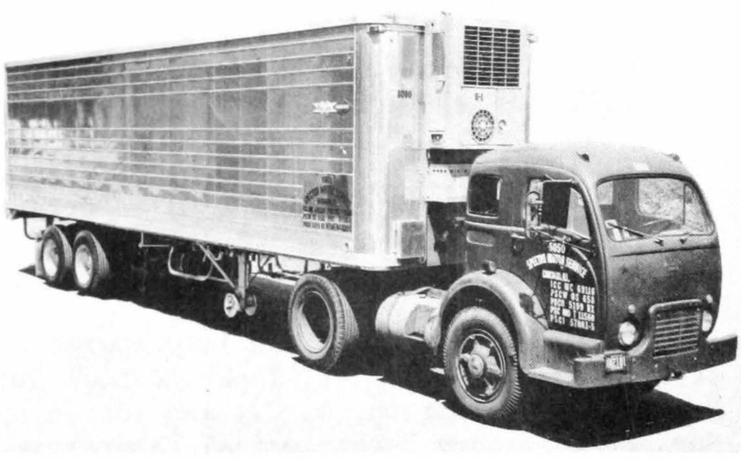
## REFRIGERATION OF FISH - PART 5

# DISTRIBUTION AND MARKETING OF FROZEN FISHERY PRODUCTS

UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, Secretary

FISH AND WILDLIFE SERVICE

John L. Farley, Director

Fishery Leaflet No. 431

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, John L. Farley, Director

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# REFRIGERATION OF FISH: PART FIVE

## DISTRIBUTION AND MARKETING OF FROZEN FISHERY PRODUCTS

By

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This leaflet is part five in a series of five on "Refrigeration of Fish." Titles of the other four leaflets are:

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Part 2 (Fishery Leaflet 428) -- Handling Fresh Fish
Part 3 (Fishery Leaflet 429) -- Factors to be Considered in the Freezing and Cold Storage of Fishery Products
Part 4 (Fishery Leaflet 430) -- Preparation, Freezing, and Cold Storage of Fish, Shellfish, and Precooked Fishery Products

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SECTION 1

# TRANSPORTATION OF FROZEN FISH

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## INTRODUCTION

The "freshness" and quality of frozen fish is determined to no small extent by the temperatures and humidities they encounter while in cold storage. Storing frozen fish at 0° F. or lower and at relatively high humidities makes possible the maintenance of a high quality of frozen fish over a considerable longer time than is possible if high temperatures of storage and low humidities are used.

The geographical location of the comparatively few coastal fishing ports and the large demand for frozen fish in inland cities early resulted in the need for refrigerated methods of transportation. Many obstacles have been overcome since the first refrigerated shipment by rail, in July 1851, when several tons of butter were shipped from New York to Boston in a railroad refrigerator car insulated with sawdust and packed with ice. Since then, modern techniques and research have produced the low-temperature refrigerated carriers of today.

This section of the leaflet will discuss common carriers--railroad, truck, ship, and airplane--and insulated containers used to transport fish from producer to market.

## RAILROAD

### History

The railroads were the pioneers in transportation by refrigerated carrier. The development of the present-day refrigerated railroad cars since the first refrigerated shipment over 100 years ago has been made possible through extensive research by both industrial and governmental agencies. During this period of research and experimentation, many unsatisfactory types of refrigerated cars were introduced that were later discarded because of operational difficulties and high costs.

The first 30 insulated refrigerated railroad cars were constructed by the Pennsylvania Railroad in 1857. These cars were made of wood and were insulated with sawdust in the walls, ceiling, and floor. Blocks of ice stacked in the car produced the refrigeration effect. A hole in the floor of the car allowed the water from the melting ice to drain. In 1860, the first refrigerated shipment of meat was made from Chicago to New York and then to Boston in a car similar to the one previously described. This 1860 car was stacked with 2,000 to 3,000 pounds of ice, and the meat was unloaded at Boston in good condition. In 1868, the Davis car was patented. It was insulated with sawdust and had cylindrical containers--one in each corner of the car--that were loaded with a mixture of ice and salt. The Davis car later became obsolete because the refrigeration was inadequate, resulting in a high temperature of product during transit. In the early 1900's, the end-bunker basket-type car was introduced. No further changes in the basic design of railroad cars were then made until 1919 when the United States Department of Agriculture, working in conjunction with the

United States Railroad Administration, established a standard design for refrigerator cars. The new standards called for a minimum thickness of insulation of 2 to 2½ inches, basket bunkers, insulated bulkheads, floor racks at least 3-3/4 inches high (to allow circulation of air under the products), and an ice capacity of 5 tons.

In 1923, the use of "dry ice" in a refrigerated car began with a shipment of fish from Halifax to Montreal. Then, in the summer of 1926, the first refrigerated car of frozen fish was shipped from New York to Detroit by the Atlantic Coast Fisheries Company. Again, dry ice was used as the refrigerant. Later in the year, several carloads of frozen fish were shipped from Provincetown and New York City to Kansas City and Saint Louis with 1,400 to 2,400 pounds of dry ice having been placed in boxes scattered over the top of the load. As a result of these shipments, the United States Bureau of Fisheries reported that it was practical to ship frozen fish, using dry ice as a refrigerant.

The introduction of frozen fish in this country was largely brought about by the appearance of the silica-gel refrigerator car in 1927. A fleet of these cars engaged in the transportation of frozen fishery products between the Pacific Northwest and the Atlantic Coast. The silica-gel cars were later converted to end-bunker cars, however, because of the high cost of operation and the inadequacy of the refrigeration in hot weather.

Early in the 1930's, experiments were conducted to determine the effect of increased insulation and of the use of 25 to 30 pounds of salt per 100 pounds of ice to obtain lower temperatures. As a result of these experiments, 100 super-insulated refrigerated cars were constructed in 1932. These cars were heavily insulated with blanket-type insulation 7-inches thick on the roof and floor and 6-inches thick on the walls. The car was increased in length to 42 feet, 6 inches, giving it a capacity of 2,612 cubic feet. The refrigeration was furnished by 14,000 pounds of ice and salt in end bunkers. This car was the forerunner of the present-day super-insulated end-bunker refrigerator car.

In 1935, the Association of American Railroads created standards for new refrigerator cars. The standards called for steel sheathing in place of tongue-and-groove wood sheathing, heavy steel roofs in place of the existing flexible thin steel roofs, and increased thickness of insulation from 2 to 3 inches in the walls and from 2½ to 3½ inches in the floors and roofs.

During this same period, experiments were conducted by the Canadians on an overhead-bunker refrigerator car. The results of their experiments indicated that this type of car could maintain lower and more uniform product temperatures than could the existing end-bunker cars. These experiments led to the adoption, in 1939, of the overhead-bunker car as a standard refrigerated car by the Canadian railroads.

Very little progress was made in improving the design of refrigerator cars during World War II. Immediately after the war, however, standards were set for all new general-service refrigerator cars. These standards included 4 to 4½ inches of insulation, sidewall flues to allow complete air circulation around the inside of car, and fans for the circulation of air.

Meanwhile, those engaged in the production of frozen foods asked for lower-temperature (0° to -10° F.) refrigerated cars. In the following years, extensive research was conducted by some of the major railroad companies in order to determine a suitable method of obtaining a low-temperature refrigerated carrier. This work resulted in the introduction of the dry-ice and split-absorption refrigerated cars. These cars, although capable of maintaining low temperatures, proved too expensive, both in initial cost and in operational cost, for commercial use.

Tests on the dry-ice and split-absorption cars showed, however, that it was possible to maintain low temperatures of product during transit. This finding paved the way for the present mechanical refrigerated car. The first shipment of frozen foods in a mechanical refrigerated car was made in 1949 by the Fruit Growers Express Company. The highly satisfactory performance of this type of car resulted in the production of the low-temperature car and, subsequently, the all-purpose mechanical refrigerated car. In 1954, there were 127,000 ice-and-salt refrigerated cars and 1,000 mechanical refrigerated cars. Additional mechanical refrigerated cars are now being manufactured in order to meet the increasing demand of the frozen-food market.

In the following remaining discussion on refrigerated railroad cars, the silica-gel, dry-ice, split-absorption, end-bunker, overhead-bunker, and mechanical cars will each be considered separately in detail.

## Silica-Gel Car

The principle of the silica-gel refrigeration system is based on the physical properties of silica gel. This substance, if mixed with sulfur dioxide gas, will liberate the gas when heated and reabsorb the gas when cooled to ordinary temperatures. The silica-gel refrigerator car was similar to the end-bunker car except that the refrigeration system was placed in an insulated fireproof compartment located at one end of the car. Two silica-gel units were used to supply the necessary refrigeration. Each unit consisted of a small-diameter cylinder loaded with a mixture of silica gel and sulfur dioxide. This cylinder was connected by suitable piping to a finned-type condenser and then to a receiver, both of which were located on the roof of the car. The receiver was connected to a finned cooling coil placed just under the ceiling. Two automatically operated gas burners were used to supply the heat to the cylinders containing the silica gel and sulfur dioxide.

The refrigeration cycle was as follows: the gas burner under one of the cylinders containing the mixture of silica gel and sulfur dioxide was lighted. The resultant heat liberated the sulfur dioxide gas from the cylinder causing the gas to flow into the condenser, where it was cooled to a liquid. From the condenser, the liquid sulfur dioxide flowed to the receiver and then to the evaporator coils attached to the ceiling of the car. A float valve in the receiver maintained the proper level of liquid in the coils. After a period of heating of approximately 30 minutes, the gas burners under one unit were extinguished, causing those under the other unit to ignite automatically. The lines connecting the cooling cylinder of silica gel to the condenser and evaporator coils then were closed and opened, respectively, by means of automatically operated solenoid valves. This action of the valves resulted in absorption by the silica gel contained in the cylinder of the sulfur dixode gas from the cooling coils, causing evaporation of the liquid sulfur dioxide, which in turn lowered the temperature in the car.

The fuel gas was carried in tanks located under the car. The system operated completely automatically, and theoretically, temperatures of 15°F. could be maintained within the car during transit. In actual use, however, the silica gel disintegrated and the sulfur dioxide gas was not properly absorbed during hot weather. Therefore, these cars, of which there were about 100, were converted to salt-and-ice end-bunker refrigerated cars.

## Dry-Ice Car

As previously was mentioned, the first dry-ice cars consisted of standard box cars with dry ice placed in boxes scattered over the top of the load. Improvements were made by placing the dry ice in overhead tanks, the carbon dioxide gas being permitted to gravitate to the floor through wall flues. The consumption of dry ice was somewhat controlled by a complicated damper arrangement that varied the amount of air coming in contact with the dry ice. These systems, although capable of maintaining low temperatures, were too costly for wide commercial use.

The possibility of using dry ice, however, was not completely disregarded and subsequently two indirect dry-ice systems, known as the Broquinda system and the Dieco system, were developed. These systems were very similar to each other in principle, the main difference being in (1) the location of the equipment in the car and (2) the method of circulating the secondary liquid. The following is a description of these two systems:

### Broquinda System

The Broquinda system utilizes dry ice to cool a secondary liquid, which is then circulated through cooling coils supported from the ceiling of the car. The car is similar to the standard end-bunker car, except for two insulated compartments located between the roof and the ceiling. Each compartment contains a metal dry-ice receptacle, the outside of which is enclosed by a jacket that contains the secondary liquid. The top and the bottom of this jacket are connected to a set of finned cooling coils, which are supported from the ceiling.

The refrigeration cycle is as follows: Dry ice is placed in the two dry-ice receptacles through hatches located in the roof of the car. The dry ice in each receptacle absorbs the heat from the secondary liquid, which then flows from the lower jacket connection into the finned cooling coils, where it, in turn, absorbs the heat from the load within the car, thereby providing the necessary refrigeration effect. In absorbing the heat from the load, the secondary liquid expands causing it to flow out of the cooling coils into the upper jacket connection, where it is again cooled by the dry ice. The flow of liquid to the cooling coils is regulated by thermostatically controlled valves. This system is capable of maintaining car temperatures as low as -20° F. The limited availability of dry ice in many places and the frequent re-icing required, however, has limited its application to only a few special-purpose refrigerator cars.

Dieco System

The Dieco system is somewhat similar to the Broquinda system, and the appearance of the refrigerator car is similar to that of a regular refrigerator car except that, instead of the usual ice bunkers at each end, there is a dry-ice refrigeration compartment located at one end of the car (figure 1). This compartment is divided, by means of an insulated bulkhead, into two parts, one containing a dry-ice bunker and the other containing a dry-ice pressure tank (figure 2). The equipment that contains the secondary liquid (alcohol solution) consists of coils at the bottom of the dry-ice bunker, two banks of cooling coils suspended from the ceiling of the car, and an upper and a lower float cylinder located adjacent to the pressure tank.

