

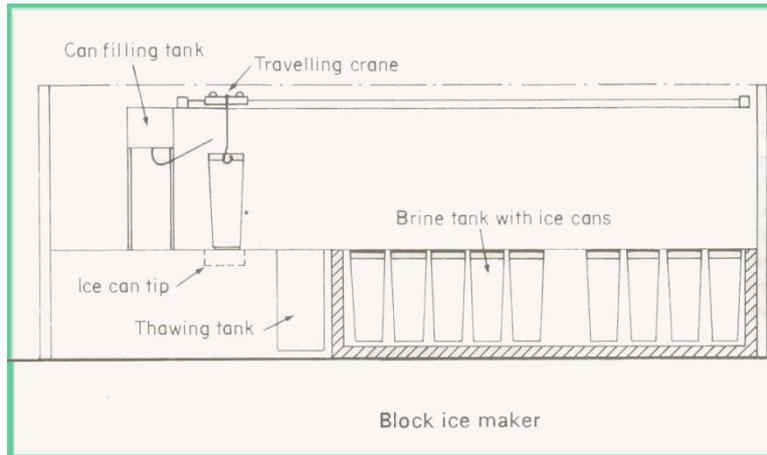
Manufacturing of different types of Ice, Super chilling (0°C to -4°C), Application of ozone / chlorine in seafood processing

2.3.1. Introduction

There are many methods of producing ice. The manufacturing process of one may involve efficiencies or advantages over another or the ice produced by one process may be better suited to the intended application than another. **Commonly used ices are block ice, flake, plate and tube ice.**

2.3.1.1. Block Ice

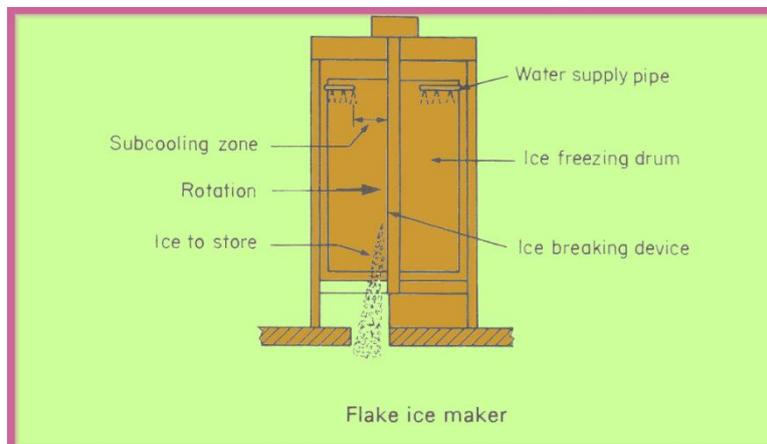
In the manufacture of block ice, tapered rectangular cans filled with potable water are immersed in a tank of refrigerated brine solution .



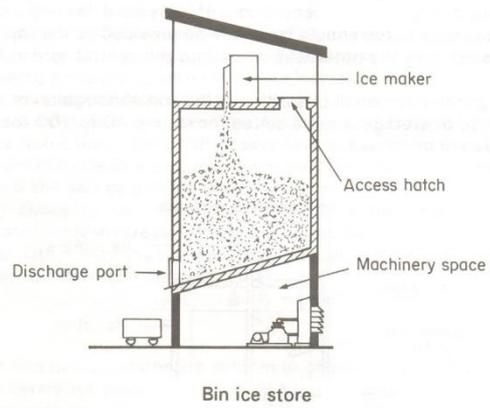
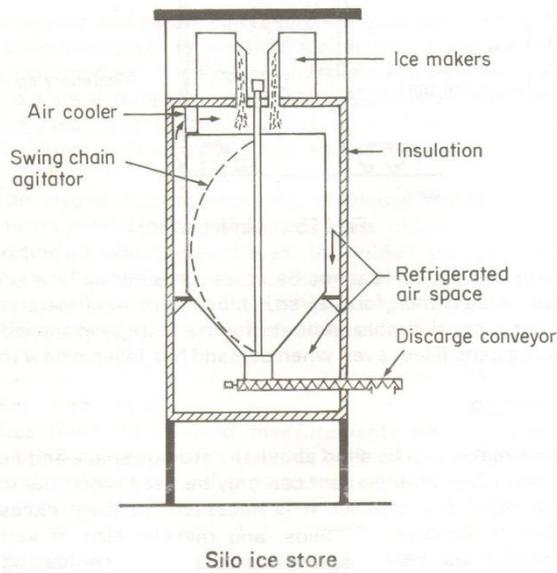
The brine solution which is cooled to about -30°C by a refrigeration process extracts the heat from the water and produce block ice within the can. The cans are then removed from the tank and thawed for a short time in a tank of water to release the block from the can. The blocks are then stored in a chill room and can be crushed on demand. The freezing period is typically between 16 and 24 hours although plants known as rapid blocks are available that have freezing period of only a few hours. The quick freeze is achieved by the direct evaporation of the refrigerant in a jacketed mould fitted with finger evaporators. The blocks are released by a hot gas defrost and are sub-cooled below 0°C . Rapid block plant requires less floor space than brine tank system.

