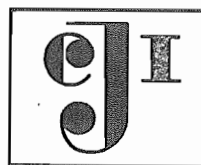


**Project Planning for Small and
Medium Scale Industries No.9**

**Ice Making, Refrigeration
and Cold Storage Plant**

March 1985



JAPAN CONSULTING INSTITUTE

This technical brochure was compiled to help in the drafting of a suitable plan for the construction of Ice Making, Refrigeration and Cold Storage Plant.

The production scale and manufacturing process have been described in this brochure on the basis of a typical instance.

The profitability was estimated by fixing certain required conditions, which may differ from country to country.

We hope that the data contained in the brochure will help you to draw up the most suitable plan for the industrialization of your project.

In case a government or public organization requests the Japan Consulting Institute to conduct a feasibility study of the above industry for the purpose of establishing the most suitable plan, it is possible for us to carry this out free of charge.

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Part I Ice Making Plant

1. Introduction

Man has utilized ice in life since ancient times. Going back in history people cut ice blocks from lakes and rivers in the winter and stored them in caves until summer when they were used to cool rooms. Today this custom of storing winter ice for cooling food in summer is still used in some area. People also used to bury perishable foods such as chicken and vegetables under snow to keep them fresh. This is a popular way of food storage employed by mountain climbers today. Such methods were learned from long period experience. Man came to understand the specific character of ice and its uses such as air-conditioning and refrigeration.

In early 1897, a block ice making system using ice cans in rectangular steel tanks filled with refrigerated and agitated brine was developed. Since then, various ice making systems have been developed.

Ice is used extensively in the following industrial sectors:

- (1) Processing: Fish, meat, poultry, dairy products, baked goods, etc.
- (2) Storage & transport: Fish, meat, poultry, etc.
- (3) Production: Chemicals, pharmaceuticals, etc.
- (4) Others: Retail consumer ice, concrete mixing, as a curing agent for large scale constructions such dams and a heat storage medium at other than peak periods.

2. Ice Making System

At present, widely used ice making systems are classified into four types. These are block ice,

plate ice, tube ice and flake ice systems.

Plate ice, tube ice and flake ice systems repeat making cycle in a short time (within one hour) while the block ice system is a relatively large scale system requiring 24 hours freezing time.

2.1 Characteristics of Various Systems

(1) Block ice system

This system produces transparent ice which is purer and more sanitary than that of other systems. The block ice plant, unlike tube ice and plate ice plants, is not an on-and-off or intermittent type but operates continuously for 24 hours. It does not have intricate components because short time breaks in operation or suspension of operation to discharge hot gas and warm water for thawing and melting are not required. Continuous operation of the block ice system leads to such merits as less frequent load change, unstrained operation of compressor, long durability of the compressor and motor, and unskilled operation. Maintenance of the compressor is also far easier than with other ice making systems.

(2) Plate ice system

Since the freezing time and melting time can be freely set, ice thickness is adjustable between 6 and 20 mm.

The ice is produced very slowly and is highly transparent. One drawback, however, is the use of hot gas (high temperature refrigerant gas) and warm water in the melting process. This means that freezing capacity is reduced. The required freezing capacity has to be larger than that for flake ice. Also, the system employing warm water for melting requires a heating device for raw water and for melting water in the winter.

(3) Tube ice system

This system operates at rather high suction pressure compared to other systems. By increasing the thickness of the ice, high transparency is possible, and a large heat transfer area is assured than that of the block ice. The height of the tube ice making unit is taller than other ice making systems. Ice melting is carried out by hot gas flow at 10 to 15 min. intervals and a considerable quantity of ice can be produced in a short period of time. Also, all water available can be used for ice making without waste. The quantity of ice formed on the inner or outside surfaces of the tube depends on the temperature difference of the water supplied to the tube. Accordingly, in the case of large scale tube ice plants, it is advisable to establish the most economical system taking into account the use of an independent water cooling high suction refrigeration cycle together with refrigeration cycle of the unit.

(4) Flake ice system

The flake ice system employs continuous production means while tube ice and plate ice systems employ intermittent production and ice melting. Since this system has no processes such as suspension of freezing operation at regular intervals for ice melting and heating of freezing surface with hot gas or warm water, flake ice, compared with tube ice and plate ice, has the merit of small refrigeration capacity per 1 ton of ice production. All the water in use can be changed to products (ice) without loss. Flake ice is produced at lower temperature than tube ice and plate ice and is best suited for automated warehouses, especially where low temperature ice is required. Further, flake ice is the most suitable ice for certain applications such as chemical processing and concrete curing where rapid cooling is required, because of large area

needing cooling.

On the other hand, the drawback of flake ice is its opaque color resulting from numerous bubbles and impurities due to the rapid freezing. Consequently, this ice is not suitable for applications requiring sanitary, transparent ice.

2.2 Outline of Respective Systems

(1) Block ice system

Among ice making plants, the block ice plant is the most basic system, backed by the longest history. Tube ice, plate ice and flake ice systems are suitable for making ice within a short period of time and do not require the purest water and transparency. Block ice making is suitable ideal for sanitary, high purity and high transparency block ice, although it is sometimes used for making ice from seawater or opaque ice. The freezing system of this method is as follows.

Ice cans filled with raw water, the base is for ice, are immersed in a freezing tank filled with a brine of CaCl_2 or NaCl used as the heat-exchange medium to freeze the raw water by removing heat.

(2) Plate ice system

Usually, plate ice is made by pouring water over many vertical type freezing plates. As the water is pouring on the upper portion of the freezing plate, it flows down along the full surface of the plate. Refrigerant liquid (-12°C to -20°C) is supplied under the freezing plate and as the water comes in contact with the plate it is rapidly cooled and frozen.

The thickness of the ice can be adjusted by setting the refrigeration cycle time and adjusting the thickness, usually 6 mm to 20 mm. The freezing time is optionally set between 45 and 12 minutes. A sump and water circulation pump are necessary

for plate ice making. The water circulation pump draws up water from the sump and supplies it to the freezing plates.

