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FISH REFRIGERATION

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Fish may be divided into two broad groups according to the flesh composition. The first group includes fish which store oil or fat in their livers and for this reason are generally referred to as the non-oily varieties, such as cod, haddock, and pollock. The other group contains those fish which store their oil in the muscle tissue throughout the body and are termed the oily or fatty species. Some of the well-known representatives of this group are salmon, mackerel, and herring. The percentage composition of the oil in the flesh varies considerably within these two classifications. The flesh of the non-oily fish, in general, contains less than 3 per cent fat, while those placed in the oily class contain more. Shellfish would be placed in the non-oily group if classified according to fat content. This classification of fish is suggested since the type of spoilage in cold storage is, within certain limits, dependent upon the degree of fatness (Table 1).

There are three primary types of spoilage responsible for deterioration: (1) the action of bacteria which contaminate the seafood through handling after removal from the water; (2) the oxidation of the oil or fat in the flesh; and (3) the action of enzymes contained within the tissue.

When fish are frozen and stored at a low temperature, the action of the bacteria is almost entirely arrested, and, for all practical considerations, this type of spoilage is eliminated so long as the fish are held in a frozen condition. There are some types of bacteria which are able to resist extremely low temperatures by remaining in a state of hibernation. These types may cause considerable damage through spoilage if the temperature of the storage room is for any reason raised to a point favorable for growth, or if defrosting occurs during transit from one point to another.

The oxidation of the oil or fat is another source of spoilage of frozen fish, even in cold storage rooms at low temperature. Oxidation is indicated by yellow discoloration appearing on the surface of the skin or on the flesh at points where it is exposed to the oxygen of the atmosphere in the warehouse. Low temperatures usually employed in the storage of fish retard but do not entirely prevent the chemical combination of oxygen and the oil or fat of the fish. If the fish are stored

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Note: Reprinted from The Refrigerating Data Book, Applications Volume, 1946, pp. 15-29.

Table 1. Chemical Composition of Common Varieties of Food Fish

Species	Total solids, %	Fat %	Pro-tein, %	Ash %	Cal-ories per lb.
Abalone	26.0	0.5	21.7	1.4	460
Albacore	33.8	7.6	25.3	1.3	770
Alewife	25.6	4.9	19.4	1.5	550
Barracuda (California)	25.0	3.1	21.2	1.3	510
Bass (Atlantic sea black)	20.7	1.2	19.2	1.2	395
Bass (California white sea)	23.7	0.5	21.4	1.4	410
Bass (striped)	22.3	2.7	18.9	1.2	455
Bluefish	25.4	4.0	20.5	1.2	535
Bonito (Atlantic & Pacific striped)	32.4	7.3	24.0	1.4	735
Butterfish	28.6	10.2	18.1	1.4	745
Carp	22.1	2.2	18.2	1.2	420
Carp (river)	23.8	3.2	19.2	1.2	480
Clams	19.4	1.7	13.6	2.0	355
Cod	17.4	0.4	16.5	1.2	315
Crabs (Atlantic & Pacific)	20.0	1.6	16.1	1.7	370
Croaker	22.6	2.2	17.8	1.3	415
Drum (red)	19.8	0.4	18.0	1.3	345
Eels	28.4	9.1	18.6	1.0	710
Flounder	17.3	0.5	14.9	1.3	290
Grayfish	27.7	9.0	17.6	1.0	685
Grouper (spotted)	22.5	1.2	19.1	1.3	395
Haddock	18.3	0.3	17.2	1.2	325
Hake	18.4	1.1	16.3	1.1	340
Halibut	24.6	5.2	18.6	1.0	550
Herring (Atlantic)	27.0	6.7	19.0	1.6	620
Herring (lake or cisco)	26.0	6.8	18.5	1.1	615
Herring (Pacific)	20.4	2.6	16.6	1.3	405
Horse mackerel (Pacific)	28.6	5.6	21.6	1.2	620
Kingfish (Pacific)	20.3	0.8	18.0	1.3	360
King whiting	22.7	3.0	18.3	1.3	455
Lake trout	29.2	10.3	17.8	1.2	745
Lobster	20.8	1.9	16.2	2.2	380
Mackerel (Atlantic)	31.9	12.0	18.7	1.2	830
Mackerel (Pacific)	30.6	7.6	22.2	1.4	715
Mackerel (Spanish)	33.9	13.3	19.8	1.3	900
Mullet	24.9	4.4	19.3	1.2	530
Mussels	22.9	2.3	14.4	1.6	435
Oysters	19.7	2.0	9.8	2.0	365
Perch (white)	24.3	4.0	19.3	1.2	515
Perch (yellow)	20.7	0.8	18.7	1.2	370
Pike (common)	20.2	0.6	18.7	1.0	365
Pilchard	29.2	8.6	19.3	1.2	700
Pollock	24.0	0.8	21.6	1.5	435
Pompano	27.2	7.5	18.8	1.0	665
Porgy	23.8	0.9	21.4	1.5	425
Red snapper	21.6	0.9	19.8	1.3	395
Salmon (Atlantic)	36.4	13.4	22.5	1.4	955
Salmon (king)	36.6	16.5	17.4	1.0	990
Scallops	19.7	0.1	14.8	1.4	335
Shad	20.8	3.8	20.9	1.5	535

Source: Fisheries Document No. 1000.

over long periods of time, the development of rancidity in the oil or fat is more likely to occur than when the storage period is only of short duration. When the fish are properly glazed with a thin coating of ice, or are covered with one of the several available moisture-proof wrappings, this reaction between the oxygen of the air and oil or fat of the fish is greatly retarded. However, the losses through oxidation or rancidity will be held at a minimum if the fish are carefully re-glazed when it is noticed that the coating of ice has become thin due to evaporation, and if the fish are not held in storage over periods of excessive length.