2.3.1.2. Flake Ice

A thin sheet of ice, 2 to 3 mm thick, is formed by spraying water on to a refrigerated drum; it is scraped off to form dry sub-cooled flakes. In some models, the drum is rotated; in others, the scraper or knife is rotated; in most designs, the drum is vertical. Flake ice production is continuous and automatic; ice is formed within a few minutes of starting up the machine, which can be adjusted so that the thickness of the ice produced can be varied.

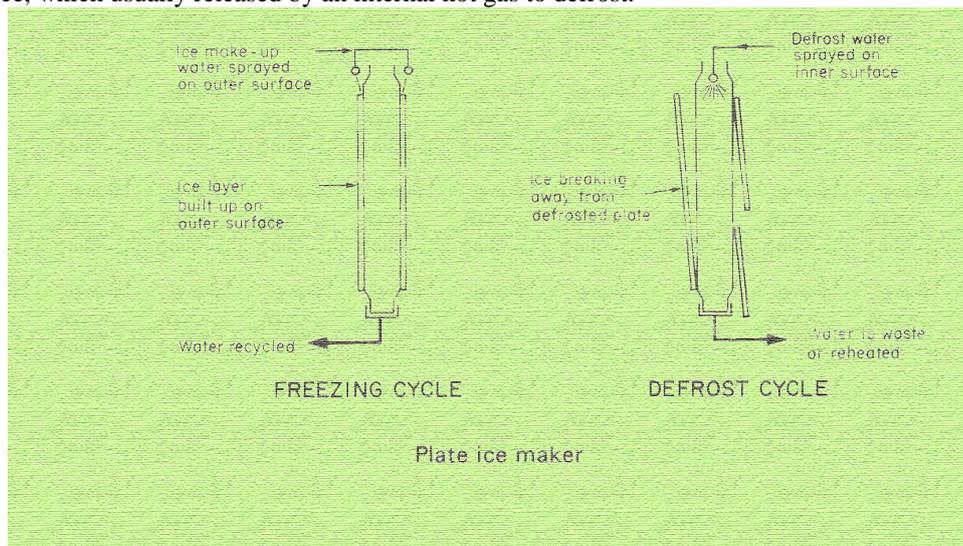


The ice leaving the drum is cooled below 0°C (sub-cooled) and is stored in a refrigerated silo, usually immediately below the ice-making machine. Flake ice is ready for use immediately it leaves the refrigerated surface. It is important that the ice shall be kept sub cooled condition, if it is not, then regelation can occur so that the ice forms a solid mass which is very difficult to handle.



2.3.1.3. Plate Ice

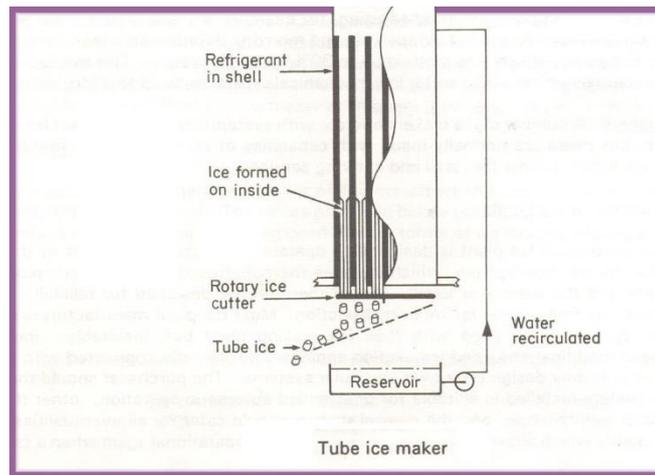
In the manufacture of plate ice, water is sprayed and frozen on to the outer surface of refrigerated plate to form a sheet of ice, which usually released by an internal hot gas to defrost.