Regarding ice harvesting, two different methods are employed. With one, hot gas (high temperature refrigerant gas) is used to heat the refrigeration cycle of the freezing plate surface to $4^{\circ}\sim 7^{\circ}\text{C}$ in order to separate the ice from the freezing plates heating the plate surface to the ice melting point. With this method, ice making can be done on both sides of the plate. The other method uses warm water on the back of the freezing plate to heat the refrigerant within the plate over the ice melting point, allowing the ice to separate from the plate. With this method, the warm water exchanging heat with the refrigerant in the plate is precooled. It is then collected in the sump as raw water for the next ice making cycle.

(3) Tube ice system

The tube ice making machine is designed to freeze water spread on the inner or outer surface of vertically arranged stainless steel pipes. Ice making time is 10 to 15 min. After freezing, the ice separates from the pipe and falls by its own weight.

The cylindrical ice is then cut to the desired length using a rotary cutter prepared at the bottom of the unit.

(4) Flake ice system

The flake ice making system freezes water being spread on the inner or outer surface of a cooled drum. Drums can be arranged vertically or horizontally. There are various models such as stationary or portable systems available. A harvester is provided on the drum and the ice is fed into an ice bin at the bottom of the ice making machine. The thickness of the ice is adjustable within a range of 1 mm to 3 mm by regulating the speed of the rotat-

ing parts, temperature of the evaporator and water quantity fed to the freezing surface.

3. Outline of Block Ice Plant

This brochure describes details of a block ice plant, the most common and easiest to operate. Block ice plant system can be classified into the high pressure and low pressure sides. The high pressure side consists of a refrigeration compressor, oil separator, condenser, receiver, gas purger and the piping, valves and joints of the respective devices. Usually, ice making plants store the ice product in a low temperature room. Ice produced in the winter or during a low demand period is also stored in a low temperature room until demand increases. Accordingly, an ice storage facility is usually attached to the ice making plant. This brochure assumes that an ice storage facility is attached. Regarding the low pressure side, the ice making room houses the freezing tank (brine tank), evaporator, brine agitator, ice cans, can grid devices, air agitation system, core water pump, crane and hoist, can dumper, water supplier, accumulator, suction trap, raw water tank and the piping, valves and joints for the low pressure refrigerant and brine.

The ice storage facility uses ceiling hair pin coils hung from hanger bolts. Fig. 1 shows a block ice plant flow sheet. Fig. 2 gives a bird's eye view of a typical plant.

(1) Brine tank (ice freezing tank)

Usually, ice freezing tanks are constructed of 6 mm steel plate. Tank depths depend on ice can dimensions but must be such as to allow submerging all ice can water levels below brine level by 2.5 to 3 cm. A depth of 122 cm to 132 cm depth is required for 135 kg. ice cans.

(2) Brine

The brine for the freezing tank is usually

NaCl or CaCl₂. Since rock salt is often substituted for NaCl, the corrosion of piping and the iron and steel parts of the

brine tank is unavoidable, unlike with CaCl₂. Consequently, it is advisable to employ CaCl₂.

