling. That is why temperatures are held in a narrower range, e.g. -18° to -20°C. Since the danger of micro-organism activity is eliminated,relative humidity can be increased up to 95 per cent or more. In turn this allows frozen food products to be tightly packed and the refrigerator volume more efficiently used.

Storage of food products in a frozen state may have two purposes: storage for direct consumption, or preservation for subsequent processing. Freezing may also be applied as preparation for other processes (e.g., freeze drying or cryogenic concentration) or to receive a specific product such as ice cream.

Before freezing and storing,many products are subjected to preliminary preparation which in many cases may be complicated and demanding of space. Vegetables have first to be sorted, washed, cut, blanched, metered out and packaged, and then sent for freezing. All this work is carried out on specialized process lines, usually using the same equipment as that in the related branch of the food industry. In these production lines, however, equipment is also included specifically for refrigeration.

Food products generally freeze at temperatures of the order from 30° to 45°C below zero. These are maintained in special freezing tunnels and equipment that may be either convective or conductive. The products to be frozen are either in a packaged or bulk state. The construction, the level of mechanization, the intensity of heat exchange vary with the freezing tunnels' design. Freezing tunnels may also be either specialized or universal.

Some of the basic trends and requirements related to freezing and storing of food products are as follows:

(a) Only products of high quality are accepted for freezing since this process fixes their initial state which cannot be corrected later;

(b) The period between product preparation (i.e. harvesting of fruit and vegetables) and initial freezing is kept as short as possible;

(c) The freezing process is performed at relatively high speed using intensive methods. In recent years, there is growing interest in extending the method using liquid cooling media, boiling refrigerants, and liquid nitrogen;

(d) Fruit and vegetable varieties are grown specially for freezing;

(e) Freezing is taking over part of the chilled raw materials and semi-manufactured articles destined for further processing. At the same time, strong growth is evident in frozen, ready-to-cook and ready-cooked foods.

On the other hand there is also a trend to lower storage temperatures of some more valuable and less stable products, e.g. down to -30° and even to -40°C. Such storage is characterized by common requirements such as:

(a) Stability of temperature and relative humidity values. In all cases variations in the storage temperature beyond set limits unfavourably affect the product structure and quality;

(b) Normal circulation of the air within the refrigerating chamber volume in order to achieve uniform temperatures throughout;

(c) Introduction of high capacity production lines having a high degree of mechanization and automation;

(d) Continuity in the cold chain;

(e) Introduction of palletization.

VII. MANPOWER REQUIREMENTS

The characteristics of the refrigeration industry's plant and equipment - their design, erection and maintenance - indicate the the need for specialists in all areas. These also include specialists from institutions of higher education that are well acquainted with refrigeration, refrigerating systems and equipment, food products (their properties, processing methods and variations), organization of work and the basic economics of a given refrigeration plant. Their tasks include research, design, supervision and management during maintenance of the different types of refrigerators.

Engineers, also trained in institutions of higher education, are needed too. Usually these are people specially educated for refrigeration engineering who can be used for design calculations, for supervising erection and for managing and operating the plants.

Depending on the type of refrigerator - i.e. its designation, capacity etc. - the need for such specialists varies. For medium capacity plants, one engineer could manage the technical maintenance, a second engineer-technologist would supervise the whole plant. If a given enterprise is mainly intended for processing and storing food products then at least one more technologist would be needed. In the case of a production plant, their number must be further increased depending on the type, output and the organization of the plant.

In designing, erection and maintenance of a refrigerating plant, specialists with secondary education, especially those trained in special institutions of secondary education, are also be needed. Their part is especially important during plant maintenance since they are the skilled personnel responsible for the technical side. For example, a medium capacity refrigeration plant needs at least four to five technicians to be responsible for shifts in the machine room and for equipment repair.

On principle, specialists with higher and secondary education should be employed from the very beginning of erection. This enables them to take part in the erection process and become acquainted with the site. If necessary these specialists should be sent for training in a similar plant or to a country with a developed refrigeration industry.

From the above, it is clear that a large organization and technical support system (research, design, erection, commissioning and maintenance) have to be created for a plant for processing and storing of fruit, vegetables and foodstuffs.

In the process of solving these complex tasks, two parties are involved: the investor - the owner of the plant - and the general contractor who is responsible for many subcontractors. Continuous contact between the investor and the general contractor are vital for efficient solving of problems arising during the project.