Thickness of the ice can be varied within limits, by alteration of the defrost cycle, but it is commonly get between 8 and 15mm. As the ice falls it is chopped by a rotating cutter and this process is automatic.

2.3.1.4. Tube Ice

Tube ice is formed a vertical shell and tube vessel by passing water inside the tubes which are cooled by the circulation of refrigerant on the outer surfaces.



When the ice reaches the desired thickness the water flow is stopped automatically. The refrigerant is removed to a surge drum and hot gas circulated around the tubes causing the ice tubes to melt and slide down. As the ice falls from the tubes a rotating knife blade breaks it to desired size. The ice tubes are about 50mm in diameter with a wall thickness of 10-12mm.

Physical characteristics of ice utilized in chilling fish

Types	Approximate Dimensions	Specific (m ³ /t) Volume	Specific Weight (t/m ³)
Flake	10/20-2/3 mm	2.2-2.3	0.45-0.43
Plate	30/50-8/15 mm	1.7-1.8	0.59-0.55
Tube	50/D-10/12 mm	1.6-2.0	0.62-0.5
Block	Variable	1.08	0.92
Crushed block	Variable	1.4-1.5	0.71-0.66

Properties of water and ice

Properties	Metric units
Pure water Density at 15°C	1 kg/l 1/m ³
Specific heat	1.0 kcal/kg°C
Latent heat of fusion	80 kcal/kg
Thermal conductivity (at 10°C)	0.5 kcal/m°C
Freezing point	0°C
Boiling point	100°C
Sea water density	1.027 kg/l, 1.027 t/m ³
Specific heat	0.94 kcal/kg°C, 0.93 kcal/kg°C
Freezing point at salinity of	
1.0%	-0.6°C
2.0%	-1.2°C
3.0%	-1.6°C
3.5%	-1.9°C
4.0%	-2.2°C

Chapter 4: Super chilling (0°C to -4°C)

2.4.1. Introduction

Storage of fish at temperatures between 0°C and -4°C is called super chilling or partial freezing. The shelf life of various fish and shellfish can be extended by storage at sub-zero temperatures. Sub-zero storage temperatures in fishing vessels can also be obtained in refrigerated sea water (RSW) where the freezing point of water is reduced by NaCl or refrigerant. Compared to ice storage, the RSW systems chill fish more rapidly, reduce the exposure to oxygen, reduce the pressures that often occur when fish are iced and also give significant labour-saving. Super chilling extends product shelf life, but a negative effect on freshness/prime quality has been observed for some fish species. Merritt (1965) found that cod stored at -2°C for 10 days had an appearance and texture inferior to fish stored at 0°C in ice. The drip of the super chilled fish was increased and at -3°C the texture of whole cod made them unsuitable for filleting. RSW storage gives several fish species a salty taste due to the up take of salt from sea water.

2.4.1.1. Refrigerated Sea Water (RSW)

Seawater has a salt content of around 3 to 3.5%. At 3.5% salt, seawater has a freezing point of about -2°C. Thus, if seawater is refrigerated, it is possible to reduce the temperature so that a storage temperature of -1°C can be achieved. The most important advantage of RSW over icing is the ease of handling and storage onboard, with a resultant saving of labour. In a purse - seiner, the fish can be brailed from the net direct into the tank and brailed out of the tank at the landing point. Pumping systems have been developed for unloading fish as large as 10kg each at a rate of more than 25 tonnes/hour. In the most sophisticated systems, the vessel can be equipped with a pump which pumps the fish out of the sea into holding tank and the same pumps can be used for unloading. RSW is popular on large vessels, while CSW can be applied even on small boats. For RSW, larger capital investment is required for the mechanical refrigeration system. In order to avoid inefficient, too slow chilling of the catch, not more than 800kg of fish should be packed per kilo litre of the brine. RSW may also be used to cool the catch by spraying over the top surface of ungutted fish or shrimp in the hold. Rapid chilling and holding of the catch in RSW is a popular practice on board large vessels which catch shrimps.