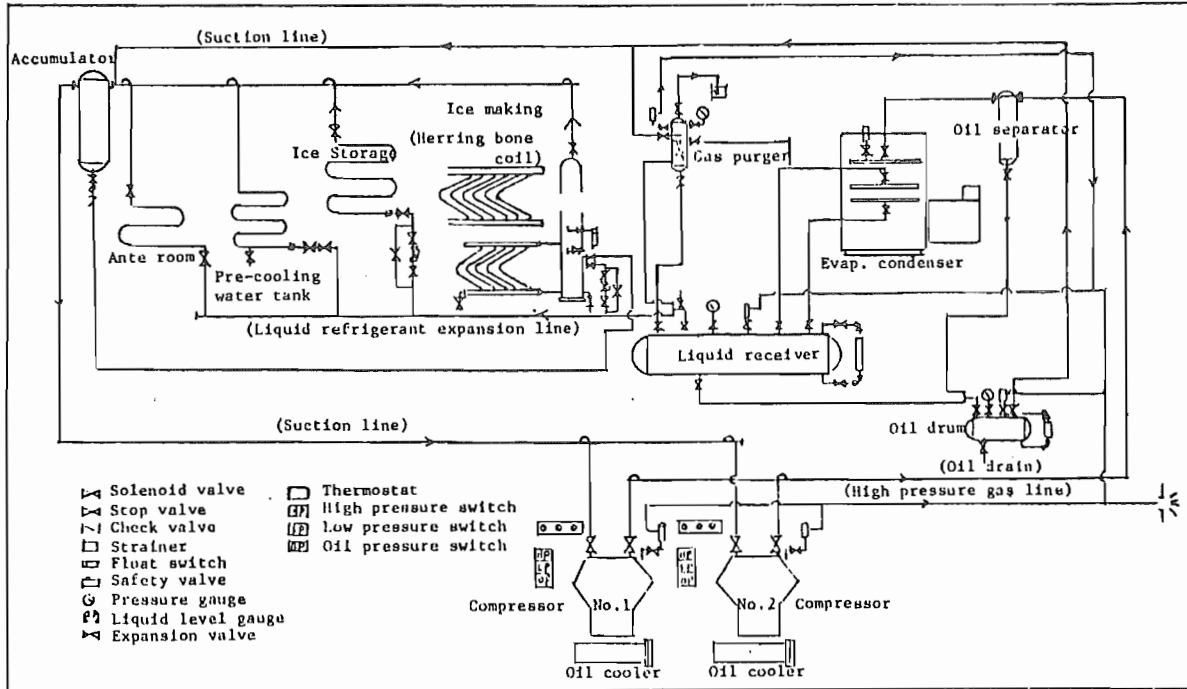


Fig. 1 Ice Making Plant Flow Sheet

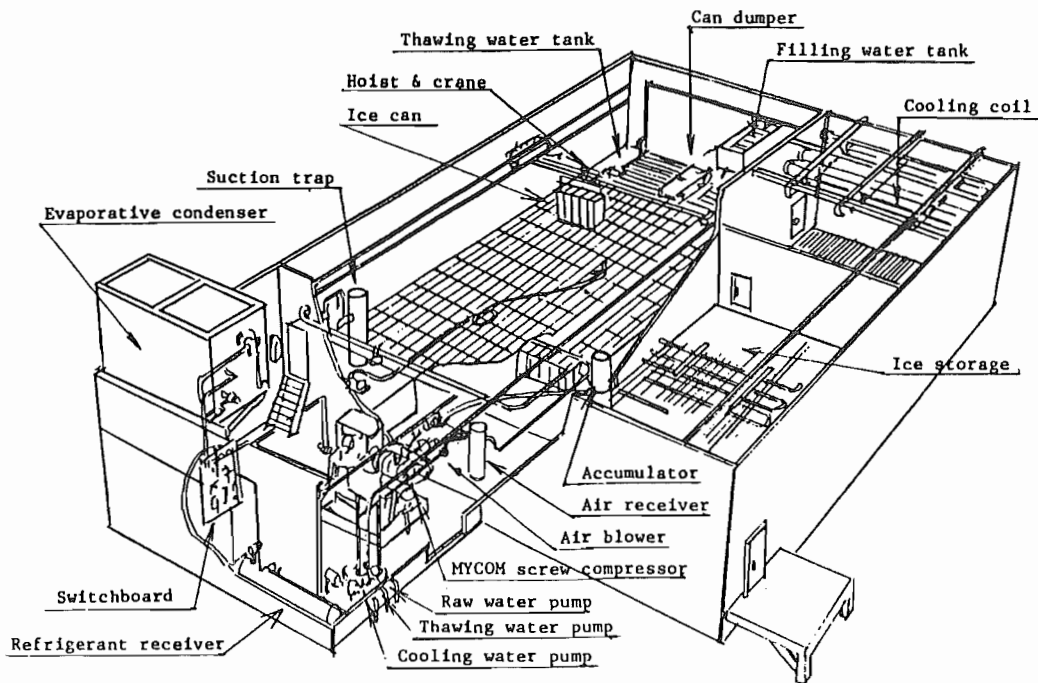


Fig. 2 Bird's Eye View of Ice Making Plant

(3) Brine tank insulation

For tanks with a -12°C to -9°C brine temperature, the usual tank bottom insulation consists of 10 cm ~ 13 cm of cork sheet applied in two layers. Tank sides and ends are usually insulated with 25 cm ~ 30 cm of granulated cork.

ice making process to create high purity, transparent ice. Insufficient pre-cooling of the raw water for refilling therefore has an influence on the ice freezing time.

Even if sufficiently pre-cooled raw water is used, 30~60 minutes for core pulling and refilling is required (refer to Paragraph on core pulling and refilling).

(4) Ice cans

Ice cans may be found in practically any size from 11 kg. to 135 kg. capacity. Standard dimensions are given in Table 1 below.

(6) Brine concentration and freezing point

The brine concentration and freezing point vary with kind of brine. The brine used in ice making is the cooling medium for freeze water in the ice cans and so a lower brine temperature results in faster freezing. When the concentration of the brine becomes weak and the temperature reaches the approx. freezing point of the brine itself, the brine cannot perform its essential function as refrigerant.

Accordingly, periodic checking of brine concentration and securing that the correct concentration is stable must be carried out. Usually, a Baume's hydrometer is used to check the brine concentration.

(5) Can ice freezing time

The time required for freezing depends on the thickness of the ice and the temperature of the brine (refer to Table 2).

The effective surface resistance value from brine to ice varies with brine velocity. Brine velocity is reasonable with less surface resistance and freezing time must be reduced by rapid heat exchange.

Core pulling and refilling operations when freezing are carried out during the block

Table 1 Standard Dimensions of Ice Cans

Dimensions of ice cans (unit: mm)								
Capacity		Internal dimensions			Overall length	Steel hoops		Thickness of Galvanized sheet
Kg.	Lbs. (ref.)	Top	Bottom	Depth		(T)	(W)	
11	25	100 x 260	90 x 250	560	580	3	25	0.9
22	50	130 x 300	115 x 285	790	815	5	32	0.9
45	100	190 x 405	170 x 385	790	815	5	32	1.2
90	200	290 x 570	265 x 545	790	815	6	38	1.59
135	300	290 x 570	265 x 545	1120	1145	6	38	1.59

Table 2 Relationships of Brine Temperature, Ice Thickness and Freezing Time

Ice can freezing time (hr.)															
Thickness Brine temperature (°C)	Thickness of ice														
	10 *	12.5	13 *	15	17.5	19 *	20	22.5	25	27.5	28 *	29 *	30	32.5	35
- 5	10.60	16.60	17.90	23.80	32.50	38.30	42.40	53.60	66.25	80.25	83.00	89.30	95.50	112.00	130.00
- 6	8.85	13.80	13.80	14.90	27.10	31.90	35.40	44.80	55.25	66.90	69.35	74.30	79.50	94.50	108.30
- 7	7.57	11.85	12.80	17.10	23.20	27.30	30.40	38.40	47.30	57.40	59.30	63.60	68.20	80.00	93.00
- 8	6.62	10.36	11.20	14.90	20.30	23.90	26.60	33.60	41.40	50.15	52.00	55.70	59.60	71.00	81.50
- 9	5.90	9.22	9.95	13.25	18.10	21.30	23.60	29.80	36.80	44.60	46.30	49.60	53.00	62.30	72.40
-10	5.30	8.29	8.95	11.92	16.25	19.15	21.20	26.80	33.10	40.10	41.50	44.60	47.80	56.00	65.00
-11	4.83	7.55	8.14	10.85	14.75	17.40	19.30	24.40	30.10	36.40	37.70	40.60	43.40	51.00	59.10
-12	4.41	6.92	7.45	9.95	13.55	15.95	17.70	22.35	27.60	33.40	34.60	37.20	39.70	46.70	54.20
-13	4.08	6.37	6.87	9.20	12.50	14.70	16.35	20.66	25.50	30.90	31.90	34.30	36.70	43.10	50.00
-14	3.79	5.92	6.40	8.51	11.60	13.65	15.15	19.15	23.60	28.65	29.70	31.80	34.10	40.00	46.50
-15	3.53	5.52	5.96	7.95	10.83	12.75	14.15	17.90	22.10	26.75	27.70	29.70	31.80	37.40	43.40
-16	3.31	5.18	5.59	7.45	10.15	11.95	13.30	16.77	20.70	25.10	26.00	27.90	29.80	35.00	40.70
-17	3.12	4.88	5.26	7.02	9.57	11.25	12.50	15.80	19.50	23.60	24.40	26.20	28.10	33.00	38.30
-18	2.94	4.61	4.96	6.63	9.05	10.65	11.80	14.90	18.80	22.30	23.10	24.80	26.50	31.20	36.10

Note: * 10 cm represents top size of 11 kg. can, 13 cm for 22 kg. can, 19 cm for 45 kg. can, 28 cm for 2 kinds of 135 kg. can & 90 kg. can, 29 cm for 135 kg. can & 180 kg. can respectively.