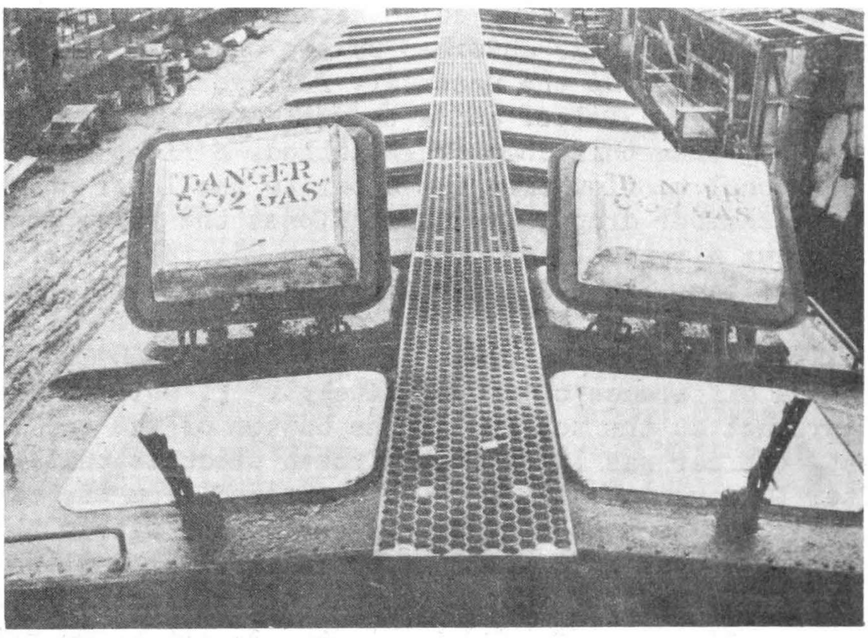

Figure 1.—Hatch covers providing access to dry-ice bunker. (Photo courtesy of U. S. Department of Agriculture)

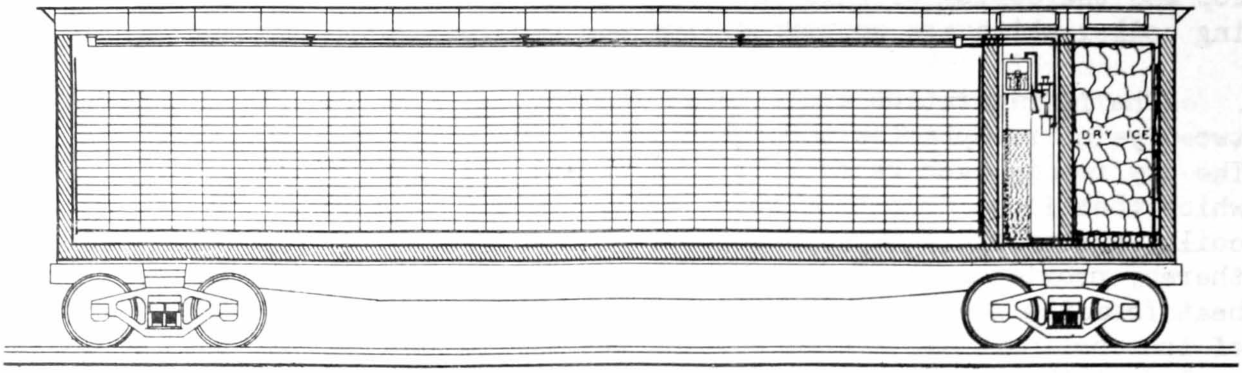


Figure 2.--A railroad car with an indirect type of dry-ice system of refrigeration. Note the dry-ice bunker and pressure tank located at one end of the car. (Photo courtesy of U. S. Department of Agriculture)

The refrigeration cycle is as follows: Approximately 12,000 pounds of dry ice is placed in the bunker, and 2,000 pounds is placed in the pressure chamber. The sublimation of the dry ice in the pressure tank produces a pressure of approximately 7.5 pounds. This pressure is transmitted by suitable piping to the lower float cylinder, causing the alcohol solution to flow from the lower float cylinder through the cooling coils located under the dry ice in the bunker. The alcohol, after being cooled by the dry ice, flows from the cooling units of the bunker through the two banks of cooling coils attached to the ceiling of the car. The heat from the car is absorbed by the cold alcohol within these coils, thereby furnishing the necessary refrigeration effect. The alcohol then flows through a filter and a thermal-control valve to the upper float chamber. When this chamber is filled, a float opens a valve that allows the alcohol to flow from the upper to the lower chamber. When the level in the chamber drops, the float closes the valve connecting both chambers and opens a valve that admits carbon dioxide, under pressure from the pressure tank, to the lower float chamber, where the cycle begins again.

This car will maintain temperatures of 40° to -20° F., with a minimum difference of approximately 1° F. between the average temperature of product at the top and at the bottom of the car (figure 3). In one test, the car was loaded with frozen products that were at -15.1° F. After 10 days, the products were removed from the car at -4.6° F. Approximately 13,880 pounds of dry ice were used within this 10-day period. Based on a cost of dry ice of 63 dollars per ton, the total cost of dry ice used during the test was about 437 dollars. This cost was considerably higher than the prevailing cost of approximately 160 dollars for salt and ice necessary for a 10-day trip in an end-bunker car. The high cost of refrigeration and the frequent re-icing required has restricted the use of this type of car to a very few special applications.

## Split-Absorption Car

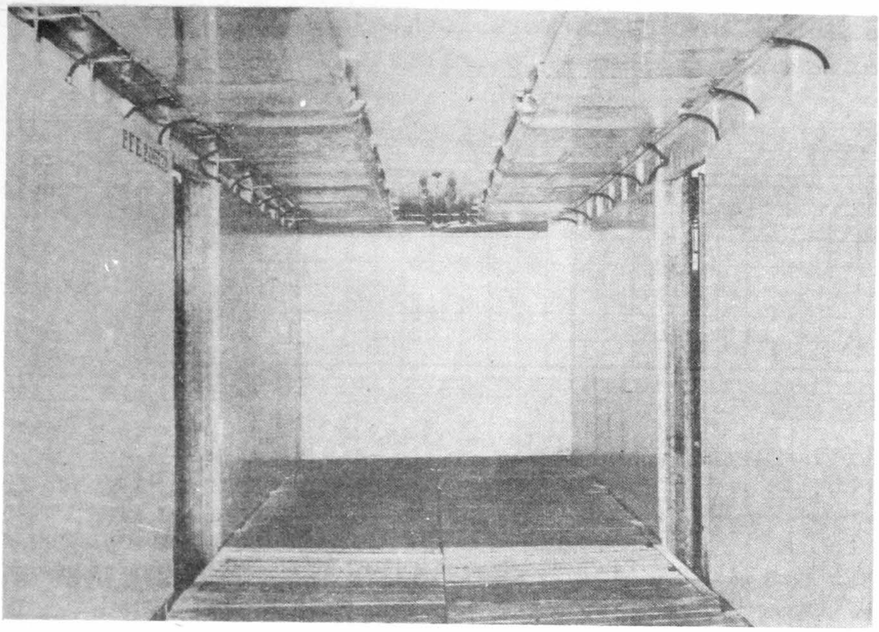

Figure 3.--Interior view of a dry-ice car. Note coils attached to ceiling of car, and floor racks for providing air circulation under stored products. (Photo courtesy of U. S. Department of Agriculture)

After World War II, the search for a low-temperature refrigerator car led to the development of a split-absorption refrigeration system. The split-absorption system is really an ordinary absorption system separated into two parts. (A description of the principles involved in the absorption system are given in Fishery Leaflet 427, section 2.) In the basic absorption system, a continuous regenerative refrigeration cycle occurs with the evaporation, absorption, and recovery of ammonia. In the split-absorption system, however, the evaporation and absorption of the ammonia take place on the railroad car, whereas the recovery of ammonia from the aqua ammonia in the absorber takes place in a stationary ammonia-recovery plant.

The split-absorption system is comprised of receiver (ammonia storage tank), expansion valve, refrigeration coils, and absorbers. The distillation column, aqua-ammonia pumps, condenser, and heat exchanger necessary to complete the absorption system have been eliminated, leaving a simple refrigeration system, with no moving parts. In 1947, the United States Department of Agriculture conducted a test, at the request of the Frigid Transport Corporation and the Birdseye Snider Division of General Foods Corporation, on a refrigerator car equipped with a split-absorption system. The following is a discussion of the test:

The experimental split-absorption refrigerator car was similar to a standard refrigerator car, the only difference being in the method of accomplishing the refrigeration. The refrigeration system (figure 4) consisted of two ammonia receiver tanks with a combined capacity of 1,900 pounds of ammonia, finned cooling coils consisting of 865 linear feet of 1-inch aluminum tubing, and 2 finned absorber tanks charged with 500 gallons of fresh water. The storage and absorber tanks were attached to the underframe outside of the car, whereas the cooling coils were attached to the ceiling. Drip pans were located under the cooling coils to carry off water when the coils were defrosted.

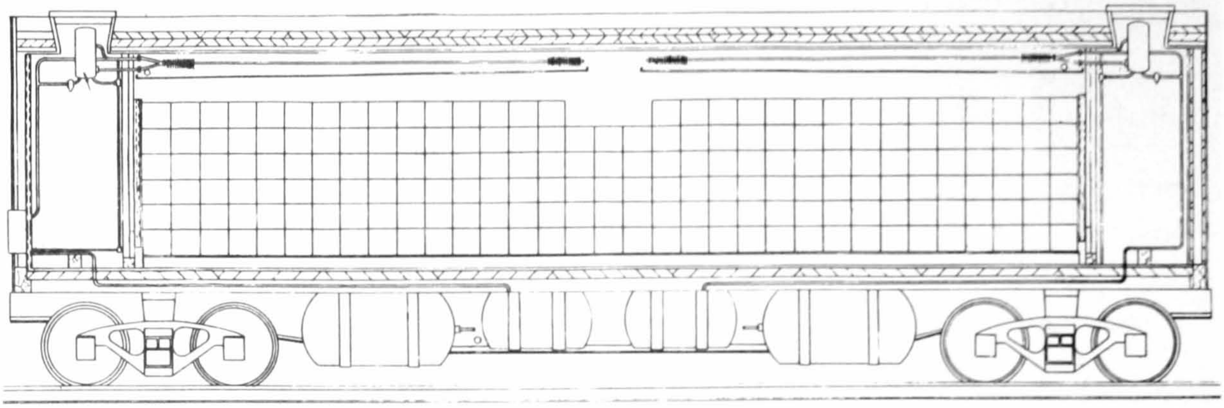

Figure 4.—A railroad car with a split-absorption system of refrigeration. Note the ammonia receiver and absorber tanks located underneath the car, the surge tanks located in the bunker compartments, and the finned cooling coils attached to the ceiling of the car. (Photo courtesy of U. S. Department of Agriculture)

The refrigeration cycle was as follows: liquid anhydrous ammonia stored at 120 pounds per square inch gauge in the storage tanks flowed through a surge tank and an expansion valve into the finned cooling coils, where it expanded at low pressure, thereby accomplishing the refrigeration effect. The gaseous ammonia from the cooling coils then flowed into the absorbers, where it mixed with the fresh water, forming aqua ammonia. The car was serviced every day during the test. This servicing involved adding approximately 1,000 pounds of anhydrous ammonia to the receiving tanks, removing the aqua-ammonia solution from the absorbers, and adding 500 gallons of fresh water. A total of 11,000 pounds of anhydrous ammonia at a rate of approximately 42 pounds per hour, and a total of 5,000 gallons of water at a rate of approximately 19 gallons per hour were used to maintain an average temperature of 0° F. within the car during the 10-day test.

This test proved that the split-absorption system had sufficient refrigeration capacity to maintain 0° F. temperatures for the transportation of frozen products. The railroads have not found it commercially feasible for wide usage, however, because of the high initial cost of constructing ammonia recovery plants, excessive labor costs for servicing cars and operating ammonia recovery plants, and danger to personnel and harm to produce from any leakage of ammonia.

## End-Bunker Car

Most of the refrigerator cars in use in this country today are of the end-bunker type. The first end-bunker cars were of many designs. In some, the flow of air to and from the bunkers was restricted by braces and other structural members, whereas in others, perforated bulkheads were used to separate the bunkers from the loading compartment of the car. Floor racks, if used, were supplied by the shippers.

Ice was first used in the bunkers to accomplish the necessary refrigeration. Ice alone, however, would not produce temperatures low enough for the proper protection of frozen foods during transit. It then was found that, by adding 25 to 30 percent salt to the ice in the bunkers, temperatures as low as 15° to 20° F. could be maintained in the cars.

From 1920 until the present (1956), considerable improvements have been made in the end-bunker car, resulting in (1) increased thickness of insulation, (2) insulated bulkheads between the interior of car and bunkers, (3) adjustable ice grates to permit half-stage icing[1/], (4) higher floor racks and wall flues to allow a complete envelope of circulating air around the product, and (5) fans to provide for the forced circulation of air.