The enzymes responsible for the third type of spoilage are substances contained in the flesh of the fish which build up and tear down the tissues during the life processes. These reactions are common to all forms of animal life and are automatically controlled so long as the animal is alive. Upon death, the enzymes which act as builders of tissue during life are inhibited, and only those which tear down the tissue remain active. The temperature at which the tissue is stored has a definite effect upon the rate or speed of the digestive reaction due to these enzymes. According to a well-known physico-chemical law, the rate of this reaction is doubled for each 18° F. increase in the temperature of the tissue. Thus, in fish stored at 32° F. the rate of the reaction is reduced by one-half compared to those stored at a temperature of 50° F. And at a temperature of 14° F., the rate of the reaction is theoretically only one-fourth that of 50° F. While the reaction is retarded by storing food substances at low temperatures, it is not possible to lower them sufficiently to stop it entirely. It is not economically feasible to make use of excessively low temperatures, and the effect of them on food products may in itself cause damaging results. It has been found that -10° F. is usually low enough to store fishery products so that minimum deterioration and maximum storage life may be obtained.

While the action of the enzymes will eventually cause complete spoilage of any animal tissue as a food, they cannot be considered entirely detrimental, since the process of ripening is necessary for meats derived from warm-blooded animals. The ripening process is the result of enzymatic action and is not necessary or desirable for fishery products, since the texture and composition of the flesh are such that a change in texture is undesirable and the flavor is available without it.

CHEMICAL COMPOSITION OF SEAFOODS

The accompanying tables set forth the composition of the most common varieties of seafood. The first column of Table 1 contains the percentages of dry substance of the various species; the moisture content can be derived by deducting the amount shown in this column from 100 per cent. It has been stated that fish could be divided into two groups, fatty and non-fatty; those in which oil or fat content is above 3 per cent are generally considered in the former class while those having less compose the non-fatty.

The third column contains the protein value of the whole fish. Protein is the substance found in all animal tissue and composes a large portion of the muscle. It will be noted that the protein variation in the percentage composition of the fish is considerably less than any of the other components excepting the ash.

The ash or inorganic matter of fish flesh contains minerals necessary in every well balanced diet. Fish are particularly valuable in the diet since they contain large proportions of inorganic salts necessary for proper growth and development and are an excellent source of the necessary element iodine. The analysis of the ash of some of the sea-foods as expressed in Table 2 indicates that these compare very favorably with some of the other common foods.

Table 2. Mineral Content of Fillets of Fish and Comparable Foods

Species	Dry Matter	Calcium	Magnesium	Phosphorus	Iron	Copper	Iodine
	Percentage by weight of the fresh edible portion						
Cod	17.7	0.0110	0.0280	0.1859	0.000518	0.000041	0.000103
Flounder	21.3	.0117	.0305	.2053			.000029
Haddock	18.7	.0165	.0236	.1731	.000516	.000041	.000513
Lake herring	17.9	.0116	.0172	.1518			
Mackerel	19.9	.0048	.0281	.2169	.001224	.000115	.000053
Mullet	23.9	.0261	.0318	.2198	.001779	.000082	.000485
Pilchard	20.5	.0422	.0237	.2115	.002483	.000166	.000013
Red snapper	21.7	.0162	.0276	.2279	.001158	.000038	.000031
Beef	36.9	.012	.024	.216	.0030	.00010	.000001
Milk	12.7	.120	.012	.093	.0002	.00002	.000007
Potatoes	26.6	.014	.028	.045	.0009	.00017	.000004
Tomatoes	5.7	.011	.010	.026	.0006	.00007	.000004
White bread	59.3	.027	.023	.093	.0009	.00034	.000006

Source: Bureau of Fisheries Investigational Report 41.

Where fish are received at the warehouse in an unfrozen condition and are to be frozen and stored, it is necessary to judge the quality of the fish before placing them in the freezer. This serves not only as protection to the warehouse operator, but also indicates to the shipper who has forwarded the fish, the condition of the shipment when received for freezing. When he has received this report, the shipper can then judge the length of time he can expect these fish to remain in good condition after they have been frozen and stored.

Table 3. Salinometer Values for Mixtures of Salt and Water

Salinometer reading	Salt, lb.	Water, lb.	Salinometer reading	Salt, lb.	Water, lb.
100	26.3	73.7	50	13.3	86.7
90	23.7	76.3	40	10.7	89.3
80	21.1	78.9	30	8.1	91.9
70	18.5	81.5	20	5.5	94.5
60	15.9	84.1	10	2.6	97.4

Table 4 outlines the distinction between fresh and stale fish but leaves considerable latitude to human judgment. More scientific methods for judging the condition of fish are at the present time in use in various laboratories. Not any of these is suitable for use except in a laboratory.

Table 4. Criteria of Quality in Fish

Strictly fresh fish	Stale fish
1. Odor of fish, fishy.	1. Odor stale, sour or putrid.
2. Eyes bright, not wrinkled or sunken.	2. Eyes dull, wrinkled, sunken.
3. Gills bright red, covered with clear slime; odor under gill covers fresh, fishy.	3. Gills dull brown or gray, slime cloudy; odor under gill covers sour and offensive.
4. Colors bright.	4. Colors faded.
5. Flesh firm; in quite fresh fish the body is stiff; impressions made by fingers do not remain; slime present and clear (eels, halibut).	5. Flesh soft and flabby; impressions made by fingers remain; slime absent (halibut), slime cloudy, ropy (eels).
6. Belly walls intact.	6. Belly walls often ruptured, viscera protruding.
7. Muscle tissue white.	7. Muscle tissue becomes pinkish, especially around backbone.
8. The vent is pink, not protruding.	8. The vent is brown, protruding.

Source: Refrigeration of Fish, by Harden F. Taylor, Bureau of Fisheries, Document No. 1016.

FILLETING OF FISH

The term fillet is applied to a slice of fish, taken the length of one side of the body; thus, each fish furnishes two fillets. The fillets are usually cut so that they contain no bones or only a very few. The skin is generally removed, though a few dealers prefer to leave it on since without the skin it is practically impossible to identify the species of fish from which the fillet was prepared. Filleting has the advantage of concentrating all waste in one point so that it can be utilized for meal and thus is not a total loss. The purchaser has all edible meat without the bother of dressing; there is no waste such as heads, backbones and entrails. The most common species of fish utilized in the filleting industry are haddock, small cod, flounder and whiting, pollock and rosefish. Usually those fish weighing 4 lb. or less are cut as fillets, since the object of the fillet is to prepare a cut suitable for cooking, and the larger fish are usually too thick to fry without further cutting.