(7) Brine agitator

The purpose of agitation is to forcibly mix the brine in the brine tank to facilitate conduction and transfer of heat as well to promote heat exchange at the cooling tubes (herring-bone coil). Once the brine reaches a certain velocity, conduction and transfer of heat and enforcement of heat exchange are achieved and a faster velocity does not serve to improve the freezing effect.

Consequently, the best suited type and capacity of agitator and motor should be selected as the hours of usage during the year represent a considerable consumption of power.

(8) Air agitation, core pulling and refilling

Blowing air into ice cans filled with raw

water is necessary for the production of transparent ice. The air affects water agitation during freezing. This agitation assists in forming transparent, pure water ice crystals by rejecting the major volumes of dissolved salts and coloring into the unfrozen water core. It is normal procedure to pump out the core and replace it with fresh water, preferably pre-cooled, to avoid prolonged freezing time.

(9) Ice can lift, grid and tank cover

Usually, ice cans are kept in position by a wooden framework at the top. If the scale of the plant is small, two 135 kg. ice cans can be lifted and transported to the harvestor at one time using a ceiling crane or lift but the achieve a higher lifting speed requires that the numbers of ice cans be

increased.

The ice can grid system has been developed to meet this requirement, and lifting operation can be carried out within a short period of time. The can grid should be galvanized and weight is important in preventing the cans from floating up and tipping into the brine. The required weight per 135 kg. ice cans is 10 to 25 kg.

(10) Thawing tank and harvester

Ice can groups are carried by overhead travelling crane to the thawing tank harvester end and submerged under water until the ice floats up the water surface. Thawing tank water is preferably not more than 20°C to avoid ice cracking or undue melting.

After the ice thaws from the can and floats up to the water surface, the ice together with ice can is lifted and advanced to the harvester.

(11) Refrigeration devices for ice making plant

(a) Compressor

There are many kinds of compressors available, e.g., high speed multi-cylinder compressor type, screw compressor type and single acting vertical compressor type, etc. Among the above, the single acting vertical compressor is not commonly in use today. The high speed multi-cylinder compressor is the most common refrigeration compressor for small and medium scale ice making plants. The screw compressor is ideal for large scale ice making plants because of the fewer frictional parts, easy after service and maintenance and fewer compressors required.

(b) Other devices

Refrigeration devices other than compressor include the oil separator, oil drum, condenser, cooling water pump, liquid receiver, accumulator, suction trap, herringbone coils in the brine tank, cooling tubes in the storage room and piping, valves and joints between these devices and the compressor (refer to Fig. 1 and 2).

(c) Devices in the ice making room

Devices in the storage room include the brine agitator, hoist and travelling crane, thawing tank, water refilling tank, core pulling pump, raw water pump and air agitator. The use of automatic controls and alarm devices is important for plant maintenance and safe operation.

A water filter and other raw water purifying equipment to assure high ice quality are also commonly used.

(12) Room for day storage and seasonal storage
Day storage should accommodate the full production of block ice for 3 days, with the ice stored on end, based on a 1.2 m² per ton.

Usually, it is advisable to install seasonal storage accommodating 1~2 months production adjacent to the day storage at the lower floor level.

Insulation for the day storage and seasonal storage is based on maintaining -2.2° ~ -4°C room temperature.

The working height to the ice stacker should be reasonable and loading or unloading work capable of being carried out by one person. One stacker can handle about 50 tons of ice per 8 hour shift.

(13) Required manpower

Operations such as harvesting and transport to storage can be done at five to six 135 kg.

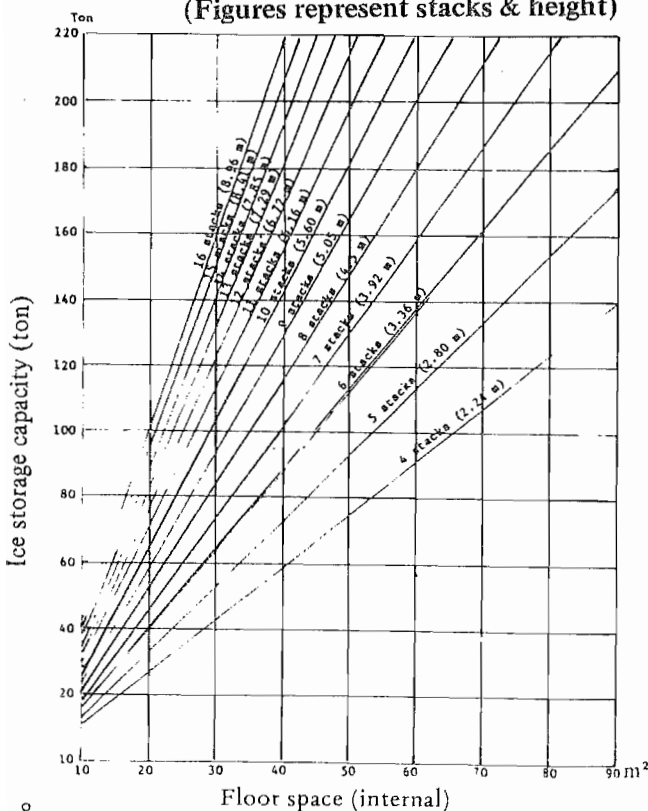
blocks per minute. It is usual in plants of 40 ~ 70 tons for a single person per shift to operate the plant, attending to engine room duties, thawing, harvesting, storing ice and scoring it. In plants of 80 ~ 100 tons daily capacity, it is usual for one person per shift to operate the plant in this same manner, except that he gets some help from a day laborer who assists in all duties, particularly for core pumping, filling and scoring in storage.