The standard end-bunker car is approximately 40 feet in length, is equipped with fans for the circulation of air, and has 4 to 4½ inches of insulation. In 1955, about 1,700 cars 50 feet long with 6 inches of insulation were constructed specifically for the transportation of frozen foods. Openings 12 inches wide located at the top and at the bottom of each partition allows the circulation of air through the bunkers and over the load. The refrigeration is accomplished by the circulation of air around a mixture of salt and ice contained in galvanized metal baskets located in the bunkers (figure 5).

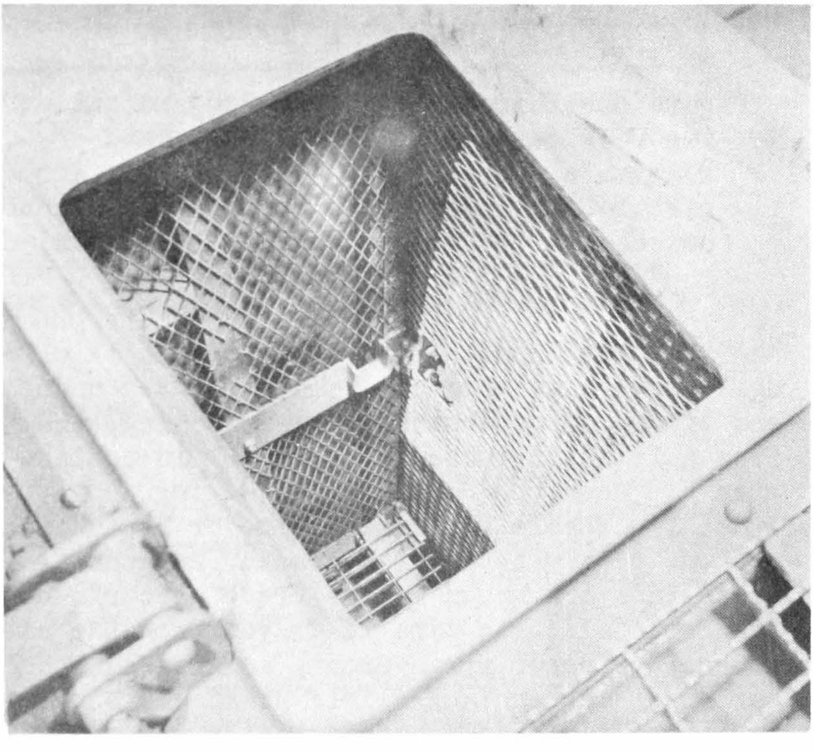

Figure 5.--View of basket in bunker, which contains a mixture of salt and ice. (Photo courtesy of Baltimore and Ohio Railroad)

1/ In half-stage icing, the lower half of the bunker is shelved off and only the upper half is iced.

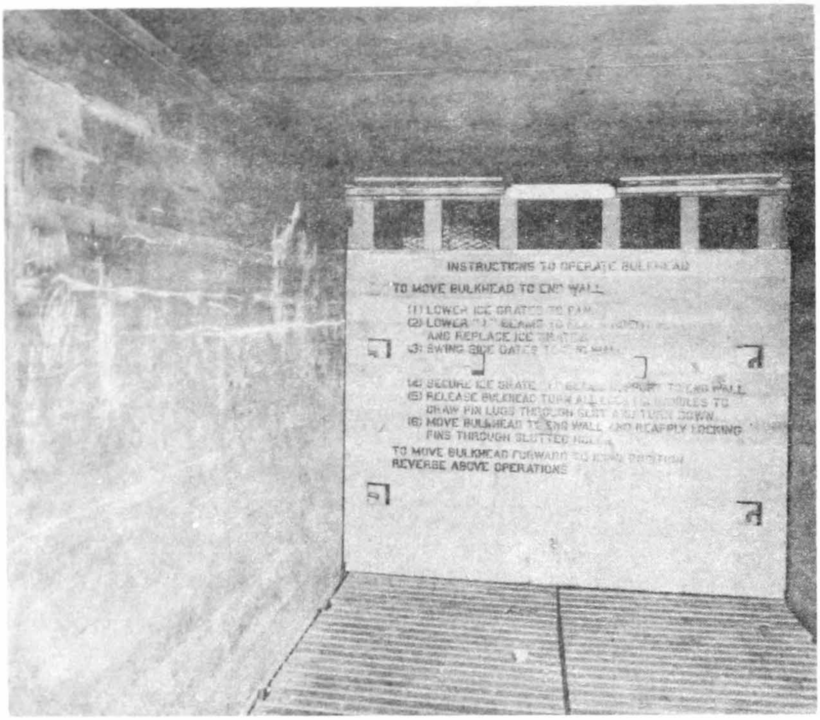


Figure 6.--Inside view of a standard salt-ice refrigerated railroad car. Note removable floor racks, which provide air circulation under stored products. (Photo courtesy of Baltimore and Ohio Railroad)

Each basket holds 5,000 to 6,000 pounds of salt and ice, which is loaded through two hatches located in the roof over the bunker. The walls and ceiling are generally constructed of plywood and are framed to form an air flue between the insulation and the plywood. The floors are constructed of matched boarding placed on top of the insulation. The products rest on floor racks that are constructed of slats running the width of the car and that are supported on longitudinal structural members $6\frac{1}{2}$ inches high. These floor racks can be removed when the car is used for general freight services (figure 6).

The air in most cars of this type is circulated by seven centrifugal blowers mounted on a shaft located under the floor racks at each end of the car. When the car is moving, the fans are driven by a V-belt from a friction-rubber drive wheel in contact with the tread of the car wheels. When the cars are not moving, power to the fans is supplied by a small portable gasoline engine or by an electric motor. Some cars use one of two types of overhead fans that recently have been perfected. These fans are known as the Preco electric type and the Equipeo type. The Preco electric type is driven from the car wheel through an electric alternator motor arrangement, and the Equipeo type is driven from the car wheel through a flexible shaft connected to the fan. In the latter type, the fan blades automatically reverse their pitch when the car reverses direction. The use of overhead fans permits lower floor racks, allowing a larger amount of storage space.

Tests conducted by the Association of American Railroads in 1946, with a car similar to that described above, indicated a range of product temperatures from 8° to 17° F. or an average product temperature of approximately $12\frac{1}{2}$°, while heavily insulated cars without fans (natural air circulation) maintained product temperatures of 14° to 22° F. or an average product temperature of approximately 18° F. When shipping frozen fish in an end-bunker car, the shipper therefore would be wise to secure one that is equipped with fans.

These cars can use either ice alone or salt and ice in order to accomplish the refrigeration. Ice alone has a definite limitation because it is not possible to obtain temperatures of air lower than 32° F. in the bunker, or 40° F. in the car. The addition of salt at the rate of 30 percent of the weight of ice (30 pounds of salt per 100 pounds of ice) will produce bunker temperatures of about -5° F. and average car temperatures of about 10° to 12° F. It is important to note that the ratio of weight of salt is expressed in percentage of the weight of ice alone and not of the total weight of salt and ice combined.

When the bunkers are loaded with salt and ice, the amounts of salt used should be varied as is shown in table 1, otherwise a mixture of 30 percent salt in the lower part of the bunker will result in excessive waste, owing to large quantities of salt falling through the grating.

Table 1.--Mixtures of salt and ice used in bunker sections

| Bunker section | Percent of salt 1/ |
|---|---|
| Bottom quarter | 20 |
| Second quarter | 15 |
| Third quarter | 20 |
| Top quarter | 30 |

1/ Weight of salt is expressed in percent of weight of ice.

## Overhead-Bunker Car

The overhead-bunker car is the standard salt-ice type of refrigerator railroad car used in Canada for the transportation of frozen and perishable products. This car is somewhat similar to the end-bunker car used in this country except that the ice bunkers are located in the roof of the car rather than in the ends of the car. The location of the bunkers in the roof permits natural circulation of air between the products and the bunkers, whereas in the end-bunker car, the circulation of air is longitudinal, resulting in an excessive difference in temperature between the products at the top and at the bottom of the car. This temperature difference, however, has been decreased somewhat by the installation of fans. Since the inception of the first overhead-bunker cars, improvements have been made that have resulted in (1) more insulation, (2) air flues, (3) increased cooling surface on the bunkers, and (4) increased circulation of air within the cars.

The standard overhead bunker refrigeration car is approximately

40 feet long, has a capacity of 2,185 cubic feet, and has 4 to 5 inches of insulation on the floor, ceiling, and walls. Recently, cars 50 feet long with 6 inches of insulation have been made exclusively for the transportation of frozen foods.

The refrigerant is held in eight overhead containers, which are called brine tanks and which are located between the roof and the ceiling of the car. The tanks are of steel with a corrugated surface on the outside. This corrugation increases the effective cooling area on the sides of the tanks, resulting in more efficient transfer of heat between the air and the refrigerant in the tank. Each brine tank has a row of holes in the sides, which serve as an overflow for excess brine. With this provision for overflow, it is possible to maintain the correct level of brine in the tank at all times. The inside walls and ceiling of the car are generally constructed of plywood so arranged that an air flue is formed under the brine tanks and down the side walls of the car. These flues are lined with metal to allow drainage of the brine overflow from the brine tanks. The floor is protected by a waterproof cover and has four drains through which the brine overflow passes. The ceiling is made in two partitions running longitudinally with a space in the center between each partition. The partitions are pitched toward the side walls in order to carry the brine overflow from the brine tanks. Products are placed on floor racks constructed of corrosion resistant steel transverse stringers with longitudinal wood slats. These floor racks allow air circulation between the load and the 1½-inch-thick matched flooring. The warmer air around the products rises into the opening in the center of the ceiling and into the metal-lined air space between the ceiling and the brine tanks. The air "scrubs" the corrugated surface of the brine tanks, where it is cooled. The cold air then flows down in the side-wall flues on both sides of the car, under and up through the slats in the floor racks around the products, and up to the ceiling again.

Ice can be used for transporting perishable products at temperatures of about 40° F. To obtain lower temperatures suitable for frozen fish and other frozen products, however, a mixture of 30 pounds of salt for every 100 pounds of ice is generally used in the brine tanks. This mixture will maintain temperatures of the products within the car at 5° to 10° F. Tests conducted by the Canadian government indicated that, by the use of a mixture consisting of 25 pounds of salt, 12½ pounds of ammonium nitrate, and 100 pounds of ice, temperatures can be obtained that are 7 degrees lower than those possible in the conventional overhead-bunker car using ordinary salt and ice. Subsequent road tests, however, showed that the use of ammonium nitrate increased the amount of ice used by 16 percent and the cost of refrigeration by 50 percent. This refrigerant therefore has not proved acceptable for commercial use.

Before the car is loaded with frozen fish, the bunkers should be filled to their full capacity of 8,000 pounds with a mixture of 30 pounds of salt to 100 pounds of ice. After the car has reached the operating temperature (5° to 10° F.), the frozen products should be loaded and the bunkers should be re-iced. The bunkers then should be re-iced periodically during transit.

The advantages of the overhead-bunker car as compared with the end-bunker car are (1) the overhead-bunker car will produce lower temperatures (5° to 10° F.); (2) it will reduce the variation in temperature within the car; (3) it has approximately 22 percent more available cargo space; (4) it is approximately 1,500 pounds lighter in weight; and (5) it does not require fans to obtain proper circulation of air.

The disadvantages of the overhead-bunker car as compared with the end-bunker car are (1) it has a higher initial cost and a higher maintenance cost, and (2) it requires greater time and labor for the re-icing of eight hatches instead of two. These disadvantages are the main reasons for the limited use of the overhead-bunker car in this country, where frequent re-icing is necessary because the ambient temperature here is higher, on the average, than it is in Canada.

## Mechanical Car

The demand for zero and sub-zero temperatures for frozen foods during transit and the inability of a salt-and-ice refrigerant to produce these temperatures has resulted in the development of a low-temperature refrigerated railroad car utilizing the basic compression system. The compression system has been used almost universally in cold-storage and industrial plants for many years prior to its adoption for refrigerated railroad cars. The large number of available salt-ice bunker cars, the aversion to change, and the many engineering and operational problems peculiar to this type of carrier, however, are some of the reasons why the mechanical-compression system has not been adopted for use in this type of carrier until recently.

### Problems that Affected the Design of Mechanical Cars

Many problems were solved in the development of the present-day mechanical refrigerator car. To discuss all of them would prove too lengthy. This discussion therefore will deal only with some of the major problems such as (1) power for the refrigeration unit, (2) maintenance of low temperatures, and (3) dependability and maintenance of equipment.