After the fillets are cut from the sides of the fish, they are brined in a solution containing approximately 3 lb. of salt to each 12 gal. of water; frequently, the solution is chlorinated so that the surface bacteria are killed. The strength of the chlorine should be about five parts per million or strong enough to give a distinct odor of chlorine.

Water for use in preparing a brine and chlorination bath for washing fillets prior to freezing should be taken from the most sanitary supply available. It is preferable to make use of the city water supply, which in most cases is chlorinated and is suitable for drinking purposes. The water should be placed in the brine tank and sufficient chlorine added to give a concentration of approximately three to five parts per million. There are various test papers which can be purchased which will indicate the concentration of chlorine in solution. This constitutes a simple and sufficiently accurate test for control and can be manipulated by one who is not scientifically trained. The maintenance of the concentration of chlorine is important if the bath is to be effective. There should be sufficient salt added to give a salinometer reading of 25 to 35 degrees. The preparation of this strength brine can be made by referring to the attached Table 3 showing the salinometer readings for brine of different strengths, the weight of water being considered as 8 lb. per gal.

If the fish plant does not have access to the equipment for preparing chlorine solutions from steel cylinders of liquid chlorine, it is possible to use chemicals. There are several compounds of chlorine known as hypochlorites available at chemical supply and wholesale drug houses. These compounds are in a powdered form, and directions for making up solutions with water to yield definite quantities of free chlorine are carried on the labels. From some of these, concentrated solutions of chlorine can be prepared which can be diluted with water to make the strength desired for the brine bath.

If possible, the brine tank should be fitted with cooling coils of sufficient capacity to hold the temperature of the brine at 35 to 45° F. In a number of installations the brine tank is fitted with a belt conveyor which carries the fish through the brine at such a slow speed that it is thoroughly chilled when it reaches the wrapping table. If the capacity of the plant is not sufficiently large to make such an installation economical, ice and salt can be added from time to time to hold the temperature at the desired point. The fillets can be placed in wire baskets or trays and immersed in the brine until they are cool. This precooling is important since it shortens the time for quick freezing the fillets.

If the temperature of the brine tank is permitted to rise and the concentration of chlorine is not maintained, the fillets may be damaged by being dipped. Both the chlorine and the cold brine reduce the growth

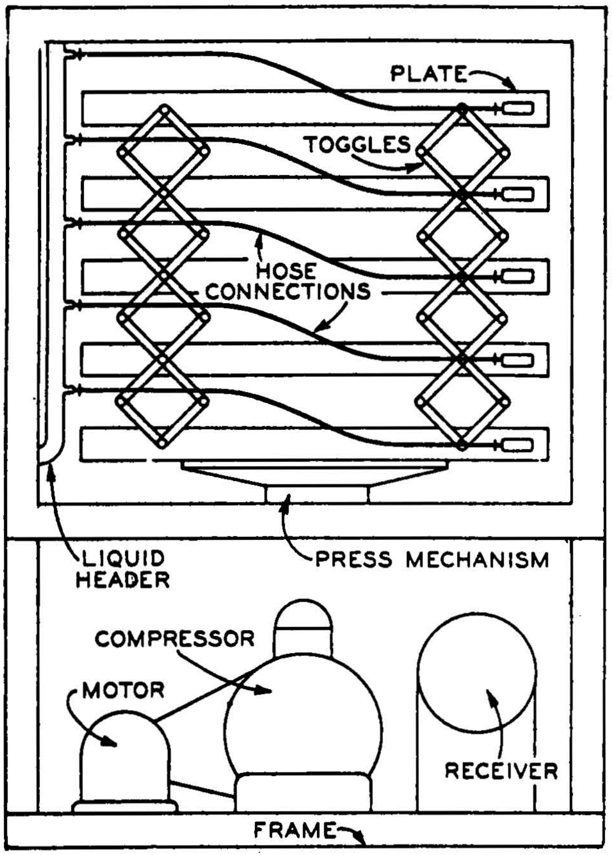

Fig. 1. Section of Accordion Plate Freezing System.

of bacteria if the concentration and temperature are maintained as suggested. It is further suggested that the brine be dumped when it has become discolored with blood and diluted with slime, and fresh brine be prepared. The frequency of dumping will depend upon the quantity of fillets passing through it.

The fillets are removed from the bath and, in many instances, wrapped in some type of moisture-proof wrapper and packed into paper cartons, tin or wooden boxes of sizes varying from 5 to 30 lb. In general, those fillets which are to be shipped to the market and sold unfrozen are packed in tin boxes or fibre cartons fitted with a tight cover. These boxes are then packed in large wooden boxes and covered with crushed ice.

Those which are to be frozen are packed in paper cartons and sent to the freezer where they are frozen in the carton. There should be as little delay as possible in sending the packed cartons to the freezer for freezing, since delays permit the fillets to become warm, and the advantage gained by chilling in brine is lost. In many operations the cartons are wrapped in some type of moisture-vapor-proof material and hermetically sealed by one of the many methods in use for this purpose. These cartons are, in turn, packed in large single corrugated paper cartons lined with additional corrugated board or in cartons of double-walled construction, and sealed for storage or shipment.

Occasionally fish fillets are packed in the 10 and 20-lb. containers and frozen in a solid block. It would be advisable to revise this method to include a piece of parchment, waxed paper or cellophane between each layer of fish. Unless this is done it is difficult to separate the fillets without complete defrosting, and, unless the entire package is to be used at once, considerable deterioration of the package may result. If attempts are made to remove the fillets without defrosting they are likely to be badly torn, since without separators of some type they adhere tightly to each other. A piece of material between each layer in the box would make it possible to remove the fillets one at a time while still frozen.