In plants of under 75 tons daily capacity, small floor space and minimum foundation work at less cost is possible.

4. Outline of Construction of 45 kg. Ice Making Plant

Table 3 shows the construction costs and Fig. 3 the relationship between storage capacity and floor space for 5 tons/day, 10 tons/day, 20 tons/day, 30 tons/day and 50 tons/day cases of 45 kg. of an ice making plant respectively.

Fig. 3 Block Ice Storage Capacity
(Figures represent stacks & height)



8.

5. Profitability of Ice Making Model Plant

An ice making plant should be established at a favorably situated place considering operational profitability. Water, the main raw material of the plant, is relatively low in cost excepting for in a few countries of the Middle and Near East, Africa, Central and South America. In addition to water, other factors such as labor cost, tax, maintenance and administrative expenses and electric power changes are included as ordinary expenses but it is difficult to quote correct figures because unit prices differs by country.

Therefore, this article gives only a rough estimation of profitability for a daily capacity of 10 tons of ice making and a 30 ton storage facility based on up-to-date figures obtained in Tokyo, Japan.

(1) Selling cost

(a) Equipment

Approx. value of devices

FOB ¥23,000,000

Approx. construction cost

of building ¥14,000,000

Approx. installation cost

¥17,000,000

Ocean freight & import tax

¥10,000,000

Total

¥64,000,000

The above cost of equipment can be recovered in 15 years at an annual rate of equal redemption.

$¥64,000,000 \times 1/15 = ¥4,270,000/\text{year}$

(b) Utilities

The cost of water and electric power vary considerably depending on the country so the following are calculated based on business records of a certain Japanese ice making factory in 1984.

Table 3. Construction Costs of Ice Making Plants, 5 tons/day, 10 tons/day, 20 tons/day, 30 tons/day and 50 tons/day with Respective Ice Storage

General Information for Constructing 45 Kg Block Ice Plant with Concrete Flat Building						
Ice production	Ton/day					50
	Tons					
Ice storage		20	30	50	100	150
Floor space (m ²) (Approx.)	Ice making room	55	75	120	155	270
	Ice storage and platform	20	25	30	50	75
	Machine room	10	10	15	20	30
	Total:	85 m²	110 m²	165 m²	225 m²	375 m²
Thickness of insulation	Freezing tank	150 mm				
	Ice storage	100 mm				
Compressor capacity (US RT)	For ice making	11	21	42	63	105
	For ice storage	1	1.5	2.5	4	6
	Total:	12.0	22.5	44.5	67.0	111.0
Compressor (Model and quantity)	Type: High speed multi-cylinder reciprocating type	1	1	2	2	2
Ice freezing tank (Can grid type)	Number of cans/grid	6 cans x 20	7 cans x 32	9 cans x 50	10 cans x 68	10 cans x 56
	Depth (mm)	920	920	920	920	920
	Number of brine tanks	1	1	1	1	2
	Width of tank (mm)	3,900	4,300	5,300	5,800	5,800
	Length of tank (mm)	5,600	8,400	12,700	17,100	14,100
Approx. price of equipment	Unit: FOB in Japan Yen (1,000 Yen)	18,000,	23,000,	35,700,	46,000,	71,200,
Approx. cost of building construction	Unit: in Japanese Yen (1,000 Yen)	11,600,	14,000,	20,000,	24,000,	40,000,
Approx. cost of installation works	Unit: in Japanese Yen (1,000 Yen)	11,000,	17,000,	22,000,	25,600,	34,400,
Electric power required	Approx. KW	35 - 40	55 - 60	90 - 100	130 - 140	220 - 230
Manpower required for operating the plant	Approx. No. of persons	8	12	15	20	30

Part II Refrigeration and Cold Storage Plant

1. Introduction

The product shape, freezing system, freezing time and storage system have considerable influence on the quality, appearance and commodity price of harvests and catches. Since the deterioration of all foodstuffs begins immediately after the harvest because of bacteria and microbes begin to breed, the most important point is how to protect harvests and catches from bacteria and microbes and deliver a fresh, sanitary and outstanding taste, as harvested or caught, to the consumer's table.

Freezing of fish and cold storage of frozen fish should be provided together not only at the production base but from the moment of catching on board the fishing boat. The present tendency, however, is to construct refrigerated warehouses without freezing units because goods are being delivered in a frozen state and freezing is not required in the refrigerated warehouses located at the consumption area.

For example, in the case of transport of bananas, a typical fruit from the tropics, 7 or 8 years ago bananas had to be harvested while green transported to the consumer destination within three weeks using reefer carriers. Color was then developed in maturing rooms and the product put on to the market.

Recently, however, introduction of refrigeration systems which maintain hold temperature, humidity, etc., has resulted in substantial extension of the allowable marine transport period to over 3 months or 5 times what was possible in the past.

On the other hand, as the reefer carrier speed increases, bananas that is need not be matured in maturing rooms at the consumer destination but which are fully mature and colored on the trees can be delivered directly to the consumer. It is matter of course that variety, quality and fresh-

ness have a considerable influence on commodity prices irrespective of the country though there exist different conditions in the case of such commodities as bananas, which turn black when bruised, and the case of fish and meat, which cannot be checked simply from the appearance.

2. Fishery Products Freezing System

As freezing method differs by type of foodstuff, this brochure describes the freezing of fish as a representative sample. There are several freezing systems used, according to size, kind, color and shape of fish. The following are representative methods.

(1) Semi-air blast freezing system

With this method the fish is placed on freezing plates on pipe shelves with ammonia, freon (R-12, R-22) or a secondary refrigerant brine supplied to cooling pipes above the pipe shelves in an enclosed freezing room.

Usually, many fans are installed on the ceiling to agitate air in the room and secure uniform room temperature and uniform freezing time of all of the products.

(2) Air blast freezing system

With this method the fish is frozen in a small freezing room or tunnel in which cold air cooled down to below freezing temperature is circulated around the fish. A refrigerant such as ammonia, freon (R-12, R-22) or brine flowing through cooling pipe furnishes the necessary refrigerating effect.