Power for refrigeration unit.--It is sometimes necessary to hold a railroad car for a long time before it can be unloaded. In the operation of the refrigeration unit, it therefore is not practical to obtain the motivating power by means of a direct-driven axle system or an electrical system depending on axle generators or batteries charged by axle generators. The use of steam also is not practical because of its limited use in railroads today. Because of these limitations, an independent power supply capable of operating the unit under all conditions had to be employed.

The gasoline engine and the diesel engine were tried, and the latter proved more satisfactory because of its greater reliability and cheaper fuel costs. Another serious disadvantage of the gasoline engine was the fire hazard involved in handling and storing the gasoline.

The standard drive unit used in most refrigerated railroad cars consists of a diesel engine driving a 3-phase direct-connected self-excited alternator. The generated electric power runs the motors driving the compressor and the fans used for circulating the air. This system is also versatile inasmuch as the diesel engine can be shut down, and the power for compressor and fans can be obtained from an electrical system in the freight yard or processing plant when the car is standing for pre-cooling, loading, or unloading.

Maintenance of low temperatures.--If low temperatures are to be obtained, the capacity of the refrigeration unit must be adequate, the air must be properly distributed, the coils must be maintained relatively free of frost, and there must be sufficient thickness of insulation.

With a mechanical refrigeration compressor being used, capacity was no problem. Two 5 hp. air-cooled condensing units took up less space and were lighter than the ice needed in bunker cars. A system designed to precool the cars in 10 to 16 hours produced 2.5 tons of refrigeration at a car temperature of -10° F. (figures 7 and 8).

During the early period of development of the mechanical refrigerator car, the method of circulating the air was a problem.

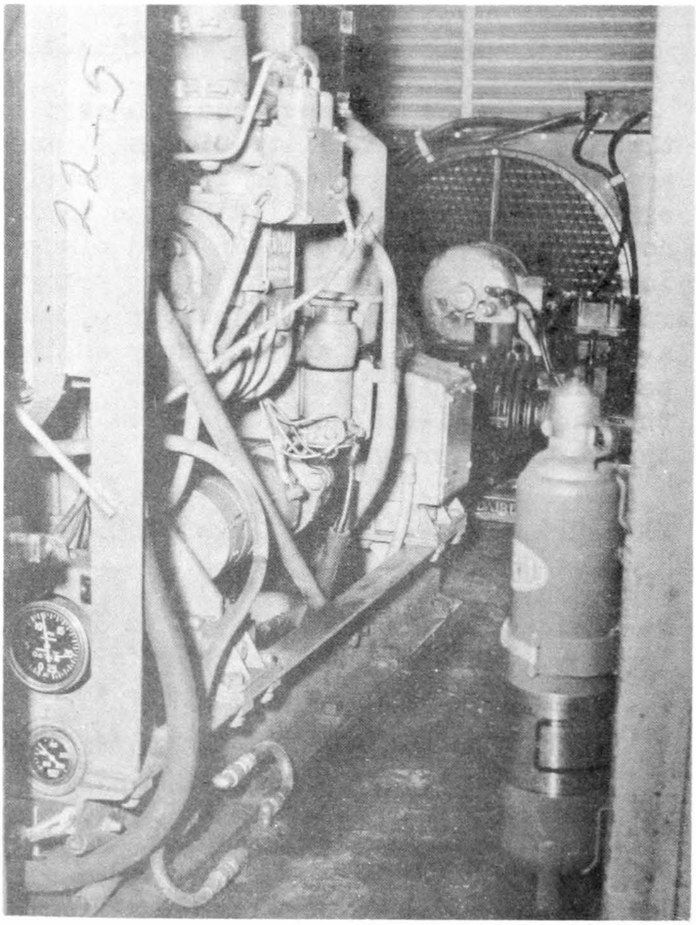

Figure 7.--View of diesel engine and compressors used in a mechanical refrigeration system on a refrigerated railroad car. (Photo courtesy of Pacific Fruit Express Co.)

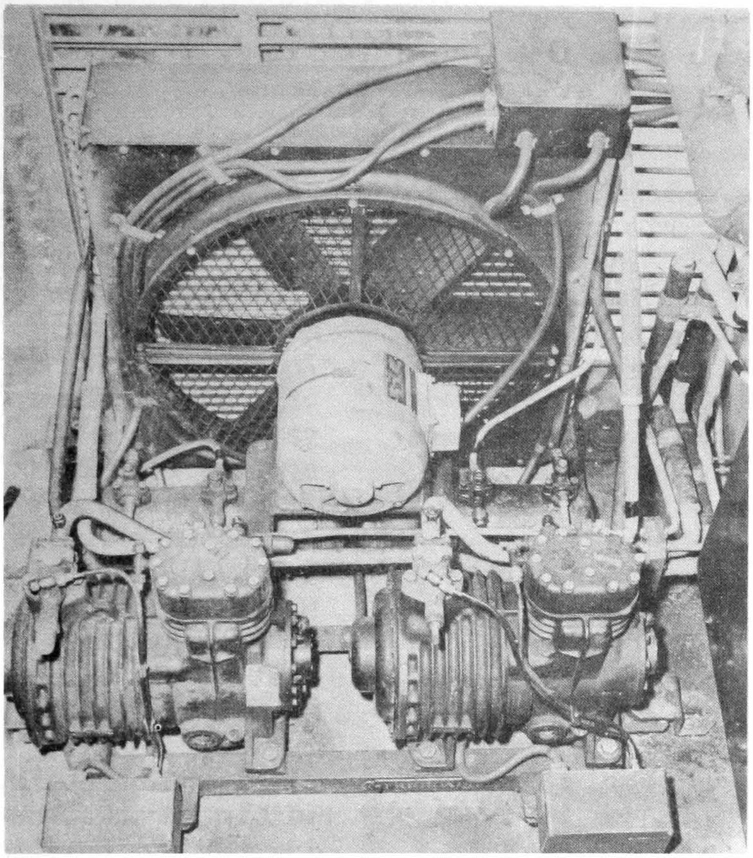

Figure 8.--View of two compressors and condensing units used in a mechanical refrigeration system on a refrigerator railroad car. (Photo courtesy of Pacific Fruit Express Company)

The use of wide-finned cooling coils, forced circulation of air, and the complete envelope system of air ducts in walls, ceiling, and floors of the cars, however, has now made it possible to hold the variation in the temperature of the product to within 2 degrees. (For details of the envelope system, see "Modern Low-Temperature Mechanical Car" in this section of the leaflet.)

The defrosting of the cooling coils was another problem. Some of the early mechanical refrigerator cars used closely finned cooling coils with automatic hot-gas defrost. This system necessitated frequent defrosting and was not completely reliable. Since then, electric heaters have been used, giving very satisfactory results. The recent use of wide-finned cooling coils (1-inch between fins) and the envelope system of air distribution have now eliminated the necessity of defrosting during trips as long as 15 days.

Insulation in a low-temperature refrigerator car hardly would seem to be a problem because for a long time prior to the inception of the mechanical refrigerator car, cold-storage plants had been kept at zero and sub-zero temperatures with 6 to 8 inches of insulation in walls, ceilings, and floors. Yet, for many years, the railroads did not follow accepted practice in using insulation sufficient for the temperatures encountered. Research, however, showed that the direct radiant heat from the sun and from the roadbed raised the surface temperatures of the car greatly above the ambient temperature. This research, along with a knowledge of the high ambient temperature to which the car is often subjected while in transit, resulted in (1) the use of light-colored paint or metal sheathing in order to reflect the rays of the sun and (2) an increase in the thickness of insulation. The mechanical refrigerator car now usually has 6 to 9 inches of insulation, and some of the cars that recently have been built have 7 to 12 inches of insulation.

The first mechanical cars employed cooling coils and fans located within the storage compartment. This system proved satisfactory for obtaining the desired temperature. The buildup of frost on the cooling coils and the saturation of the insulation due to air infiltration when the cars were being loaded and unloaded, however, were major problems. In the solution of these problems, various types of systems for distributing the air developed (figures 9 and 10), one of which is known as the envelope system. In this system, fans circulate cold air, over cooling coils, within a jacket between the insulation and the inside walls, ceiling, and floor of the car. The walls, ceiling, and floor thus act as cooling surfaces and provide the necessary refrigeration effect. The circulation of air within this envelope carries to the cooling coils any moisture that migrates through the insulation, thereby preventing frost from accumulating on the insulation. It is interesting to note that, in respect to the use of the envelope system, the railroads have forged ahead of the cold-storage plants in this country, almost all of which still employ overhead cooling coils. A number of cold-storage plants in

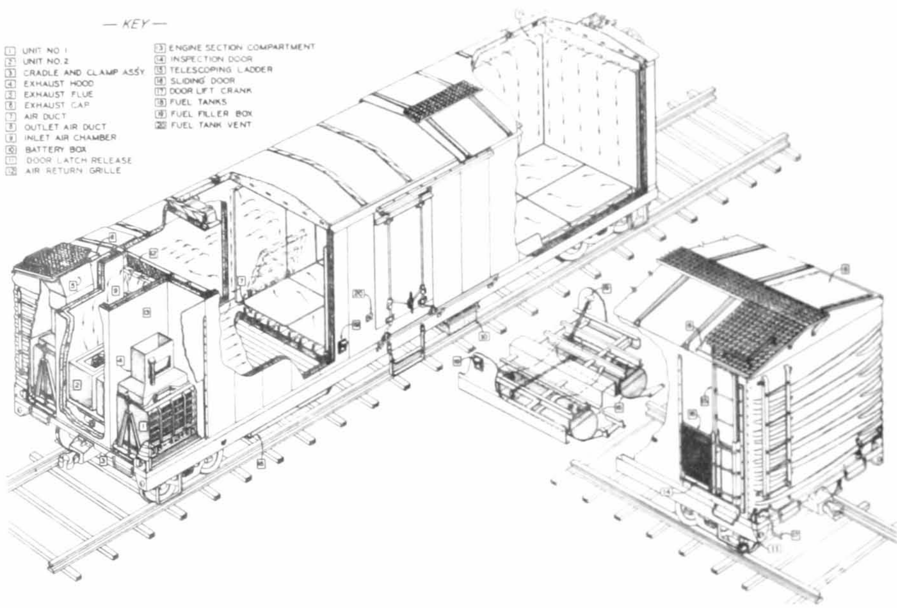


Figure 9.—A semi-"cold wall" refrigerated car. In this car, an air space is provided for the circulation of air between the walls and floor and the insulation of the car. The envelope system is similar to this one except that the cold air does not come in contact with the product but is circulated through an air space located between the walls, ceiling, and floor of the car and the insulation. (Photo courtesy of Industrial Refrigeration)

Canada, however, do use the envelope or jacketed system.

Figure 10.—Inside view of a mechanical refrigerated car. In this car, cold air circulated in a duct between the ceiling and the insulation, by fans, enters the product storage space through holes located in the ceiling. (Photo courtesy of Santa Fe Railroad)

<u>Dependability and maintenance of equipment</u>.—Refrigeration equipment similar to that now used in mechanical refrigerator cars has proved to be rugged and dependable in its long use in commercial cold-storage and industrial plants and, with the aid of a few simple controls, to be capable of automatic operation. The manufacturers of refrigerated railroad cars, however, still were not completely satisfied as to the dependability of this refrigeration equipment when subjected to considerable vibration and shocks and to long periods of operation with little attention. Consequently, most mechanical refrigeration cars have two complete refrigeration systems so that, in the event of a breakdown of one unit, the other will automatically start up and take over the load. The units are located within a separate compartment and are installed in such a way that they can be removed quickly. Engine and temperature controls are located outside the car, so that the operating conditions within the car can be determined at a glance. These controls are periodically checked during transit, greatly reducing the danger from breakdown. Some of the present mechanical refrigeration cars have been operated for periods of 10,000 hours, or more, without major overhaul.

## <u>Modern Low-Temperature Mechanical Car</u>

A more recent development in the transportation of frozen foods is a mechanical refrigerator car employing the envelope or jacketed system. This car is especially suited for the transportation of frozen fish either in the round or in packages. Tests conducted by the Canadian government on fish stored in a freezer employing a jacketed system showed that losses from dehydration were greatly reduced. Also, very little defrosting was required because, once the cooling coils within the jacket have drawn the moisture out of the air, there is no pickup of frost. The following is a description of a mechanical car employing the jacketed system:

The typical car is about 50 feet long, which is 10 feet longer than the standard end-bunker car, and has a carrying capacity of approximately 128,000 pounds of lading. By a simple adjustment of a thermostatic temperature control, the temperature within the car can be fixed at any desired point ranging from 70° F. to below zero. Insulation 6- to 9-inches thick is used on the floor, walls, and ceiling. The inside walls and ceiling are built of plywood, and the floor is built of tongue-and-groove boarding. The car is so constructed that an air space is formed between the insulation and the inside walls, ceiling, and floor of the car.