In many instances, the larger size fish represented by halibut, some species of salmon, swordfish, large red snapper and a few other species are prepared for the market as steaks. The fish steak is prepared by slicing the fish crosswise at intervals of approximately ½ in.; each steak of all except swordfish usually contains one joint of the backbone as well as some of the smaller bones. These steaks are often cut by means of a band saw after the fish have been frozen. The cuts are washed and wrapped in a manner very similar to the fillet and packed in various size packages either for storage or immediate sale.

REFREEZING PACKAGES DEFROSTED IN TRANSIT

There are occasional instances in which frozen packages of seafoods become partially or totally defrosted during transit or even while in storage. When this has occurred it is necessary to exercise considerable care in the handling, or the loss due to spoilage may be excessive. The first step in making an examination of such a shipment is a careful inspection of each package in each carton. The packages should be separated into two groups, those only partially defrosted and those which are completely defrosted. The first lot, the partially defrosted cartons, can be placed in a quick or sharp freezer and handled in the same manner as that which was used in the original freezing operation. After they are refrozen the individual packages can be repacked in the shipping carton for storage. If attempts are made to refreeze in the original shipping carton it is likely that excessive losses by spoilage will be experienced. This is explained by the fact that the carton is a fair insulator, and, should the packages be placed in it before they are solidly frozen, several days would probably be required for freezing those in the center of it. During this lapse of time spoilage could occur and then the packages in the center would be unfit for food.

In handling the second lot, or those which are completely defrosted, extreme care should be used in separating those which are in first class condition from those in which a slight off odor has developed. The former can be refrozen as described above, while the latter should be disposed of immediately. It is never advisable to refreeze fillets or other sea-foods which show signs of decomposition. This results not only in an unfavorable reaction toward the particular type of sea-food but to frozen fishery products in general, and the consumer may assume that all fish which have been frozen are of an inferior grade.

FREEZING METHODS

Fish are frozen by any one of the great variety of quick freezing installations in use at the present time. These are too numerous to treat individually and for this reason they may be classed into four groups: (1) sharp freezer, (2) air circulating freezer, (3) chilled metal contact freezer, and (4) brine spray freezer.

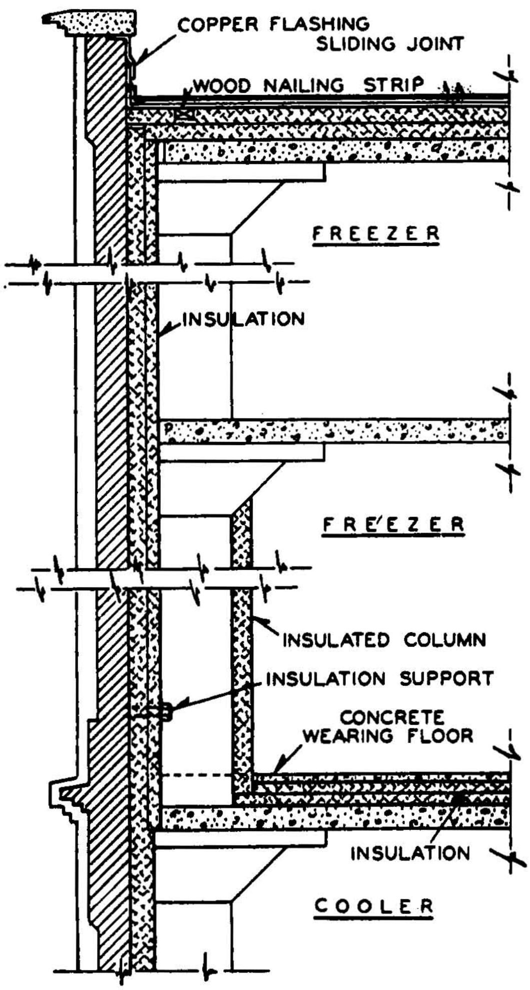

Fig. 2. Insulation of Typical Freezer Storage in Cold Storage Building Using Curtain Wall.

The first method of freezing to be adopted was the sharp freezer method. The fish to be frozen were placed in a room which was maintained at as low a temperature as possible and left there until frozen. This method depends upon conduction of the heat from the fish to the refrigeration coils by air circulation. The process is generally considered a slow one, since air is a relatively poor conductor of heat. There are a number of methods for attaining a rapidly circulating air system. A few types of freezers use solid carbon dioxide as a refrigerant instead of the conventional brine coils.

Another class of freezers is that in which the fish are placed in contact with a chilled metal plate. In some, the plates are in contact with brine or direct expansion coils, while in others the plates are arranged so that one surface is in contact with brine while the other is in contact with the fish which are to be frozen. Still another variation of the plate system depends on the fish, usually packaged, being placed between two plates chilled by direct expansion ammonia coils or by brine sprayed on both the top and bottom plates.

The brine spray or fog systems, as the name indicates, force a fine spray of chilled brine into a cabinet in which the fish are frozen. In this type of freezer, the brine is usually sprayed directly upon the surface of the fish, after which they are packaged when frozen. There are many variations in the method of arranging the spray nozzles and handling the fish to be frozen. Some of the freezers of this type are arranged so as to be continuous.

SHELLFISH AND CRUSTACEANS

All species of shellfish may be frozen by any one of the varieties of quick freezing methods which are in use. While there is no set general practice in the preparation and freezing of this seafood, the following suggestions will be of value. Only those in a prime condition of freshness should be selected for freezing and storage for future market. They may be frozen either in tin containers having a crimped-on top or in paper cartons which are impervious to evaporation of moisture. The loss of moisture from any of these species causes a discoloration. The size of the container is governed by the market for which it is being prepared. The individual consumer package is usually the 1-lb. size; for the hotel and restaurant trade, the 5 to 10-lb. package is the most generally used.