(3) Contact plate freezing system

This method freezes the fish by refrigerant flowing through connected passageways in a horizontal, movable plate flat tank tacked vertically in the center of the cooling room. Usually, a specific amount of shrimp or fish are packaged in consumer-size cartons, put in freezing pans and arranged on the flat tank.

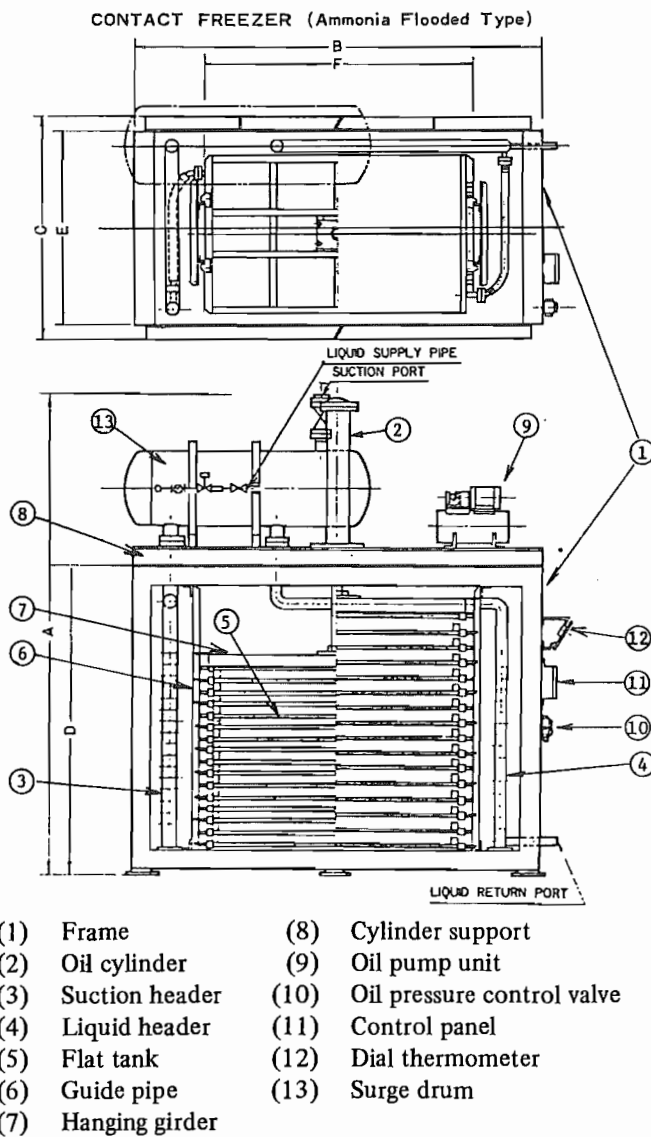


Fig. 1 Cross Sectional View and Parts Names of Contact Plate Freezer

The flat tank is pressed down by oil pressure to assure heat exchange by contact between the top and bottom of the goods in the freezing pan and the flat tank. This is one of the most common freezing methods employed these days.

Since the entire freezer is covered with insulated outer wall, free selection of the installation place is possible and insulation work for storage buildings is not required. Besides, this method has the merit of saving energy because cooling is not for entire freezing room as only the products in the flat tank are cooled.

The energy requirement for refrigeration of products becomes larger as the thickness of the products increases.

Fig. 1 shows a sectional view of a contact plate freezer. Fig. 2 shows the relationship between freezing speed and thickness of fish fillets and fish sticks.

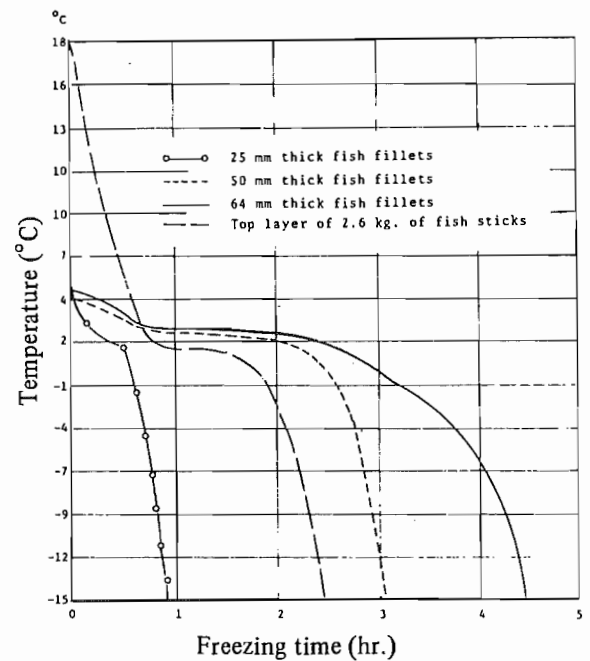


Fig. 2 Freezing Time of Packaged Fish Fillets and Sticks in Plate Freezer

(4) Brine immersion freezing system

Direct immersion in low temperature brine is one of the most effective methods of forced freezing of products because there is 100% contact between the product and the brine. Immersion freezing is used primarily for the freezing of tuna, shrimp, salmon and crab at sea.

An important consideration in freezing is the selection of a suitable brine medium. Recommended is a mixture of glucose and salt in water. This medium has the merit of reducing salt penetration into the fish and at the same time providing a glaze on the fish that protects it from loss of weight resulting from dehydration.

Recently, the liquid nitrogen spray freezing method has come into wide use for the individual quick freezing (IQF) seafood products such as shrimp, scallops and fillets. The quality of products frozen by this method is good and there is virtually no weight loss from dehydration but the energy cost is high.

(5) Steel belt freezer system

The steel belt freezer has excellent features such as:

- * Stepless speed adjustment of belt speed in freezer within a range of 6~60 min. according to size, shape and kind of product.
- * Since this method is a combination of contact plate freezing and air blast freezing methods, it provides outstanding freezing efficiency compared with other methods.
- * This method is not only sanitary and compact, different cooling face lengths according to installation space are available.