The refrigeration effect is provided by fans forcing cold air at the proper temperature into the air space between the ceiling and the insulation, then down into the air space between all four walls, under the floor, and back to the cooling coils, where it is recooled to the proper temperature. The cycle then starts again.

Two complete refrigeration units consisting of diesel-electric generator sets, Freon 12 compressors, cooling coils, fans, and necessary component parts are located in an insulated compartment at one end of the car. An electric heating element mounted on the cooling coil and operated by means of automatic controls insures a frost-free coil. The machinery compartment can be serviced by means of a door that opens to the outside of the car. The fuel tanks are suspended under the floor and have a capacity sufficient for a trip from coast to coast. A car of this design can be precooled from 70° F. to 0° F. in 10 to 16 hours. The initial cost of this type car is slightly higher than that of the type that utilizes a cooling coil and blower circulating air directly over the products. The added advantages, however, of constant air temperatures, little defrosting, maintenance of high humidity, and prevention of the accumulation of moisture in the insulation have more than offset the slightly higher initial cost.

## Comparisons between Mechanical and Salt-and-Ice Bunker Cars

There are over 125,000 ice-bunker cars and over 1,000 mechanical cars now in use in this country. Mechanical cars are still rolling off the production lines, but whether they eventually will replace the bunker car for all types of services is not determinable at present. There is little doubt, however, that the mechanical car will replace, within a very few years, the bunker cars used in frozen-food transportation because bunker cars cannot obtain the low temperatures necessary to insure adequate quality of the frozen product. A cost study now in progress by some of the car manufacturers and railroads will soon establish the economic feasibility of the mechanical refrigeration car for the transportation of nonfrozen products.

The following is a summary of the known advantages and disadvantages of the mechanical car in comparison with the standard salt-and-ice end-bunker car.

The advantages of the mechanical refrigeration car are that it:

1. Can maintain temperatures from 70° F. to below zero.
2. Can maintain high humidity, thereby preventing excessive dehydration of fish and other products.
3. Has approximately 20 percent more space for revenue load.
4. Is approximately 10,000 pounds lighter.
5. Can be precooled from 70° F. to 0° F. in 10 to 16 hours, whereas an end-bunker car cannot be precooled in much less than 24 to 48 hours.
6. Does not require icing and re-icing. Considerable labor and time are saved thereby.
7. Will last approximately twice as long as an end-bunker car because the corrosive effects of salt have been eliminated.
8. Is heavily insulated, resulting in considerably less rise in the temperature of the product from lack of refrigeration.
9. Is so constructed that the operating conditions and temperatures within the car can be readily determined by gauges, thermometers, and controls located outside the car.
10. Has less danger of spoilage of product during transit because it is not dependent upon being re-iced at regular intervals.
11. Has a standby refrigeration unit that can be used in event of a breakdown of the primary system.

The disadvantages of the mechanical car are that it:

1. Has approximately twice the initial cost of that of an end-bunker car.
2. Represents too large an investment to be used as a nonrefrigerated freight car.
3. Like all mechanically operated equipment, is subject to possible (though highly unlikely) breakdown, which could result in the loss of an entire carload of produce.
4. Must be periodically inspected and serviced.
5. Requires trained personnel for this inspection and servicing.

## TRUCK

### History

The development of the refrigerated truck was similar in many ways to that of the refrigerated railroad car, whereas in other ways, it differed. It was similar, inasmuch as practically the same methods of furnishing the necessary refrigeration effect were tried, with some being discarded and others being improved upon throughout the years. The development of refrigerated trucks, however, differed from that of refrigerated railroad cars, owing to the fact that the size of the railroad car was more or less standardized, whereas the size of the truck varied considerably, depending on the particular service.

In the late 1800's, open trucks were used to transport fish over short distances from the fishing plant to the processing plant or from the processing plant to the local market, whereas fish to be transported over longer distances were packed with ice in wooden boxes and shipped in railroad cars.

In the early 1900's, some truck bodies were insulated in order to reduce the entrance of heat from the surrounding atmosphere. This use of insulation made it possible to transport frozen fish satisfactorily without refrigeration for comparatively short distances. While the design of trucks was progressing, the conditions of the roads also were being improved. The use of trucks for shipments of frozen foods over long distances, directly from processor to market, then became possible and the development of the refrigerated truck began.

The first refrigerated trucks were insulated with cork, kapok, or balsa wood and were cooled by a mixture of ice and salt located in end bunkers or overhead brine tanks within the truck body. The end-bunker system used was similar to that previously described in the section on refrigerated railroad cars. An overhead brine-tank system widely used was known as the automatic brine circulation system. The brine tank employed in this system was similar to a heat exchanger with tubes running lengthwise through it. The ice and salt, which were added by a hatch located in the roof of the truck, cooled the outside surface of the tubes. The air within the truck circulated through these tubes, where it was cooled to the proper temperature.

In the early use of dry ice as a refrigerant in trucks, the dry ice was stacked on top of the boxes of fish, just as it was in the railroad car. By 1928, however, an improved system was developed. In this system dry ice was placed in overhead containers with ducts leading from them. The carbon dioxide gas (given off by the dry ice) passed through these ducts and was released over the product, thereby providing the necessary cooling. Another system that was developed at about this time was similar to the one mentioned above. It consisted of dry ice contained in a metal-lined compartment in the front part of the truck body. The natural circulation of air over the cold surfaces of the compartment and the carbon dioxide gas emerging from the ducts leading from the compartment provided the necessary refrigeration effect.

The first mechanical refrigerated truck was developed in 1925, using a motor-driven methyl chloride reciprocating compressor. The power to the motor driving the compressor was supplied by a generator driven from the drive shaft of the truck engine. A separate motor coupled to the compressor could be plugged into an electrical outlet to supply the power when the truck was in the garage. The refrigeration effect was accomplished by the expansion of the methyl chloride through overhead coils located within the body of the truck. During this same period, a silica-gel system similar to that used in refrigerated railroad cars was developed for a refrigerated truck. This truck, although capable of obtaining temperatures of about 15° F., was unsatisfactory because of high costs and difficulties of operation. The silica-gel truck, however, was one of the first super-insulated carriers having a thickness of 5-3/4 inches of kapok on the floor, ceiling, and walls.

The improvements in roads and in motor trucks during the late 1930's and early 1940's revolutionized truck transportation. Extensive research conducted by industry and government resulted in the development of high-speed super-insulated refrigeration trucks capable of transporting frozen fish from coast to coast at temperatures below zero.

In the fishing industry, a processor finds it difficult to predict the amount of fish that can be shipped on a definite date because the supply of fish is dependent upon many indeterminate factors, such as the abundance of fish and the weather. Thus, railroad cars often were used at less than full-load capacity, resulting in higher costs of transportation per pound of fish.

This need for flexibility in the transportation of frozen fish coupled with the improvements in refrigerated trucks and the fact that large companies could lease or operate their own trucks led to the increased use of refrigerated trucks for transportation of frozen fishery products. Today, considerable quantities of fish are transported by refrigerated trucks from vessel to processor, then from processor to cold storage, and finally from cold storage to the various markets within the country. The refrigerated truck has indeed played no small part in the wide, flexible transportation system that now is used to distribute frozen fish.

The modern refrigerated truck varies considerably in size, depending on the required capacity. Most refrigerator trucks are cooled by a dry-ice or a mechanical refrigeration system. Some trucks are still being cooled by a mixture of ice and salt. Because this system is very similar to that previously described for railroad cars, however, and because it is not suitable for maintaining zero temperatures, it will not be discussed here. The following is a description of the dry-ice and mechanical refrigeration systems used in large modern refrigerated trucks.

## Dry-Ice Refrigerated Trucks

Dry ice, when first used to furnish the necessary cooling in motor carriers, was placed in boxes located directly over the products. This method of application resulted in uneven temperatures of product, high costs of handling, and high costs of dry ice. To reduce these disadvantages, the manufacturers developed dry-ice systems providing efficient heat transfer between the dry ice and the air within the storage compartment. Inasmuch as these systems are similar in principle and application to those mentioned previously in dry-ice railroad cars, the following will be concerned only with a description of the overhead-bunker, the end-bunker, and the indirect systems, which are the principal dry-ice systems used in refrigerated trucks.

Overhead Bunker

In the overhead-bunker system, the necessary refrigeration effect is provided by blocks of dry ice contained in a receptacle built into the ceiling of the truck body. This receptacle is loaded through a hatch in the roof of the truck and is insulated on all sides except for the bottom surface. The bottom of this receptacle consists of a metal plate, which forms the effective heat-transfer surface. In small trucks, natural circulation of air over this exposed plate is sufficient. In large trucks, however, one or more fans must be used in order to insure even temperature of product during transit.

This system, although capable of producing temperatures of 0° F. and lower during transit, with a minimum amount of added weight, has the disadvantage of (1) excessive handling of dry ice during loading and (2) small area of heat-transfer surface.

Removable dry-ice bunker units with capacities of 50 to 200 pounds of dry ice have recently been developed. These units are rectangular in shape, are constructed of corrosion-resistant metal, and are supported by metal brackets attached to the ceiling of the truck.

A thermostatically operated fan located at the end of the bunker unit provides the refrigeration effect by circulating the air in the storage area over the blocks of dry ice. The dry ice is added to the bunker by means of a sliding door located at one end of the unit.

The removable dry-ice bunker offers the advantage of low initial cost, low power requirements, easy replacement of dry ice, and maintenance of nearly constant temperatures (figures 11 and 12). The cost of replacing dry ice in transit and the limited supply of dry ice in some areas,

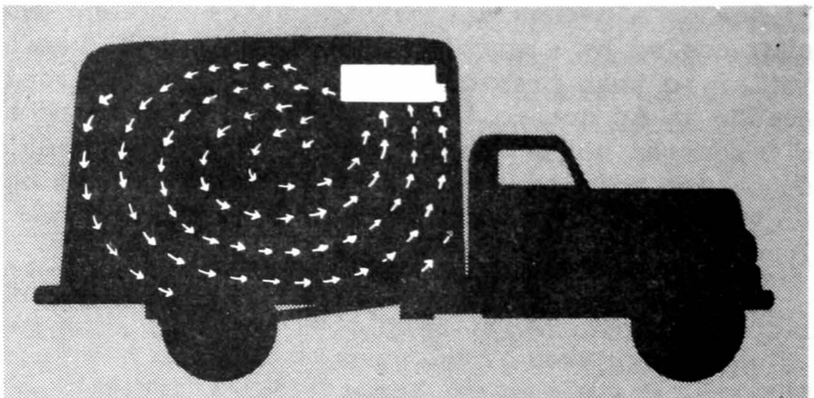

Figure 11.--Circulation of air in a truck refrigerated by a removable dry-ice bunker. (Photo courtesy of Foster-Built Bunkers, Inc.)

however, are disadvantages that must be given consideration.

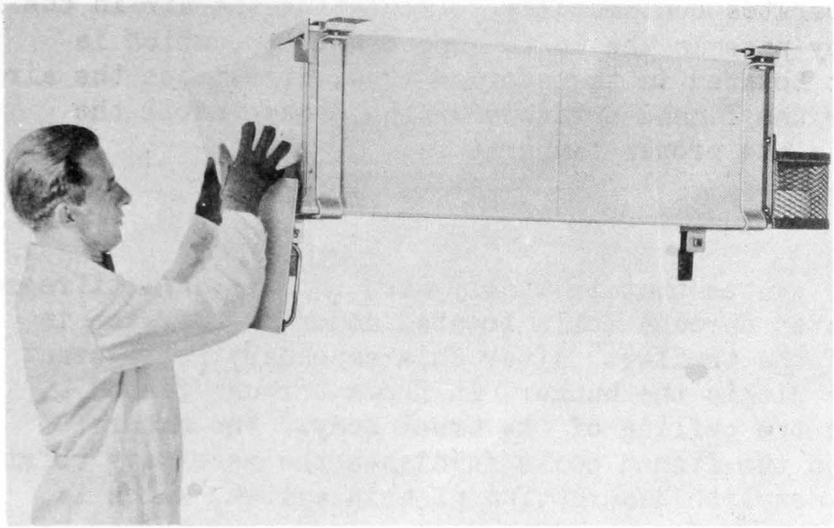

Figure 12.--Loading a removable dry-ice bunker with dry ice. (Photo courtesy of Foster-Built Bunkers, Inc.)

End Bunker

A system in which dry ice in an aluminum bunker located in the front of the truck body provides the refrigeration effect has proved successful in tests conducted by the Department of Agriculture (Johnson and Garrity 1953). The basic unit of this refrigeration system is a welded aluminum ice bunker, with a capacity of 900 pounds of dry ice (figure 13). The exterior surface of this bunker is made up of fins in order to increase the effective surface for the transfer of heat. The dry ice, after being loaded into the bunker through an access door, is placed on aluminum shelves that are welded to the aluminum metal forming the sides of the bunker. The carbon dioxide gas, which is released in the sublimation of the dry ice, is vented to the cargo space or to the outside by means of suitable valves.

