compounds. It is, therefore, important that the evaporator coils in the freezer be sized properly so that the desired high relative humidities can be obtained. However, because of material costs and space limitations, a temperature difference of 10 F between the evaporator coils and the room air seems to be the most practical.

High relative humidities have been obtained by modified design of the cold storage room. A jacketed-type cold storage room used for storing round-frozen fish in Canada, and to some extent in this country, has been proven successful in this regard. The jacketed freezer is so designed that cooling of the room is accomplished by cold air circulating in an annular space (referred to as the jacket) between the walls, floor, and ceiling of the room and the insulation lining the exterior of the room. A fan and finned pipe coil evaporator (equipped for automatic defrosting) located in the jacket provides the necessary air circulation and air cooling, respectively. The design of the jacketed freezer is such that removal of any heat, transferred through the insulation, is accomplished by the jacket circulating air, thereby preventing the heat from entering the storage area. This, in addition to the maintenance of a close temperature differential between the inner surfaces of the room and the air within the room, makes it possible to obtain satisfactoriiy high relative humidities of over 90 percent. In tests conducted at the Bureau of Commercial Fisheries Technological Laboratory in East Boston on packaged fish blocks, samples not overwrapped and stored in a jacketed freezer compared favorably with blocks overwrapped with moisture vapor-resistant films and stored in a commercial freezer after storage at −5 F for 9 months. The use of a jacketed type freezer should be seriously considered in a plant where large quantities of round or inadequately packaged fish are to be stored if maximum quality maintenance is envisaged.

Effect of Packaging and Glazing on Quality

Adequate packaging of fishery products is important to prevent product dehydration and subsequent quality loss. The packaging of fishery products, which in most instances occurs prior to freezing, has been described previously in this chapter. Some fishery products, such as steaks, which are cut from frozen fish, and individually frozen shrimp, are usually packaged after freezing. Packaging products after freezing usually results in an air space within the package which may cause excessive product dehydration during frozen storage. Glazing of the fish in the package will greatly reduce this desiccation. Individual fish, frozen in the round or headed and eviscerated, cannot usually be suitably packaged; therefore, they must also be protected by a suitable glazing compound.

A maintained glaze acts as a protective coating against the two main causes of deterioration during storage, namely, dehydration and oxidation. It acts against dehydration by preventing moisture from leaving the product, and against oxidation by mechanically preventing air contact with the product. It may also act by chemical means to minimize these changes if the glaze carries a suitable anti-oxidant.

In the case of whole fish, glazing is done by dipping them into a tank holding the glaze solution. Large fish are dipped separately, or placed in wire baskets or pallet boxes and dipped by means of a hoist. Steaks, cut from frozen fish by bandsaws, are conveyed through a glaze tank on the way to a packaging table.

For ideal glazing, the room should be kept at 20–25 F and the temperature of the glazing solution maintained just above freezing but not so cold as to develop ice crystals. The length of a dip is about 10–30 sec. Successive dips are usually necessary if it is desired to build up the glaze on the product.

Many patents have been issued describing the addition of various chemicals to water in order to obtain a glaze, not brittle, and with less tendency to evaporate than plain water. Some inorganic salts modify the crystalline structure of ice, making it tough. Eutectic solutions of disodium acid phosphate, sodium carbonate, calcium lactate, boric acid and certain concentrations of organic compounds, are reported as non-cracking, shock resistant, and long lasting. Colloids and thickeners, such as Irish moss extractives, cellulose gum and pectinates, have been used to increase glaze weight, and to delay reglazing and improve the effectiveness of the glaze.

One alginate product known as *protan* has been reported to be of considerable value in increasing the frozen shelf life of mackerel, herring, and similar fatty fish. Other edible coatings such as distilled acetylated monoglycerides have also shown promise in reducing product dehydration.

A glaze containing corn sirup solids (glucose) has recently shown considerable promise in extending the storage life of some fishery products. In tests conducted at the Bureau of Commercial Fisheries Technological Laboratory in Seattle, Washington, frozen salmon steaks dipped in a solution containing 30 or 45 percent corn sirup solids before packaging were protected from excessive oxidation during eight months of frozen storage.

A glaze should be non-toxic and transparent for purposes of quality inspection in frozen storage, inexpensive, and uniform in application. Those with a bactericidal action after thawing have doubtful value. In addition to the dip application, fish are often sprayed after piling into frozen storage in order to provide protection in case the original glaze has been cracked in handling. At frequent intervals during storage, fish piled loosely are examined, and glazed by spraying if cracking or evaporation has resulted in exposure. Rapid glaze loss can be expected where air movement is at all significant as in a blower-type cold storage room or storage locker. Of course the rate of evaporation also depends on the relative humidity; therefore humidities as near to saturation as possible should be maintained without working a hardship on the evaporator coils and defrosting mechanism.

Maximum storage life of fishery products can be obtained by employing the following procedures:

1. Use only high quality fish for freezing.
2. Use moisture-vapor resistance packaging materials and fit package tightly around product.
3. Freeze fish immediately after processing or packaging.
4. Glaze frozen fish prior to packaging or if round, unpackaged fish, prior to cold storage.
5. Put fish in frozen storage immediately after freezing and glazing, if required.
6. Store frozen fish at temperatures of 0 F or lower. Do not accept higher storage temperatures.
7. Renew the glaze on round, unpackaged fish as required during frozen storage.

The recommended protection and expected storage life for various species of fish are shown in Table 5.