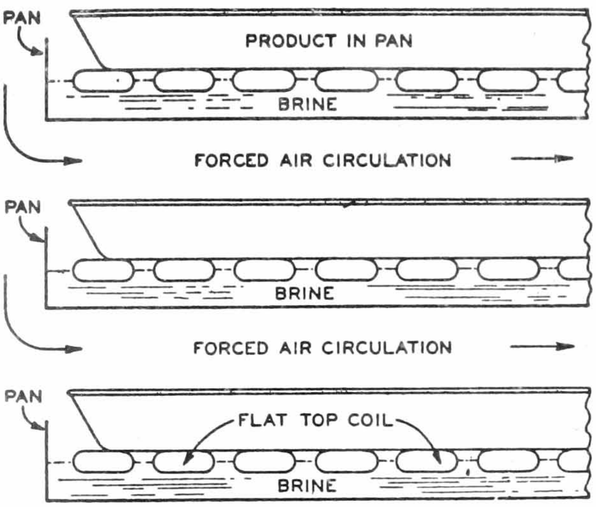

Fig. 3. Section of Murphy Freezing System.

Oysters are generally frozen after shucking and can be packed in a variety of types and sizes of package which are available and may be selected for this purpose. The tin can has been made use of successfully, as well as several types of paper cups heavily impregnated with paraffin with a closely fitting cover of the same material. Bags of moisture-vapor-proof material fitted into a waxed paper carton have also been used. Care must be exercised to cover the oysters with liquor, since any that are exposed to the air space in the top of the container soon become discolored. It is also necessary that sufficient head-space remain in the can to allow for any expansion in the contents due to freezing. After the oysters have been frozen it is necessary to be sure that they remain frozen until they are in the hands of the consumer and are defrosted only preparatory to cooking.

Shrimp are frozen in both the green and cooked state. The wholesale trade requires packages of large size. When the shrimp are prepared for freezing they are packed in pans of 1, 5 or 10-lb. sizes. The intervening spaces between the shrimp are filled with clear water and the pans are then placed in one of the various types of quick freezers. When they are frozen the cakes formed are removed from the pans by slightly warming the pans. These cakes are then wrapped in some type of water-vapor-proof material and packed in paper cartons. They are then ready for immediate shipment or storage until a market is found for them.

There are a number of packers freezing shrimp individually and, after they are frozen, placing them in packages of sizes required by the trade. This practice requires a somewhat larger container for a given weight of shrimp since it is difficult to obtain as tight a pack after the shrimp

Table 7. Time Required to Freeze Fish

Thickness of fish, in.	Time required to freeze, min.		
	In air at 14° F.	In brine at 14° F.	In brine at -6° F.
0.39	120	12	4
0.79	248	21	8
1.18	361	35	14
1.57	490	54	19
1.97	620	78	29
2.36	748	112	40
2.75	877	148	50
3.15	1000	190	67
3.54	1130	230	85
3.94	1260	275	101

Source: The Preservation of Food by Freezing, Walter Stiles.

hoist is usually employed to lift the fish in and out of the glazing tank. They are then piled in the storage room in stacks somewhat resembling a pile of cord wood. The fish can be sprayed with cold water after piling in order to cover them with an additional glaze of ice for protection in case the regular glaze has been cracked in handling. At frequent intervals during the period of storage, the piles are examined and the spraying operation is repeated when it is observed that the glaze has become thin from evaporation or has cracked from handling, exposing the surface of the fish to drying atmosphere of the storage room. This reglazing is repeated in some instances as often as every three weeks when it is found that rapid evaporation has removed a large portion of the glaze from the surface.

The rapidity with which the evaporation of the glaze occurs, depends upon the humidity of the air in the storage room. The higher the humidity the longer the glaze will remain on the fish. It is recommended that the humidity in the storage room be held at as near the saturation point as possible. Table 8 shows the approximate length of time a glaze may be expected to remain on fish in a cold storage room.

Table 8. Time Required for Ice Glaze to Evaporate from Surface of the Fish

Species of fish	Wt. in grams	Wt. of glaze, grams	Wt. of glaze, % of wt. of fish	Duration of glaze, days
Mackerel	434	56	13.0	18
Haddock	964	142	15.3	22
Cod	2588	252	9.8	28
Flounder	293	64	21.9	20
Eel	296	41	13.8	14
Pollock	4270	472	11.1	33

Source: Special Report #7, Walter Stiles.

The stacks of fish should be well separated in order that the inspection and reglazing may be accomplished with as little difficulty as possible. The size of the storage room governs to some extent the space to be left between piles. Under ordinary conditions the distance varies between 20 to 30 inches. Another consideration is to allow an 8 to 10-in. space between the stacks of fish and the outside walls, if the storage room is situated in the outisde tier of the warehouse. Particularly is this necessary where the room is on the south side of the building.

Icing unfrozen fish for the purpose of preservation until sold in the fresh market or placed in the freezer for future use has been practiced for approximately 100 years. It is the best preservative which has been devised, since the ice not only holds the temperature, but keeps the surface of the fish moist and in good condition. Various preservatives have been added to ice in attempts to prolong the period over which fish can be kept in good condition. Not any of these have been found to be effective enough to be economical. During the past few years storage rooms have been designed for sufficient mechanical refrigeration to hold the temperature between 32 and 35° F. for storage of fish prior to packing for shipment or freezing. Only sufficient ice is used in the containers of fish to keep them moist. This practice should become more generally used since it not only holds the fish in good condition over a longer period of time but prevents the loss of valuable minerals from flesh through leaching. In a room so equipped the ice melts slowly and moistens the surface but not fast enough to cause any considerable volume of water to be produced. It is economical since the quantity of fish lost through spoilage is reduced, the volume of ice necessary is reduced, and a lower temperature than it is possible to obtain with ice alone keeps the fish in better condition.

There are a number of suggestions for general practice which are worth consideration. Fish is one of the most tender of any of the food commodities and should be given extra careful consideration as such. Finely crushed ice is preferable to large pieces for packing fish in boxes. The size of the container may vary from a 50 to a 500-lb. box; the larger sizes are usually used for large fish such as halibut, tuna and swordfish. Regardless of the size of the fish it is tender and easily bruised. The finely crushed ice does not tend to bruise and dent the fish as much as is the case with large pieces of ice.