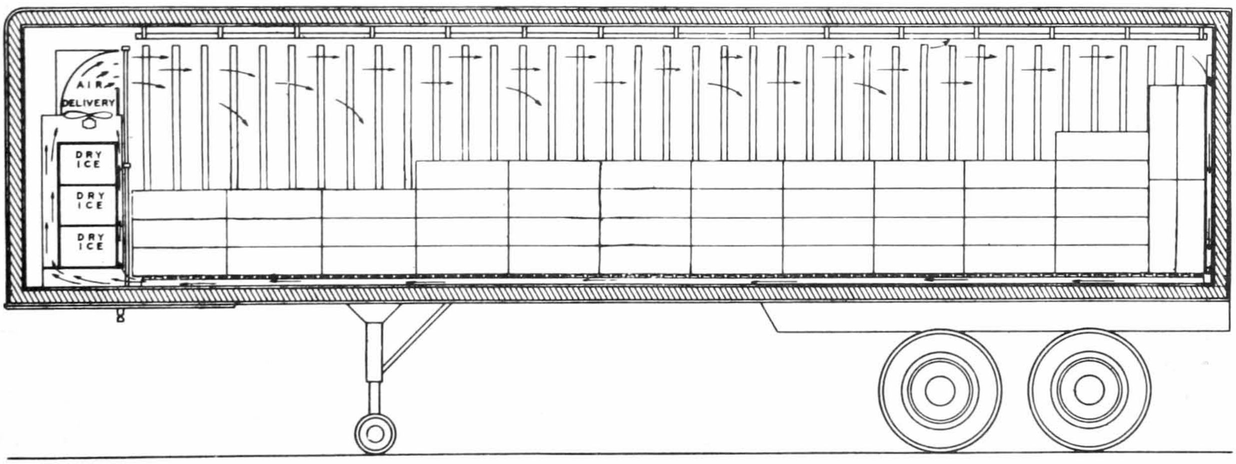


Figure 13.--Drawing of a trailer truck refrigerated by an end-bunker dry-ice system. (Photo courtesy of U. S. Department of Agriculture)

Two blower fans located above the bunker provide for the circulation of air. One fan operates continuously, circulating the air in the storage area through a by-pass in the unit. The other fan, which is operated by a thermostat located in the storage area, circulates the air in the storage area over the finned surfaces of the bunker until the storage area is cooled to the proper temperature.

Indirect Dry-Ice System

An indirect dry-ice system that is widely used employs an antifreeze solution that is circulated through coils located under the dry ice in a bunker at the front of the trailer. After this secondary refrigerant is cooled by the dry ice within the bunker, it flows through finned cooling coils located in the ceiling of the truck body. The natural circulation of air around the finned coils furnishes the necessary refrigeration effect. (For a complete description of this system, which is similar to that used in some refrigerated railroad cars, see "Dieco System" in the section on refrigerated railroad cars.) This system is capable of maintaining temperatures of -10° F. Its advantages are fast precooling and the maintenance of even temperatures of product during transit. Some of the disadvantages of this system are the labor necessary to load the dry ice and the cost of replenishing the dry ice during transit.

## Mechanical Refrigerated Trucks

The problems encountered in the application of a basic mechanical refrigeration system to a truck were similar to those in the development of the mechanical refrigerated railroad car and therefore need not be discussed here.

The mechanical refrigeration system used in present-day refrigerated trucks consists, in general, of a compressor, which is driven off the truck engine or by an independent gasoline engine, connected by suitable piping and valves to an evaporator consisting of refrigerated plates, finned pipe coils, or a blower-type unit cooler located within the food-storage compartment of the truck.

One type of mechanical refrigeration system that is widely used both in small and in large refrigerated trucks consists of a unit cooler and fan, compressor, air-cooled condenser, internal combustion engine, and the necessary piping and valves, all of which are contained in a single housing located at the front of the trailer body (figure 14). In this system, the unit cooler and fan are located inside the storage compartment, and the compressor, condenser, and internal combustion engine are located outside the trailer.

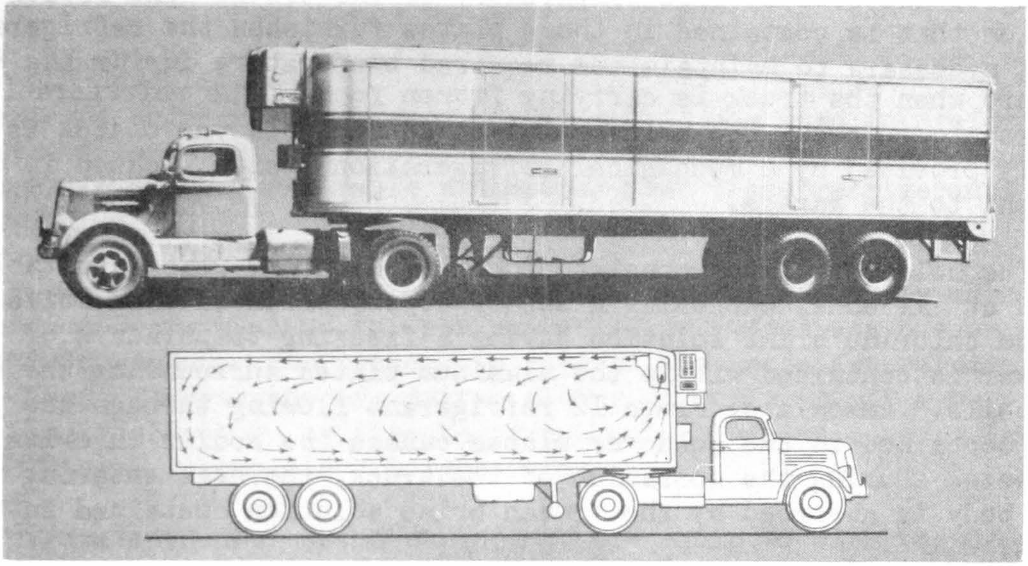

Figure 14.--A truck with a mechanical refrigeration system. Cross-sectional view shows air circulation within the trailer. (Photo courtesy of U. S. Thermo Control Co.)

Another type of mechanical refrigeration unit which is widely used, consists of a compressor, condenser, and internal combustion engine located underneath the trailer and an evaporator, consisting of a fan and unit cooler, located in the nose of the trailer.

In some mechanical refrigeration units,power for operation of the compressor is obtained from the main engine by direct mechanical drive through suitable belting, or clutch arrangement, or by an alternating-current generator delivering power to an alternating-current motor. In general, however, methods utilizing the power of the truck engine for the operation of the compressor are not as satisfactory as are those employing a separate power supply, such as an internal combustion engine. The need for the separate power supply is due to (1) the difficulty in maintaining the proper capacity of the compressor at variable truck speeds, (2) the possible overloading of the engine of the truck under extreme conditions, (3) the possible damage to the product in event of trouble with the truck engine, and (4) the need for an additional power supply to keep the refrigeration system operating when the truck is inoperative. This latter problem has been solved, at least in part, by the installation of electrical outlets for furnishing electrical power to the compressor motor when the truck is at the cold-storage warehouse.

Small refrigeration trucks that are employed for making local deliveries of fish and other frozen foods ordinarily use a frozen eutectic calcium chloride brine solution contained in holdover plates attached to the ceiling of the food-storage compartment of the truck. The frozen brine solution that is contained in these plates furnishes the refrigeration effect necessary to maintain the required temperature during the 8 or 12 hours when the truck is carrying frozen food. The refrigeration required to refreeze the brine solution in the holdover plates is usually provided by a mechanical refrigeration system located in or adjacent to the garage.

The holdover plates consist of hollow aluminum plates suitably sealed at all ends, enclosing a set of copper or steel pipe coils. A calcium chloride brine solution having a freezing temperature of -6° F. or lower is contained within the aluminum plates surrounding the enclosed pipe coils. Ammonia or Freon 12 refrigerant flowing through the pipe coils contained in the holdover plates causes the sodium chloride brine to freeze. During the operation of the truck, the heat entering the truck body is absorbed by the frozen brine solution contained in the plates.

Trucks employing holdover plates must operate on a definite schedule in order that the frozen brine contained in the plates will not melt completely while the produce is being shipped. Generally, trucks employing this system operate locally from a plant where refrigeration facilities are available. The availability of these facilities enables the operator to connect the plant refrigeration system to the plates and refreeze, for the next day's operation, the eutectic solution contained in them.

Some trucks with holdover plates also use a mechanical refrigeration unit. This use permits the plates to be recharged in transit when the truck is empty or operating under light loads and provides extra refrigeration capacity when the heat load is excessive.

## SHIP

Millions of pounds of fish and other frozen foods are transported yearly by cargo ships that have either partly or totally refrigerated space throughout. The application of refrigeration to cargo ships has lagged only slightly behind the development of cold-storage plants ashore. The first such use of mechanical refrigeration took place in 1879 in the transportation of frozen meat from Australia to Great Britain on a British ship that was refrigerated by a cold-air machine. Today, practically every ocean-going vessel is equipped with a mechanical refrigeration plant for holding perishables in the ships stores or in the refrigerated cargo space, or in both.

Except for some minor changes, the basic refrigeration plant used on ocean-going vessels is very similar to the plants found in cold-storage warehouses ashore (Fishery Leaflet 427, section 2). The following will be concerned, therefore, with a discussion of the "high-side" and the "low-side" equipment found in many ocean-going vessels today, inasmuch as this equipment differs from that used in the shore cold-storage plants.

## High-Side Equipment

The freon refrigerants (Freon 12, Freon 11) are used in preference to ammonia on cargo vessels operating under the American flag because of the nontoxic and other desirable properties that these refrigerants afford.

Ships with partly refrigerated space consisting of one or more small cargo holds or merely space for perishable ships stores use one or more Freon 12 refrigerating compressors to furnish the necessary refrigeration effect. These compressors are driven either directly or off a belt drive by an alternating- or direct-current motor that is powered from a steam- or diesel-driven electric generator.

Refrigerating compression units that are equipped with the necessary automatic controls maintain temperatures of 0° F. to 35° F. satisfactorily in the refrigerated spaces on the vessel in much the same manner as in a small cold-storage plant. Two-stage compression units are used if low temperatures of -10° F. or lower are required. In some vessels, Freon 22 is used in lieu of Freon 12 for low-temperature food storage.

Centrifugal compressors are found in large ocean-going vessels, where compression units of over 100 hp. must be used to obtain the required refrigeration capacity. These units, which use Freon 11, are especially suited for marine service because of (1) the large steam supply available, (2) the small space required, (3) the high operating efficiency, and (4) the minimum amount of wearing parts in the compressor. (More information on the centrifugal compressor is contained in Fishery Leaflet 427, section 2 of this series.)

## Low-Side Equipment

The cargo holds of refrigerated vessels are cooled by evaporators consisting of blower-type unit coolers, pipe coils, or refrigerated plates. The use of blower-type unit coolers employing a direct-expansion Freon 12 refrigeration system is preferred to the use of pipe coils or refrigerated plates because of (1) the wide range of temperatures that can be obtained, (2) the ease of defrosting, and (3) the small amount of space required. Blower-type unit coolers, if used, generally are connected to a duct made out of a corrosion-resistant metal. This duct allows the distribution of the cold air in such a manner as to form a "blanket" around the top, bottom, and sides of the stored product.

A method of cooling the cargo hold, which has found some success, consists of pipe coils, cooled by Freon 12 or brine, enclosed between the insulation on the sides of the compartment and a metal baffle. A fan attached to the ceiling of the storage compartment passes air at low velocity down over the cooling coils lining the walls, under the floor gratings on which the products rest, and up by the products to the fan suction. The cycle is then repeated. A hot-gas defrost is used if a direct-expansion refrigeration system is employed, and warm brine is used if a brine system is employed.

## AIRPLANE

The quantities of fishery products that are shipped by air are very small in comparison with the large amounts that are shipped in refrigerated railroad cars or in refrigerated trucks. The principal reasons for this large difference are (1) the higher cost of air transportation; (2) the fact that frozen fish, if kept under refrigeration, have a comparatively long storage life, and quick transportation at a high cost therefore has little merit; (3) the lack of refrigerated space in the airplane; and (4) the reluctance on the part of air lines to transport any frozen items refrigerated by dry ice or an ice that gives off a free liquid upon melting. For these reasons, the general transportation of fishery products by air, particularly frozen fish, is not now of great economic significance, nor is it likely to be in the immediate future.

The transportation by air of some of the more highly perishable fishery products--such as live lobsters, oysters, and fresh fish fillets--is, however, of commercial significance and is increasing from day to day. In the transportation of these fishery products by air, the comparatively short period of time in transit makes it possible to obtain fish of high quality, within hours after they have been landed by the fishing vessel. With such products, the increased cost of transportation is justified because if the other more common methods of transportation were used, it would be difficult and almost impossible to obtain the high quality desired, owing to the long period of time during shipment. (Information on packaging and handling fresh fish for shipment by air is given in Fishery Leaflet 428.)