Chilling of the catch in RSW before freezing on board freezer trawlers is a very effective method of preventing rapid quality loss of the fish on subtropical and tropical grounds. The shelf life and quality seafoods chilled or stored in CSW or RSW depends upon the species characteristics and the condition of chilling.

Generally, it is a few days longer than that of iced fish. Some species are vulnerable to loss of appearance due to bleaching or leaching. The uptake of salt may significantly decrease the market value of some seafoods, like shrimps, snappers. The advantages of RSW are

1. Labour saving in stowage
2. Rapid chilling, 2 to 3 times as fast as with ice
3. Elimination of crushing and ice pitting
4. Lower chill temperatures
5. Washing effect
6. Ease of unloading

2.4.1.2. Chilled sea water (CSW)

It is also possible to cool seawater by mixing ice with it. These systems are usually referred to as chilled seawater (CSW) and can be extremely simple. **A mixture of seawater and ice, usually 1:1 to 1:2 on a volume basis at the start, forms an ice slurry that has a temperature of about -1.5°C.** In such ice slurry or chilled seawater (CSW), the heat transfer between the fish and the cold medium occurs by convection. Thus, the rate of chilling is higher than in ice. Ice and salt should be added to the slurry during chilling to compensate for the loss of ice due to melting and to maintain the salt concentration at about 3%. Agitation in tank prevents accumulation of the ice at the surface and formation of a large temperature difference between the upper and bottom part of the container. Furthermore, forced convection increases the rate of heat transfer.

The rate of chilling of fish in CSW is especially high in the range from ambient temperature to about 5°C, while below 5°C, it is not significantly higher than that in crushed ice. Thus, CSW is often used only for rapid initial chilling of highly valued fish onboard. Another use of CSW is for chilling and holding the catch onboard in insulated containers. The shelf life of ungutted fish kept in CSW containers is a few days longer than that of fish carefully chilled with flake ice. Furthermore, no textural damage occurs except for some loss of scales. In the case of small fatty fish, the CSW treatment offers some protection against rancidity. Compressed air or nitrogen is injected into the bottom of the tank to ensure rapid and even cooling, the gas flow rate should be 2-4kg/h at a pressure of about 35kN/m². The contents should be agitated at least for 6 hours.

The recommended ratio of fish to seawater is between 3:1 to 4:1.

In RSW systems, it is usually necessary to provide pumped circulation of the water to ensure even mixing. This is sometimes done with CSW systems and the motion of the vessel providing adequate mixing. A rough calculation of the amount of ice needed to provide adequate cooling in a CSW system can be made quite easily in the following manner:

Suppose 8 tonnes of fish (8,000 kg) are to be cooled from 24 to -1°C and 4:1 ratio of fish to seawater is used, the mixture of seawater and fish would weigh 10 tonnes (10,000 kg) and the amount of heat to be removed would be:

$10,000 \times 25 \times 1$ (taking 1 to be the specific heat of both fish and water) = 2,50,000 kcal

But, when ice melts, it absorbs 80 kcal, thus the weight of ice required:

$$\frac{2,50,000}{80} = 3,125 \text{ kg}$$

Thus, just over 3 tonnes of ice would be required to provide the initial cooling. This would only reduce the temperature of the fish and would not be sufficient to maintain the lower temperature.

Additional ice would be required to provide against heat leak. **The amount of additional ice needed would depend on the efficiency of the insulation of the tank or fish room, the outside ambient temperature and the duration of the trip.**

As a guide it may be noted that if the same 10 tonnes mixture of fish and seawater is to be cooled from 24 to 1°C , it would impose a load of 1,000 mega joules on the refrigeration system. If this amount of heat is to be removed in about 6 hours, a plant will have to be installed with a power requirement of about 12 kw for the compressors.