There are a number of machines available, in both large and small units, which manufacture ice in various forms. One of these machines is that which freezes a fine spray of water in separate particles resulting in a snow. Since there are only small crystals formed by this method there is no need for a crushing machine to prepare ice for use with fish. The particles are so small that there is little chance of damage to the fish by bruising. Another of the machines freezes a film of water on a drum. The film breaks into small pieces and eliminates the necessity of crushing the ice for use in packing fish. Still another of these machines freezes a film of water into a ribbon which breaks into small pieces from handling. These latter two machines manufacture ice without sharp corners or edges and there is no damage to the flesh of the fish from bruising or scratching.

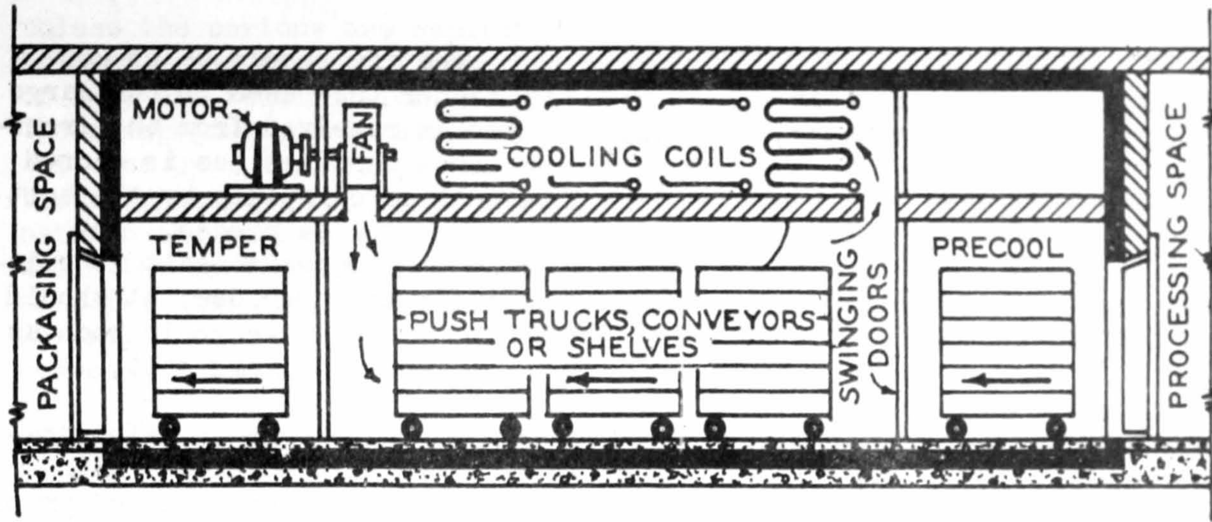

Fig. 5. Freezing Fish on Hand Conveyor Trucks.

The boxes are packed in layers alternating between fish and ice, a layer of ice on the bottom, then a layer of fish followed by a layer of ice, repeated until the box is filled. The layers should be so arranged that a layer of ice is on the top of the fish. The cover is then placed on and the box is ready for shipment.

It is not possible to estimate the quantity of ice necessary to hold the fish over a given period of time since this is almost entirely dependent upon the outside temperatures. The transportation firms are required to re-ice shipments of fish, during the warm weather, at least once each 24 hr. while the shipment is enroute to its destination. Recently, insulated containers for use in making less than car lot shipments have been placed on the market for the use of the general public. It is not necessary to re-ice this type of shipment. These containers are not sold, but are leased to shippers of perishable foodstuffs while ownership is retained by the manufacturers. They are heavily insulated and are built in several sizes; some of these are equipped with a cover attachment and can be used in the retail stores for display of either frozen or unfrozen seafoods.

In transporting either frozen or unfrozen seafoods in refrigerator cars, the same care in packing to insure free circulation of air as was mentioned above for cold storage rooms is necessary. Refrigerator cars using ice as the medium of refrigeration for shipping frozen seafoods require a lower temperature than is possible to obtain by ice alone. Salt in varying proportions to the ice produces temperatures low enough to hold the seafoods frozen. The following table gives the approximate temperature obtainable with mixtures of salt and ice in the proportions by weight shown.

Salt in mixture, %	Temperature of mixture, °F.	Salt in mixture, %	Temperature of mixture, °F.
0	32	15	11
5	27	20	2
10	20	25	-6

The ice should be broken up rather than used in the large cakes as received from the freezer since the fine ice is caused to melt more rapidly by the salt than the coarse pieces. Any grade of commercial salt is suitable for this purpose; it should be of fairly large grain such as the common ice cream salt.

When making shipments of frozen fish from the warehouse in refrigerator cars or trucks, the order for the conveyance should be placed with the carrier in sufficient time to be sure that it is properly cooled prior to loading. Unless it is possible to obtain precooled cars and trucks from the carrier, at least 24 hr. should be allowed for precooling before the loading operation is begun. The ice bunkers should be loaded with a mixture of 30 lb. of salt to 100 lb. of ice while the car is closed. It is desirable to load the lower part of the ice bunker with fairly large pieces of ice and the top part with the smaller ones; the salt should be mixed throughout the ice so that it can react with the ice more readily. The actual loading operation should not be started until the temperature inside the car has reached at least +20° F. The loading operation should be completed with as little delay as possible. If for any reason the loading is interrupted before completion, the doors of the car should be tightly closed pending the completion of the work. The temperature should be held at between 10 and 15° F. throughout the entire trip. Upon arrival at its destination the car should be unloaded as rapidly as possible and the contents placed in refrigerated storage rooms. If for any reason the unloading operation is not completed at one time the doors of the car or truck should be tightly closed until work is resumed.

PACKING FOR SHIPMENT

Packaging. A great variety of seafoods is prepared in the packaged form. One of the largest classes is fillets of fish which are usually prepared for storage in 1 to 10-lb. paper packages placed in corrugated paper cartons. Since the products contained in this type of package are prepared by covering with one of the various wrappers which are impervious to the drying atmosphere of the freezer, it is not necessary to be concerned with the development of freezer burn or desiccation.