## INSULATED CONTAINERS

Prior to the introduction of refrigerated railroad cars and trucks capable of maintaining temperatures of 0° F., frozen fishery products often were packed into insulated containers with suitable amounts of dry ice and were shipped via truck or railroad express to the markets throughout the country. The quantities of fishery products transported by this method were relatively small because of (1) the high shipping costs per pound of fish, (2) the extra handling involved, and (3) the limited time that the low temperatures could be maintained during transit.

As was pointed out previously, the development of low-temperature refrigerated carriers made it possible to ship large quantities of frozen fish, without the need of special insulated cartons containing a supply of refrigerant, to markets throughout the country. This development greatly decreased the use of insulated containers for transporting commercial lots of frozen foods. The insulated containers are, however, still used to transport small quantities of frozen foods, which may be required for laboratory tests or by restaurants in remote locations.

Several types of shipping containers are available (figure 15). These containers are heavily insulated with cork, balsa wood, or other material. A refrigerant such as dry ice placed in the container before shipping therefore ordinarily ensures adequate frozen-storage temperatures in transit. These containers, because of their cost, must be returned after each shipment. Consequently, some types of insulated containers are made in a collapsible form so as to require less storage space when returned empty.

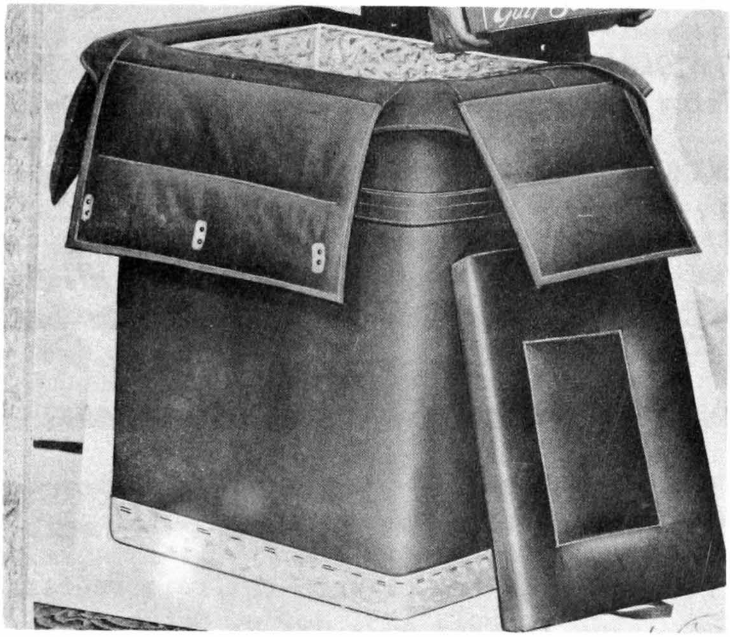

Figure 15.--An insulated container for shipping frozen foods. (Photo courtesy of Can-Pro Corporation)

From time to time, packers of frozen fishery products develop their own insulated containers for making shipments. One type is a low-weight low-cost throw-away container in which fiberglass insulation is used and is said to keep the frozen food in good condition for periods up to 24 hours without use of ice (Anonymous 1949a). The container consists of a double paperboard box encasing 1-inch-thick insulation on the sides and top and 2-inch-thick insulation on the bottom. This particular container was designed to hold 50 pounds of shrimp. Other insulated shipping containers constructed along these same lines but using different insulating materials have been reported. Several cartons wrapped in insulated pads or blankets with dry ice and placed in a corrugated shipping container is an adaptation used for shipping frozen foods. Large shipments, for example, of frozen clam meats are made in this manner.

A new method being tested for shipping frozen foods is one employing an insulated aluminum container requiring no additional refrigeration while in transit (Anonymous 1955). The container used in a shipping test was 7 x 7 x 7½ feet, with 6 inches of insulation between the aluminum liner and outer jacket. About 6,000 pounds of frozen food could be shipped in the container; liquid nitrogen was used to freeze the products to a temperature of -150° F. before the container was closed. The use of this container may result in less expense than that required for shipping by other refrigerated systems because no space is needed for refrigeration equipment or for salted ice.

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SECTION 2

# MARKETING OF FROZEN FISH

By Martin Heerdt, Chemist*

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## ILLUSTRATION



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## INTRODUCTION

Packaged frozen fish fillets were first marketed in the late 1920's to supply a demand for fillets in markets beyond the reach of the New England fresh-fillet industry. The demand for fillets was the impetus that marked the beginning of packaged frozen foods.

Prior to this time, frozen fish were simply sharp frozen and glazed to protect them from desiccation and from the development of rancidity. Fillets and steaks, which then were new market items, could not be handled like dressed fish because they were difficult to glaze and package. As a result, new packages, wrapping materials, and methods of freezing were developed.

During the early years, the sale of frozen fish was severely handicapped by the lack of marketing facilities. The greatest problems in developing these facilities were (1) the then current practice of retailing frozen fish in meat markets and (2) the lack of sufficient volume to warrant the development of separate marketing facilities for packaged frozen foods.

Some of the pioneers in the frozen-fish-fillet industry applied their experience with fish to the packing of other frozen-food products. As the quantity of frozen foods increased, these pioneers recognized a need for good marketing facilities if their products were to reach a nation-wide market, and some of them developed their own marketing organizations. These and other nation-wide marketing facilities for frozen fish and for frozen foods in general have enabled the fishing industry to grow tremendously.

This chapter does not attempt to cover the economics of marketing, the trends in marketing, or the relationships between packers, distributors, brokers, and wholesalers. Rather, it is concerned with the facilities and methods of wholesaling and retailing after the distributor has delivered packaged frozen fish to the warehouse of the wholesaler.

## WHOLESALE OPERATION

The cold-storage warehouse aids in the wholesale distribution of frozen foods, including packaged frozen fish, and serves as a place for storing these foods from one season to the next (Larson, Mixon, and Stokes 1949, 1950a, 1950b). Wholesalers receive their frozen foods either by railroad refrigerator car or by refrigerated truck from the warehouses of producers or distributors. Some wholesalers pick up their frozen foods with their own refrigerated trucks. Wholesalers who do not have their own warehouses usually rent refrigerated rooms in a warehouse for use as a working area in which frozen-food orders can be assembled and dispatched.

Frozen foods are wholesaled either on receipt of an order or directly from the truck as each trade outlet on a route is visited. Orders are assembled for delivery accordingly. If the food is sold in advance of delivery, each order is assembled as a separate unit and dispatched by a regular delivery truck. If the frozen food is sold from the truck as each retail store is visited, the truck is usually loaded with an assortment of merchandise, and the order is put up at the store. The small retail store that does not have adequate frozen-food-cabinet or storage space expects to receive service based on immediate needs.

The relative volume of frozen foods sold at large and at small food markets indicates that more sales are being made on receipt of an order in advance than are made at the store by the truck salesman. The trend therefore is toward large orders rather than toward small ones.

Exposure of the food to temperatures higher than the storage room should be as short as possible during the transfer of frozen foods from storage to the order-assembly room. Frozen foods that are held over from one day to the next in the order-assembly room should not be stacked against walls, ceilings, or directly on floors, as the product may absorb heat. Inventories should be limited to 1 week's supply, and there should be a complete turnover of the products in the room every week. Order-assembly rooms should be maintained at 0° F. and should be defrosted regularly to prevent loss of refrigeration efficiency.

The diagram on the next page (Larson et al. 1949) shows a possible layout for a frozen-food wholesale plant with an extra order-assembly room in the basement for the assembly of mixed cases only. As each customer's order comes to the assembly room, the items requested are listed on an order sheet. Items that require less than a full case are repacked with other items to make full cases. Containers are then marked with the customer's number that corresponds to his number on the order sheet. Each order, when assembled, is stacked carefully into tiers that will not fall and are marked clearly with a lot number to avoid loss of time and unnecessary opening of the truck doors when the order is loaded into the truck. Orders should not be placed on the loading platform until the truck is ready to be loaded. If the temperature of the order-assembly room is above 10° F., the orders should be made up promptly and returned to storage at 0° F., unless they are scheduled to be loaded immediately.

A more common type of order-assembly room has frozen foods in cases stacked on both sides of a conveyor belt running the length of the room and out onto the truck-loading dock. Cases destined for delivery are transported via the belt directly into the truck.

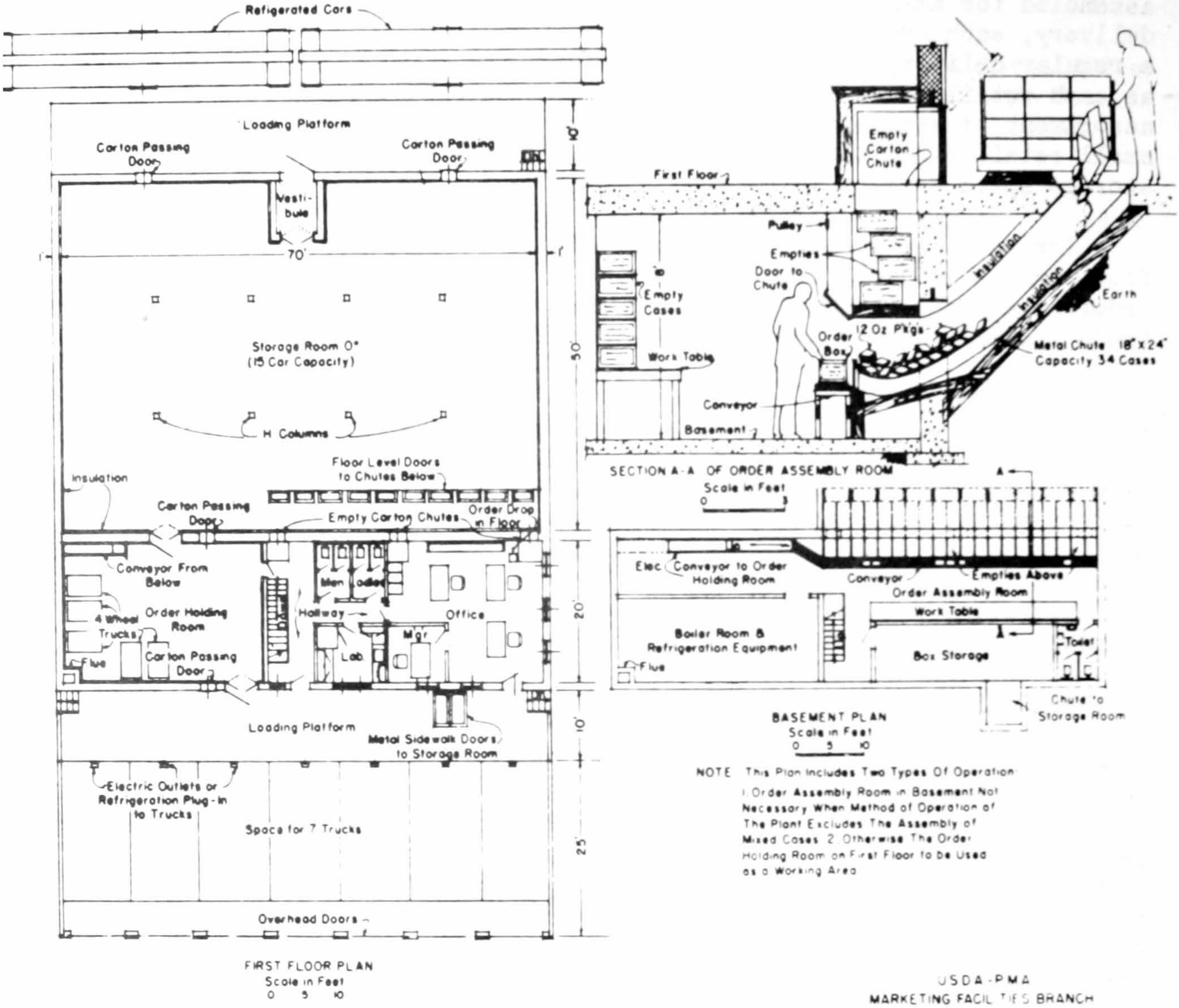


Figure 1.--Possible layout for a frozen-food wholesale plant.