3. Frozen Fish Cold Storage

Fishery products may undergo undesirable changes in flavor, smell, appearance and texture during period of storage. These changes are attributable to dehydration (moisture loss), oxidation of the oils and pigments in the products, and breeding of bacteria in fish and shellfish. No matter how good the quality of products frozen in a superior freezing unit may be, the level and constancy of storage room temperature and humidity where the product is to be stored have considerable influences on the quality and the sales price of the product.

(1) Effects of temperature on products

Frozen fish and shellfish must be kept at $-25^{\circ}\text{C} \sim -35^{\circ}\text{C}$ according to the kind of product (-55°C in case of tuna). Storage above -23°C , even for a short time of period, will result in rapid loss of quality. When the product is finally thawed, the total effect of each exposure to high temperature or other mistreatment is reflected in the quality of the product at the consumer level.

Continuous storage at a temperature lower than -25°C reduces oxidation, dehydration and breeding of bacteria, resulting in longer product life. It is important therefore that frozen product always be kept at $-25^{\circ}\text{C} \sim -35^{\circ}\text{C}$ or at -55°C in the case of tuna.

(2) Effects of humidity on quality

A high relative humidity in the cold storage room tends to reduce evaporation of moisture from the product. The relative humidity of air in the refrigerated room is directly affected by the temperature difference between the room cooling coils and the room temperature. An increase in this temperature differential results in decreased relative humidity and an accelerated rate of moisture loss from the frozen product. Likewise, a small temperature

difference between the air and the evaporator cooling coils results in a high relative humidity and reduced moisture loss from the product.

- (3) Effects of packaging and glazing on quality Adequate packaging of fishery product is important to prevent dehydration and consequent quality loss. Certain kinds and sizes of fish cannot be individually packaged, therefore they must be protected by a suitable glazing compound. A glazing acts as a protective coating against dehydration and oxidation of the product during storing period of product in the cold storage room.

Usually, the room should be kept at $-4 \sim -7^{\circ}\text{C}$ and the temperature of the glazing solution maintained just above freezing but not so low as to cause development of ice crystals. Frozen fish are depped into the solution tank to build up a glaze on the outside.

Fresh water and the solution for glazing should be nontoxic, harmless, transparent, inexpensive and uniform in application.

- (4) Space requirements for frozen fish storing The space required for storing of frozen fish depends on the height of stacking in the refrigerated warehouse. At the same time, kinds, sizes and stacking method of products are also important factors.

Packaged fishery products such as fillets and fish sticks are usually packed in cardboard cartons for storage and shipment. These cartons are stacked on pallets and transferred to various areas of the refrigerated warehouse by a fork lift.

In unpalletized warehouses the packages are usually loaded onto a hand truck and stacked within the refrigerated warehouse rooms by hand, but this work is seldom these days for personnel efficiency and health reasons. Work at low temperature

for a long time affects health care costs and labor costs.

Expediting of loading/unloading work and correct in/out and stock control requires computerized semi-automatic stacking systems and a fully automatic refrigerated warehouse.

Large fish such as halibut, salmon or hair-tail are placed in wooden boxes and then stored in wooden or metal pallets in the refrigerated warehouse or are stacked individually.

Fish frozen in metal pans such as mackerel, dace or certain kinds of codfish are removed from the pans after freezing, glazed and then packaged in wooden boxes lined with wax-impregnated paper or in cardboard cartons. Round fish stored in wooden boxes can be easily reglazed at periodic intervals during frozen storage.

Fig. 3 shows the space requirements for storage of frozen fish.

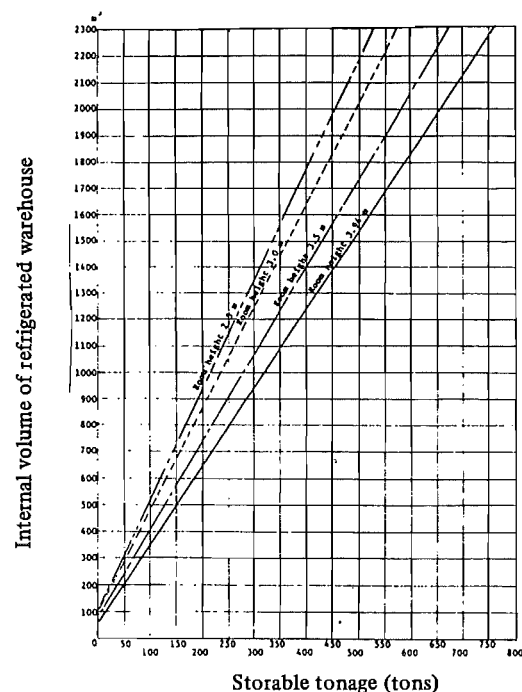


Fig. 3 Volume and Storable Tonnage of Refrigerated Warehouse

4. Refrigeration of Other Products

A controlled atmosphere (CA) refrigerated warehouse may be required for specialized storage, particularly the handling of fruit such as apples. Interest and development are growing in the application of CA techniques for other commodities. In addition to the usual refrigeration devices, CA systems also include special gas tight seals to facilitate the maintenance of an atmosphere that is lower in oxygen and higher in nitrogen and carbon dioxide than normal atmosphere. This restrains the breathing of fruit in storage and the freshness and taste of such products are almost the same as when first harvested even after 6 or more months.

5. Refrigerated Warehouse Cooler (Evaporator)

Evaporator (cooler) systems in refrigerated warehouses can be hair pin ceiling coil type, unit cooler type or ceiling duct type. Cooling systems for heat exchange are direct expansion and brine systems.

Recently, full automatic capacity control systems employing liquid refrigerant pumps are being widely adapted not only for large capacity refrigerated warehouses but also medium capacity installations.

Frost on the evaporators in refrigerated warehouse grows gradually decreases cooling efficiency, so periodic defrosting is essential. In the case of a ceiling coil system, stored products be covered with canvas to protect them from damage when defrosting. Some inconvenience is inevitable when defrosting.

On the other hand, in the case of unit cooler and duct systems, defrosted water drops only under the cooler and much convenient for automatic defrosting and for draining defrosted water.

Unit cooler and duct systems use forced air agitation, so uniform temperature of refrigerated warehouse can be secured.

Fig. 4 shows a piping flow sheet for a unit cooler.

6. Outline of Construction of Rapid Freezing and Cold Storage Warehouse

This article describes construction of a medium/small scale shrimp contact freezer and refrigerated warehouse. Details are given in Table 1.