2.4.1.3. Slurry Ice in Fish Preservation

The introduction of Deep Chill ice for direct contact cooling of fish made significant improvements in cooling and handling processes over other forms of ice. These systems have daily ice capacities ranging from 7 to 200 mt.

Deep Chill ice

The Deep Chill ice consists of small crystals, either in dry form or pumpable slurry, and has the following beneficial effects:

- **provides the best chilling of fish compared to other types of ice while avoiding freezing**
- the cooling process is maintained at a constant level as the ice melts
- prevents fish from bruising, because of the soft and flexible nature of ice
- easy to mix, handle and transport due to pumpability of ice slurry
- possibility of brine drainage to provide almost salt free ice for extended storage of fish
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2.4.1.4. Cooling and Storage Tests

While studying the chilling effect of Deep Chill ice slurry with flake ice, it was found that, ice slurry provides more efficient chilling than flake ice. **This is because ice slurry effectively eliminates hot spots in the fish container and provides maximum contact of ice surrounding the fish.**

1. It significantly retards bacterial growth and reduces fish tissue degradation.
2. The temperature drop in the fish body is extremely significant in the early stage of the cooling process.
3. The final equilibrium temperature of the fish is approximately 1°C lower, using the same amount of ice slurry compared to flake ice.
4. The difference in cooling level occurs due to the larger enthalpy change of the ice slurry. No uptake of salt was detected while using slurry with 0.8% salinity.

The quality of the product, such as the texture, colour and bacteria retardation is greatly improved. Automated fish handling with ice slurry improves the productivity of the plant, and the plant is able to deal with higher load without incurring too many shifts per day.

Chapter 5: Application of ozone / chlorine in seafood processing

2.5.1. Application of ozone in seafood processing

Pathogenic bacteria and viruses present in fish are highly sensitive to residual ozone in water. 99.9% or higher inactivation of *Aeromonas* spp., *Vibrio anguillarum* and *Yersinia ruckeri* is obtained at residual ozone concentrations of 0.15 – 0.20 mg / l within 60 seconds in natural lake, brackish and sea water. In fish farm effluent, a residual concentration of 0.3-0.4 mg/l is required for *Aeromonas* inactivation. Among fish pathogenic

viruses, high sensitivity toward ozone has generally been reported. This also applies to viruses with high UV resistance, i.e. IPNV and WSBV as reported by many researchers.

Because of its instability, ozone must be generated and used on-site. The most efficient method is by the electric discharge technique, which involves the passage of oxygen gas, or air, across the gap of narrowly spaced electrodes under high voltage. Due to the energy costs of producing ozone, it is important to optimize the transfer efficiency from gas to liquid phase.

Ozone in seafood processing and fisheries

The method of use of ozone started in late 1996 onboard purse - seiners with an idea to decrease bacteriological problems in the circulation of RSW system.

Today, ozone is used in the seafood processing and fishery industry in areas such as:

- Purse-seiners – seawater is ozonised and circulated through RSW tanks and circulation systems so that it comes in contact with every surface and carries out clearing.
- Well boats – when transporting live fish you have to obtain a high level of hygiene in order to prevent mortality by pathogens. By using Ozonised Sea water to reduce contaminants from tanks and circulation systems, and disinfects them in accordance with applicable requirements.
- Processing plants – ozonised sea/fresh water is used for cleaning and disinfection of process area, equipment and pipelines.
- Inlet water for fish hatcheries
- Waste water treatment – effluent from aquaculture, fish processing and fish slaughtering. The waste water treatment systems must be tailor-made according to regulations and are based on a combination of methods such as filtration, flotation and separation, and ozonisation.
- Odour-ozone has been successfully used in several applications to treat odour from fish or waste storage.