Space Requirements for Frozen Fish

Packaged fishery products such as fillets and steaks are usually packed in cardboard master cartons for storage and shipment. These master cartons are stacked on pallets and transferred to a certain area of the cold storage room by a fork-lift truck. In unpalletized warehouses the packages are usually loaded onto a hand truck and stacked within the frozen storage rooms by hand. Large whole fish such as halibut, salmon or swordfish are stored in wooden boxes, pallet boxes constructed out of wooden stringers, or a suitably protected metal, or stacked individually within the freezer.

Whole or dressed fish frozen in blocks in metal pans such as mackerel, or chubs, or whiting, are removed from the pans after freezing, glazed, and then packaged in wooden boxes lined with kraft paper or in cardboard cartons.

Round fish stored in wooden boxes can be easily reglazed at periodic intervals during frozen storage. The space requirements for the storage of fishery products are shown in Table 6.

Table 5 .... Storage Conditions and Storage Life for Frozen Fish

Fish	Recommended Protection*	Storage Life, 0 F, Months
Chub, pink salmon	Ice glazing and packaging	4– 6
Mackerel, sea herring, pollock, chub, smelts	Ice glazing and packaging	5– 9
Pacific sardines, tuna	Packaging	4– 6
Buffalofish, flounders, halibut, ocean perch, rockfishes, sablefish, red, sockeye, silver or coho salmon, whiting, shrimp	Packaging	7–12
Blue pike, haddock, cod, hake, lingcod	Packaging	Over 12

* All packaging should be with moisture resistant films.

TRANSPORTATION AND MARKETING

Conditions of temperature and humidity recommended for frozen storage should also be employed during transportation and marketing to minimize product quality loss. Storage of foods in a cold-storage warehouse might be described as a static condition (assuming limited access to the space), where temperatures and humidities are more or less constant. However, such is not the case in the transportation and marketing of frozen foods where, because of the continued transfer of product from one storage environment to another, the loss in quality may be dependent on the efficiency of the many mechanical devices and human agents involved. Investigators, studying the handling of frozen foods, have found that such practices as: shipment in non-, or improperly, refrigerated carriers; exposure to high ambient temperatures during transfer from one environment to another; improper loading of common carriers or display cases; equipment failure; and other poor handling practices have resulted in increased product temperature and subsequent quality loss.

Various food processing and distribution associations and governmental agencies, aware of this loss in product quality, have stressed the need for equipment and techniques which will result in maintenance of product temperatures of at least 0 F. As a result, refrigerated carriers employing dry ice or, more recently, mechanical refrigeration systems have been specified for the proper transportation of frozen foods. Likewise, the need of low temperatures in order-delivery rooms and retail display cases has been stressed. Temperature checks of product during transit have pinpointed this aspect of this responsibility and provided a basis for improvements. Trade associations are presently conducting additional studies and surveys to determine the effect of present marketing practices on quality loss. Although advancements have been rapid, and improvements many, much more remains to be done in this field to attain the desired degree of product quality at the consumer level. Education of other members of the processing and distribution industry is now needed. Recognizing the importance of maintaining the quality of frozen foods at a high level, the Association of Food and Drug Officials of the United States and industry organizations have established codes and guide lines, respectively, for improving existing handling conditions. Much more information is needed on the stability of the many species of frozen fish before realistic codes can be established.

Frozen fish are, for the most part, transported in trucks, railroad cars or ships refrigerated by mechanical refrigeration, or in some instances, dry ice. Many of these vehicles are capable of maintaining temperatures of 0 F or lower. Small lots of frozen fish are usually packed in an insulated container with appropriate quantities of dry ice and shipped by air or other non-refrigerated carriers. Additional information on equipment used in the transportation and marketing of frozen fish and other foods is given in Chapters 55, 56, and 57.

To minimize quality loss during transportation and marketing, the following procedures should be adhered to:

1. Frozen fish should be transported in refrigerated carriers employing mechanical or dry ice refrigeration systems, with ample capacity to maintain 0 F over long distances.
2. Refrigerated carrier should be precooled to at least 10 F before loading.
3. Frozen products should not be removed from warehouse until carrier is ready to be loaded. When removed from frozen storage they should be loaded directly into the refrigerated carrier and not be allowed to sit on the dock.
4. The frozen fish temperature should be checked with a dial thermometer before loading.
5. Frozen fish should not be stacked directly against floors or walls of carrier. Floor and wall racks or strips should be provided to permit air circulation around the entire load.
6. Temperature of refrigerated carrier should be continuously recorded during transit. An alarm should be used to warn of equipment failure.
7. Temperature of product should be measured when removed from common carrier at next destination.
8. If products are shipped in an insulated container, quantities of dry ice sufficient to maintain 0 F or lower temperatures during the duration of the trip must be employed.
9. Food delivery or break-up rooms should be maintained at

Table 6 .... Space Requirements for Frozen Fishery Products

Commodity	Product Package	Container for Storage	Space Required, Lb per Cu Ft
Fish sticks, breaded shrimp, breaded scallops	8 or 10 oz consumer package	Cardboard master cartons	25–30
Fish fillets, fish steaks, small dressed fish	1, 5, or 10 lb packages	In cardboard master cartons	50–60
Shrimp	2½ and 5 lb cartons	In cardboard master cartons	35
Panned, frozen fish (mackerel chubs)	None	Wooden box	35
Round halibut	None	Wooden box	30–35
		Stacked loose	38
Round groundfish	None	Stacked loose	32
Round salmon	None	Stacked loose	33–35