The prices of equipment/devices are all FOB basis because freight differs by country where the equipment is to be exported from Japan.

Construction cost of the building is calculated based on standard expenses in Japan because unit prices and labor costs differ by country.

Table 1 excludes indefinite factors such as ocean freight, insurance premiums and import duties.

7. Items to be checked for Profitability of Freezing and Cold Storage Plants

Profitability of freezing and cold storage plants undergoes a wide range of change due to various conditions such as installation place, kinds and catches or harvests of products, water and electric power utility costs and labor costs.

For this reason, it is difficult to work out profitability based on an established model plant. Consequently, the following should be checked in construction of freezing and cold storage plants to assure profitability.

- (1) Kinds and catches of fishery products
Prices of products change according to kind, size and season. Especially, the kinds of catch is divided into detailed classes, even though identically classified and prices also considerably differ.
Large catches and large demand are not always related to good profit. On the contrary, smaller catches of particular kinds often provide greater profitability. In case of fishery products to be consumed at or around the place of production, relatively easy selection can be carried out. In the case of products for export, the following should be carefully considered:

Table 1 Construction of Shrimp Freezing and Cold Storage Plant

Freezing (contact freezer)	kg/shift	500	1,000	1,500
Storage capacity	tons	50	100	150
Space in sq. m (m ²)	Contact freezer	16.0	16.0	16.0
	Processing room	95 - 110	125 - 140	150 - 180
	Cold storage	100	132	160
	Anteroom	16 - 20	20 - 25	25 - 30
	Machine room	33 - 40	40 - 50	50 - 60
	Total:	260 - 286	333 - 363	401 - 446
Insulation: (thickness: mm) Material: Styrofoam	Cold storage	200	200	200
	Anteroom	100	100	100
Compressor Model & number				
Contact freezer	1 set	42A	62A or 42B	42B or 62B
Cold storage	1 set	4A	6A	8A
Refrigerant		NH ₃ R-22	NH ₃ R-22	NH ₃ R-22
Storage height	Approx. in meter	3.0 - 3.5	3.5 - 4.0	3.5 - 4.0
Storage temp.	°C	-25 - -30	-25 - -30	-25 - -30
Approx. price of equipment	Unit: Yen 1,000	20,000,	28,000,	35,000,
Approx. price of building construction	Unit: Yen 1,000	31,515, - 34,667,	40,364, - 44,000,	48,600, - 54,600,
Approx. price of installation and construction	Unit: Yen 1,000	5,000,	7,500,	10,000,
Approx. total cost	Unit: Yen 1,000	51,515, - 58,667,	75,864, - 79,500,	93,600, - 99,600,
Required manpower (including machine room)	Including washing, selection, weighing, freezing, in/out, packing and others	30 - 50	40 - 70	50 - 80

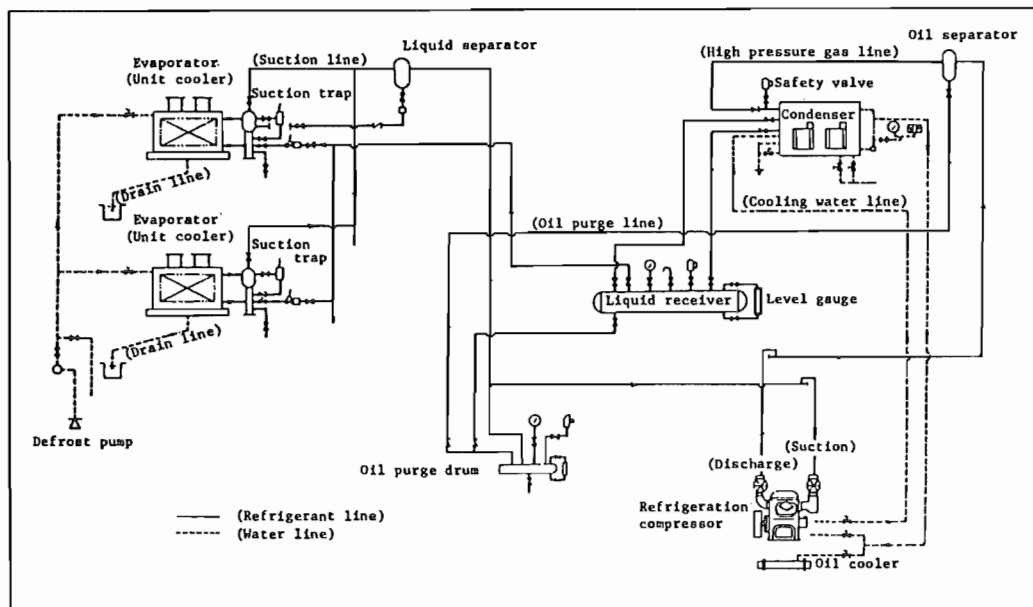


Fig. 4 Piping Flow Sheet for Refrigerated Warehouse

- * Are the products suitable for export?
- * Where is the destination country?
- * Is a long period of stabilized supply possible?

(2) Plant installation site

A place where smooth supply of utilities such as water and electric power should be secured. The site should be adjacent to the fishing port and port of call of vessels bound for abroad.

(3) Easy securing of labor

Regarding freezing and refrigeration of products, considerable manpower is required for processing of entrails, selection, washing, packing and weighing before freezing so cheap and sufficient labor is essential.

(4) Selling cost

The sales price of fishery products should be decided after full investigation of effects from price setting to payment terms based on market research.

Project Planning for Small and Medium Scale Industries

- No. 1 Rice Milling Plant and Rice Bran Oil Manufacturing Plant
- No. 2 Plastic Woven Bag Manufacturing Plant
- No. 3 Container Board Manufacturing Plant
- No. 4 Plastic Blow Bottle Manufacturing Plant
- No. 5 Concrete Block Manufacturing Plant
- No. 6 Glassware Manufacturing Plant
- No. 7 Galvanized Iron Sheet Manufacturing Plant
- No. 8 Fishing Net Manufacturing Plant
- No. 9 Ice Making, Refrigeration and Cold Storage Plant

Project Planning for Small and Medium Scale Industries No. 9

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