2.5.2. Use of Chlorine in Fish Processing

- Chlorine is used in the fish processing sector as a water disinfectant and is probably the most widespread disinfectant in use. Its uses include washing fishery products, addition to water for making ice for chilling fish, and in water for thawing frozen products. It is also used in water to cool canned fish after retorting to prevent "leaker" spoilage. Chlorine is commercially available in several forms, the most common being a granular or powdered form as **calcium hypochlorite** or in liquid form as **sodium hypochlorite (NaOCl)** or bleach. In any of these forms it acts as a powerful oxidizing agent and reacts with a wide variety of compounds. Chlorine is a gas under normal pressure and temperature. It can be compressed into a liquid and distributed in cylinders and fed automatically into water supplies of fish processing plants or on-board fishing vessels.
- The use of chlorine dioxide is less common in fish processing. Some of the reported advantages of **chlorine dioxide** over aqueous chlorine as a disinfection agent are that, **it is seven times more potent than aqueous chlorine in killing bacteria**; the bactericidal activity of chlorine dioxide is not affected by alkaline conditions and/or the presence of high levels of organic matter. For these reasons, it is under investigation by many authorities for use in the fish processing sector.

2.5.2.1. Concentration of chlorine used in Fish processing

- It has been established in the fish processing industry that the injection of chlorine into a supply cold water used for general wash-up helps to control microbial contamination. Chlorine dosage should be around 10 ppm during the normal use and 100 ppm of residual concentration during the clean – up.
- **Codex recognize that up to 10 mg/l active chlorine in fish processing water and ice that contacts seafood to be generally recognized as safe (GRAS).**
- An on-line hypochlorite injection system recommended for seawater treatment is a dosage of 20ppm. This system, together with improved handling and storage of cooked shrimp, has been found to double the chilled storage life while improving both the eating and microbiological quality of products. Concentrations of 20-30 mg/L in running water have been used to reduce the number of *Listeria monocytogenes*, while thawing frozen salmon. The removal of this pathogen from the surface of fish destined for cold smoking is a major health gain for the industry as the temperature of the cold smoking process are insufficient to kill *L monocytogenes*. Chlorine at levels of 20-25 mg/L were shown to be effective in killing strains of both *Escherichia coli* and *L monocytogenes* in a fish model system under laboratory conditions.

2.5.2.2. Marginal Chlorination

- There are two important chlorination methods: marginal chlorination and super-chlorination with or without dechlorination. The latter includes break-point chlorination and in-plant chlorination.
- Marginal chlorination is the addition of just sufficient chlorine to water to produce a residual level. The residual chlorine may be either free or combined depending on the amount of ammonia present in the water. This level of chlorination usually destroys pathogens.

2.5.2.3. Super Chlorination

- The chlorine dosage applied is much greater than that of marginal chlorination. The chlorine dosage depends on the character of the water and the purpose for which the water is used. A considerable amount of chlorine may be present after a given contact period. Therefore, for certain purposes, the water is dechlorinated. Super chlorination includes break-point chlorination and in-plant chlorination.

2.5.2.3.1. Break-point chlorination

When small amounts of chlorine are added to water, first, chlorine reacts with certain impurities present in the water. These impurities are substances responsible for chlorine demand. Chlorine reacts with nitrogenous compounds to form chloramines or other chloronitrogen compounds. On further addition of chlorine, a free residual chlorine appears. On still further addition, the free residual chlorine gradually increases until it reaches a particular concentration. The concentration of free chlorine is determined by the physical and chemical nature of the water. When the level of free chlorine is increased beyond this concentration, oxidation reaction occurs between free chlorine and chloronitrogen compounds.

The level of the free residual chlorine is decreased during the oxidation of chloronitrogen compounds. When the oxidation is completed, the addition of chlorine to water results in corresponding increase in chlorine concentration. The point after the first rise in concentration at which the free residual reaches its lowest level is known as the breakpoint.

The advantages of break point chlorination are the following:

- Complete oxidation of ammonia and other compounds in the water
- Correction of tastes and odours of biological origin
- Correction of tastes and odours due to phenol and other substances
- Reduction of colour due to organic matter
- Improvement of bacterial quality of water

2.5.2.3.2. In-plant Chlorination

- In-plant chlorination has been defined as break-point chlorination of all water as it enters the plant to a degree where a good persisting residual chlorine occurs. In-plant chlorination of processing water is employed in many food industries.
- Chlorine gas is generally considered the best source for in-plant chlorination where large volumes of water are to be chlorinated. But for chlorination by chlorine gas, a chlorination equipment is needed. Hypochlorites are a good source when only small amounts of chlorine are required. Since seafood processing industry requires only small amounts of chlorine, hypochlorites can be used by the industry.