This type of package is so well insulated by the dead air spaces inside the corrugations of the cartons that there is little cause to fear thawing during transfer from the point of freezing to the warehouse unless the cartons are separated by considerable distance. There is, however, some danger of complete or partial thawing when several hours or days are required for the transfer from one warehouse to another. The damage may become serious if the contents of a carton are slightly softened upon arrival at the warehouse and are not promptly placed in the cold storage room. In the storage room, it is well to leave space between the cartons in a stack for the free circulation of cold air. While the cartons provide insulation against the warm outside air, they also insulate against the desired refrigeration of the storage room. Several days may elapse before sufficient heat has been absorbed to refreeze soft fillets, especially if the package is placed in the center of a tightly stacked pile. During this period, spoilage may have progressed to a point at which the contents of the package are unfit for consumption.

Another type of container used for packing frozen fishery products is the wooden box or barrel. Methods of handling are much the same. Boxes should be stacked to provide space between layers and rows of of boxes, in order to insure circulation. Because of the shape, barrels cannot be packed in piles tightly enough to prevent fairly free circulation of the air. The wood of the boxes and barrels does not furnish so efficient an insulation as does corrugated cardboard. The fish stored under cold storage should be protected at all times by a coating of some material, either a glaze of water ice or a wrapper.

The pipe coils for the heat absorption in fish storage may be any one of several types which, for economy of space and operation, are suspended from the ceiling of the room. This permits a circulation of the cold air from the coils to the fish by convection currents without the necessity of mechanical means for air circulation. The provision of cooling surface should be sufficient to insure a constant temperature low enough to hold the fish in good condition.

Engineering practice dictates the requirements for mechanical equipment and insulation. Recognition of climatic conditions must be considered in calculating the necessary and economical refrigeration surface and thickness of insulation.

PACKING SHELLFISH

Shellfish are usually handled by methods similar to those reviewed above, with the possible exception of scallops. Those which are shipped in the shell are susceptible to rises in temperature and will die if they are permitted to become warm during handling or transit to the market. When these shellfish are removed from the water they close their shells until death occurs. It is possible, by this means, to separate the dead ones from those which are alive, for those having open shells are unfit for use. During extremely cold weather precautions are necessary to prevent freezing of live shellfish in transit.

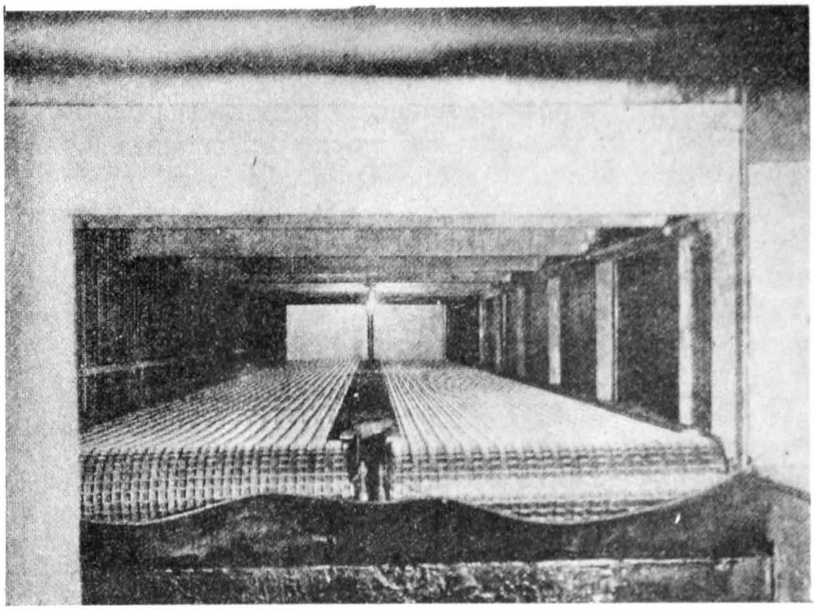

Fig. 6. Conveyors in a Freezing Tunnel at Mobile, Ala., Capable of Handling 2000 lb. of Fruit, Vegetables, or Seafood per Hour.

Shellfish should be washed so as to remove all the adhering particles of mud and sand before the shells are removed, a process which does a great deal toward eliminating one of the causes of bacterial contamination.

In the past the shippers of live lobsters and crabs have frequently experienced excessive losses through the death of the entire or a large portion of the shipment of these seafoods. In many instances they were at a loss to explain high mortality. Upon investigation, however, in nearly all cases of excessive loss it was found that the shipments of the lobsters and crabs had been made in the same express car with frozen fish refrigerated with dry ice.

Dry ice is solid carbon dioxide, and while it is not toxic it is heavier than air and tends to settle to the bottom of the car, thus excluding the oxygen and smothering the live lobsters and crabs. It is advisable to refrain from shipping either of these seafoods alive in a closed express car with shipments of frozen fish packed with dry ice.

Scallops which are taken in deep water are usually shucked aboard the boat, the shell and viscera discarded at sea, and only the large adductor muscle retained for food. These are then placed in the shipping container and packed in ice ready for shipment. Scallops taken in the shoal waters are usually carried to a shucking house where the

Table 9. Estimate of the Probable Storage Life of Frozen Fish[1]

Species	Round or headed and gutted	Packaged fillets
	Months	Months
Butterfish	6- 8	10-12
Cod	8-10	10-12
Croakers	6- 8	8-10
Flounder	8-10	10-12
Grouper	6- 8	8-10
Haddock	8-10	10-12
Halibut	8-10	10-12
Lake herring	6- 8	8-10
Lingcod	6- 8	8-10
Mackerel		
(Spanish)	6- 8	6- 8
(Boston)	6- 8	6- 8
Mullet	6- 8	8-10
Porgie (Scup)	8-10	10-12
Pollock	8-10	10-12
Pike (all species)	6- 8	8-10
Rosefish (ocean perch)	6- 8	8-10
Red snapper	6- 8	8-10
Rockfish	6- 8	6- 8
Salmon (except pink)*	6- 9	6- 9
Sole	8-10	10-12
Smelt	8-10	8-10
Sablefish	6- 8	8-10
Sea trout	6- 8	6- 8
Shrimp	6- 8	8-10
Whiting	8-10	10-12
Whitefish	8-10	8-10

*Pink salmon does not keep well when wrapped.

[1]It is often of value for a warehouse operator or a frozen fish producer to obtain an idea of the period of time that his product can be expected to remain in a salable condition. The above table contains such an estimate expressed in months in storage. The times shown in the table are based on the assumption that the fish were in first class condition when landed and that they were prepared and frozen without delay. It should also be understood that the temperature in the storage room is held at a minimum of fluctuation and other approved conditions. The estimated times are based upon experimental data and general commercial practice.

meats are removed and prepared for shipment to the market. The strictest of sanitary rules should be observed.

Crabs are prepared for market in several ways, depending upon the type of crab—whether soft or hard; and upon whether they are alive or cooked. Live, hard-shell crabs are usually shipped in barrels or baskets with sea weed and a small amount of crushed ice for refrigeration. Later they are steamed in large retorts and the meats picked at the wholesale or retail market. Soft-shelled crabs are handled with the greatest of care since they are much more subject to injury than the hard variety. They are prepared for shipment to market by packing carefully in trays holding one or two dozen crabs; these trays are then packed in large crates. The crabs are surrounded with wet sea weed and refrigerated with ice. When crab meat is prepared for market at the point of production, it is removed from the cooked crabs and packed in 1-lb. tin containers having holes in the bottom. These containers are fitted with tight covers and are packed in boxes or barrels and covered with crushed ice. A piece of burlap is usually used as a cover for the barrel.

Lobsters are usually shipped alive, and care is necessary to prevent death due to fresh water from melting ice used as a refrigerant. The lobsters are packed in small barrels in green sea weed which is moistened with sea water. This small barrel is centered inside a larger barrel and made fast, the space between the two barrels being filled with large pieces of ice. Lobsters are usually marketed in the live state. Although there is a limited quantity of lobster meat available in the market, it is prepared in a manner similar to the method described for preparing crab meat. It should be kept thoroughly chilled from the time it is picked until it reaches the consumer.

Shrimp are prepared for market by several treatments. Only the tails are of value as food. Green shrimp are those which are marketed without any preparation except washing; they are shipped in barrels, half barrels or 100-lb. boxes, with ice in the bottom and on top of shrimp. The "cooked or steamed" shrimp are prepared by boiling in a light brine solution, and can be handled either with or without the shell. They are packed for shipment in 1 to 5-gal. tin containers fitted with a tight top. These containers are packed in barrels or boxes and surrounded with crushed ice. The barrels are covered with burlap; the boxes are covered with a solid wooden top.

CALCULATION OF REFRIGERATION REQUIREMENTS

When fish are received at a cold storage warehouse in the unfrozen condition packed in ice, and are to be frozen before being stored in the warehouse, it is necessary for the operator to estimate the quantity of refrigeration required to freeze them. It will be noted in Table 1 that fish contain a considerable portion of water. In making the calculation of the refrigeration required, for practical purposes the solids can be disregarded, since they are so low.

If 100 lb. of alewives are delivered to the warehouse packed in ice at 50° F. and are to be frozen and stored at a temperature of 10° F. the refrigeration capacity required for this will be calculated as follows:

Since it is necessary to absorb 1 Btu. per lb. for each 1° F., $50^{\circ} - 32^{\circ} = 18 \times 100$ lb. of fish to be lowered to 32° F., = 1,800 Btu.
144 Btu. per lb. is to be absorbed to freeze the fish at 32° = 14,400 Btu.
0.5 Btu. per lb. to lower the temperature from 32° to 10° F., $100 \times 22 \times 0.5 = 1,100$ Btu.
$1,800 + 14,400 + 1,100 = 17,300$ Btu.

Since, however, there is only 74.4 per cent moisture to be frozen in the alewives, then the heat removal to freeze them and lower to 10° F. will be 74.4 per cent of 17,300 = 12,871 Btu. In this calculation no allowance has been made for heat losses of the freezer and storage room; these losses will be added to the required refrigeration. In these calculations only the figures in round numbers for required refrigeration are used.

SUMMARY

Fish which are frozen for future markets should be carefully selected. Only those in prime condition should be frozen.

The fish should be frozen immediately when received at the cold storage plant and be held in this condition until finally delivered into the hands of the consumer.

In instances where, for any reason, the frozen fish have defrosted enroute, extra care is required in refreezing them. Only those which are in prime condition should be refrozen. The refreezing should be accomplished as rapidly as possible.

The temperature of the cold storage room should be maintained at between 0° and -10° F., with great care to limit the range to as narrow a margin as is possible. It is advisable to control the temperature automatically with a thermostat.

Boxes or cartons containing frozen fish should be piled in the storage room so that the air can circulate with considerable freedom among them. This prevents heating and defrosting through proximity of warm surfaces. Care should be exercised in stacking the piles well away from the walls if the storage room has an outside wall or is near a room maintained at a higher temperature.

A heavy glaze of ice should coat the surface of all fish frozen in the round which do not have a wrapping of some moisture-vapor-proof material. Frequent examination of the glaze should be made and reglazing done as often as is necessary to prevent exposure of the surface. The water used for reglazing should be near freezing temperature when sprayed upon the surface of the fish.

When refrigerator cars are to be loaded with fish from cold storage, it is advisable to precool them thoroughly before the loading is begun. When the temperature of the cars has reached approximately +10 to $+15^{\circ}$ F., the loading is begun and should be accomplished as rapidly as possible. When a car is received at the warehouse, it should be completely unloaded with as little delay as possible.

REFERENCES

1. Beard, Harry R., Bureau of Fisheries Document no. 1000.
2. Nilson, Hugo W., and Coulson, E. J., Bureau of Fisheries Investigational Report no. 41.
3. Lanham, W. B., Jr., and Lemon, J. M., Food Res., vol. 3, no. 5, p. 549, 1938.
4. Taylor, Harden F., Refrigeration of fish. Fisheries Document no. 1016.
5. Lemon, J. M., Fishing Gazette, Annual Review Number, vol. 55, no. 10 p. 80, 1938.