## TRANSPORTATION OF FROZEN FISH FROM WHOLESALER TO RETAILER

Frozen fish products are delivered to small food stores in trucks of 3- to 5-ton capacity, and to food-market chain stores in trucks of 10-, 15-, or 20-ton capacity. Other frozen foods may be delivered along with the frozen fish. The amount of refrigeration provided in delivery trucks varies. Some retail stores may obtain their frozen fish products at wholesale, using nothing more than an open truck, with dry ice and an insulated blanket to protect the fish products. The standard practice with small lots of frozen fish, however, is to handle them in an insulated shipping box. If this box is used, it is precooled (held in a cold room until the temperature of the box drops to 0° F.). It is then filled in the order-assembly room and held at 0° F. until shipped. The filled box is usually charged with dry ice for all trips exceeding 12 hours' duration. On arrival at destination, the box is kept closed until the frozen fish can be transferred to storage at 0° F. Frozen fish are usually transported from wholesaler to retailer in trucks, but a relatively small amount of fish is transported in refrigerator cars or by air freight.

Frozen fish are most commonly transported in trucks having a well-insulated van body. The amount and type of refrigeration provided in the van body varies. Frozen fish are transported satisfactorily in trucks equipped with mechanical refrigeration, dry-ice refrigeration, or stored refrigeration in "hold-over" plates.

The low temperature necessary for preserving frozen fish during long hauls can be obtained best by use of a truck employing mechanical or dry-ice refrigeration. With mechanical refrigeration units, which are usually operated by a separate internal combustion engine, little or no attention is required during transit; whereas with dry-ice units, care must be taken to replenish the dry ice during transit in order to maintain the required temperature. Trucks refrigerated by means of hold-over plates are best suited for transporting fish over comparatively short distances because hold-over plates provide only a limited refrigeration effect.

Refrigerated delivery trucks are not designed to lower the temperature of the product or to serve for prolonged storage but merely to absorb the heat introduced in transit. Best results are obtained if the trucks are precooled and loaded quickly in the morning instead of the night before the deliveries are to be made. (Truck refrigeration is discussed in greater detail in section 1.)

## RETAIL OPERATION

Facilities for the storage of large reserves of frozen foods usually are not found in the retail store. Most retailers have only retail-display cabinets some of which are large enough for a small reserve of frozen foods. This arrangement requires that the retail cabinet be replenished almost daily by the wholesaler. Stores that have a large volume of business, however, need storage other than that which is available in the retail cabinet. Some retail stores have walk-in storage located in a part of their storage area. Other stores use the older chest-type storage cabinets for holding a reserve supply.

Frozen-storage facilities at the retail level are governed by the same factors that apply to order-assembly rooms, except that the temperature should be held at 0° F. or lower. Inventories should be limited to 1 week's supply, and a complete turnover of the products in the storage should occur every week. The facilities should be defrosted regularly.

Modern merchandising requires displays that place the frozen foods in quantity before the eyes of the customer so that he will be given an impulse to buy. The only display cases that fulfill this requirement are of the large self-service open-type that have their entire contents accessible at all times. These modern cases are usually quite deep so as to provide a well for the retention of low-temperature air, yet they are wide enough so that their contents are easily accessible—even down to the last package. The average food store requires at least 25 linear feet of display case to provide room for frozen fish and the variety of other frozen foods that are available.

Automatic dispensing cabinets for frozen foods have been used on a trial basis, but they do not provide for the mass display that is desired in the merchandising of foods (Anonymous 1947). Frozen-food cabinets with sliding glass doors or hinged top-opening lids without bulk storage below the display portion of the cabinet were used quite successfully in the past for selling frozen food products (Tressler and Evers 1943). Some of these cabinets are still in use, but they do not so readily encourage impulse buying or provide for such easy access to the foods as do the self-service open-type case.

The quality of frozen fish is usually subject to greater deterioration during marketing than it is during the time that the fish are in storage in the frozen-food warehouse (Munter, Byrne, and Dykstra 1953). Marketing exposes the product to the most severe conditions. It is even possible, through lack of the necessary precautions, for isolated packages or cases of frozen fish to thaw while in transit from the wholesaler or while in the retail store.

## Effect of Thawing on Quality

Packaged frozen fish that are soft to hand pressure (not hard frozen) can be considered of doubtful quality because there is no way of knowing how long they have been in a soft condition. Similarly, packages that are misshapen, yet hard frozen, may be indicative of frozen fish that thawed completely and that was then refrozen. Again, the quality is doubtful because there is no way of knowing how long the fish may have been held in a soft, unfrozen condition. It should be noted, however, that slightly misshapen packages can result when freshly packaged fish are frozen without the benefit of pressure and that slightly misshapen packages therefore do not necessarily indicate poor quality.

Once the package is opened, it is usually possible to determine if the product has thawed. Voids or spaces on the side of the opened package will be filled with a frozen cloudy liquid ("drip") that exuded from the fish as it was allowed to thaw. (Fillets held overnight in the package before freezing also may exude a noticeable amount of drip, whereas brined fillets may not release drip even on thawing.) If the carton has any remaining air space, that portion of the fish that is above the surface of the frozen drip may show evidence of dehydration. The effect of thawing and refreezing combined with the effect of prolonged storage (more than 6 months) usually results in changes in quality that are sufficient to render the product unpalatable.

## Effect of Storage Temperature on Quality

Frozen foods do not need to thaw to be subjected to accelerated rates of quality loss. Storage at temperatures of 10° or 15° F. permits much more rapid loss of flavor and color and development of rancidity and toughening than does storage at 0° F. Therefore, to obtain a reasonable storage life, frozen fish must be held at 0° F. or lower (Pottinger 1947). Frozen fish that are stored at -10°, -20°, or -30° F. may be expected to retain their quality for an even longer time. For this reason, some organizations store all of their frozen foods at these lower temperatures.

## Effect of Slow Turnover on Quality

Without a complete turnover of all of the packages in the cabinet within 1 week, those that are at the very bottom may become covered or bridged over with frost and lost from sight. Under these conditions, weeks or even months may elapse before the packages are removed and sold. During this time, the quality of the product may change from good to fair.

Packages that are not sold promptly may become shop worn. The waxed paper overwrap loses its bright appearance and may even become loosened or torn. The aged look of these packages makes them unappealing and then further delays their sale. Some packages may become so worn in appearance as to become unsalable, and a loss to the retailer results (Morin 1952).

## Control of Odor Transfer

In the past, frozen fish were segregated from other frozen foods because of the possibility of odor transfer. The use of modern packing materials for frozen foods, however, has brought odor transfer under control. Moisture-vapor- and gas-resistant packaging materials, correctly applied for the packaging of frozen fish, have eliminated the need to segregate frozen fish from other frozen foods (Elder 1947).

## Recommendations for Retaining the Quality of Fishery Products During Marketing

Retailers who observe the following recommendations will avoid most of the problems associated with retailing frozen foods (Anonymous 1953):

1. Never allow frozen foods to stand at room temperature.
2. When frozen foods are delivered, place them immediately in a room or cabinet maintained at 0° F.
3. Keep the display cabinets set to operate at 0° F., and check their temperature daily.
4. Keep refrigeration coils and the inside walls of the cabinets free from frost or ice crystals.
5. Locate cabinets where they will be subjected to a minimum of air currents.
6. Try for a complete turnover of all packages once a week and always put new supplies under the stock already in the cabinet.
7. Do not stock the cabinet above the frost line.
8. Inspect the contents of each cabinet for neatness once every day, and remove and repair torn packages or dispose of them.
9. Do not place frozen-food packages against unrefrigerated walls or above the cabinet frost line, even for display purposes.
10. Do not use walk-in coolers to store frozen foods.
11. When displaying frozen foods in island stalls, use adequate dry ice or mobile refrigerated units that will adequately protect the products.
12. Use all of the precautions recommended to wholesalers when buying frozen foods at the cold-storage warehouse. If a refrigerated truck is not available, use insulated shipping boxes that have been precooled, to protect the product while it is being transferred to the retail store.

## METHODS OF DETERMINING QUALITY OF PACKAGED FISHERY PRODUCTS

### When Consumer Selects Package

#### Appearance of Package

Torn and loose overwraps, stains on the package, and cavity ice or frost between the fish and the transparent packaging material may indicate poor quality. Ordinarily, however, the quality of a package of frozen fish is not apparent from its external appearance unless the contents of the package are visible through a window or unless the frozen fish has been wrapped in a clear film of packaging material.

#### Appearance of Fish

If the product can be seen through the packaging material, its color may furnish a clue as to its quality. Frozen white-fleshed fish that have been held in storage for long periods of time or that have been held at temperatures above 0° F. may lose their original color and acquire an off-white or light-tan color. Red-fleshed fish (salmon and trout) that are similarly stored may fade to lighter shades of red or may even lose their red color entirely and become white or gray. This fading of the red color usually occurs on the surfaces that are most exposed to any air in the package.

## When Consumer Opens Package

### If Fish Are Frozen

Frost or cavity ice.—Reliable judgment of the quality of any frozen-fish product depends on an examination of the contents of the opened package. If the air spaces in the package or between the pieces of fish contain any quantity of frost or ice crystals, cavity ice is said to be present. Cavity ice forms as the moisture in the air trapped in the carton strikes the frozen surface of the carton or of the fish and condenses out on these surfaces in the form of frost. Cavity ice does not form in any quantity unless the temperature of the package and of the air in the package is allowed to fluctuate appreciably and repeatedly over a period of time. The temperature of the package cannot change unless the temperature of the frozen-food storage space changes. If the temperature of the package and of the air in the package is allowed to rise, the air then can hold additional moisture. Under these conditions, the air acts like a sponge and actually withdraws moisture from the frozen fish by evaporation until the air is again saturated. On the downswing in the temperature of the storage space, the now saturated air becomes cooled and precipitates its excess moisture in the form of frost or ice crystals on the cold surfaces of the inside of the package and its contents. Frozen fish in a package that contains a large quantity of cavity ice probably will be somewhat tough and dry in texture because of this loss of moisture. However, if the frozen fish is packed with a minimum of air space in the package and is stored at a reasonably constant temperature, cavity ice will not be formed in any appreciable amount.

Freezer burn.--White parched or dehydrated areas that are sometimes found on the surface of packaged frozen fish are called "freezer burn." These areas usually indicate that the fish have been loosely wrapped or have been wrapped with materials that are not moisture-vaporproof. Noticeable dehydration is ordinarily accompanied by the loss of flavor and by the development of rancidity.

### If Fish Are Thawed

Color of fish.--The best way to examine the fish sample for color changes is to make a cross-sectional cut of the fish steak or fillet and then compare the color of the exposed surface with that of the inner portion of the fish. Marked differences in color between the exposed and inner surfaces of the steak or fillet usually indicate that the frozen fish is not of high quality and that it has probably reached the end of its frozen-storage life.

Space in the package.--Fish fillets and steaks are usually tailored to fit the package with close and continuous contact on all surfaces. (Steaks that are cut from frozen fish are an exception because they cannot be wrapped to eliminate all of the space in the package.) Since packages are usually made to hold a specific quantity of fish without extra space, fish fillets or steaks that are tailored to a minimum-size package and frozen in the package under pressure will completely fill it after the freezing expansion has occurred. Even if these pieces of fish were to thaw out completely and be refrozen, there would be very little excess space in the package. An abnormally large space in a package containing the full net weight therefore indicates that an oversize package was used; in addition, it may indicate complete thawing and settling followed by refreezing, particularly if the contents are not evenly distributed in the package. Fish that is carelessly packed in an oversize carton and frozen without pressure, however, may also give this appearance.

Rancid odors.--Some species of frozen fish begin to acquire an oily odor after 4, 5, or 6 months of storage, depending upon the packaging method and the storage temperature that was used. A slight oily odor shows incipient rancidity. If the odor becomes pronounced, the fish are said to be rancid. Rancid odors indicate that the fish have reached the limit of their frozen-storage life.

Honeycombed texture.--Retail-size packages of fish usually freeze so rapidly that they do not develop distinguishable individual ice crystals. If, however, packaged fish that has accidentally thawed are placed in the frozen-food retail cabinet or stored at 0° F., they will refreeze at a very slow rate over a period of one or possibly several days. The resulting ice crystals will be plainly visible, particularly in the fish nearest the center of the package. This fish, on being thawed, would have a honeycombed appearance resulting from the formation of pockets where the large crystals had been.

Honeycombed texture is normal in steaks cut from very large fish that were frozen slowly in-the-round, but in small fish or packaged-fish products, honeycombed texture may be indicative of fish that thawed and was refrozen very slowly.

Drip from fish.--An excessive amount of drip from fish that has been allowed to thaw slowly may indicate poor handling of the fresh fish aboard the vessel, prolonged storage in ice prior to freezing, frozen storage at temperatures considerably above 0° F., or thawing and refreezing prior to retail sale.

Some species of fish yield more drip than do others. For this reason, nonfatty fish are sometimes dipped for a few seconds in a light salt brine before being frozen. This treatment tends to reduce the loss of fluid from the thawed fish. Fatty fish, however, are not dipped in brine because a brine dip tends to accelerate rancidity.

## When Consumer Cooks Fish

### Color

Cooking affects the color of fish flesh in various ways. Translucent-fleshed species, like sole, become white, whereas red- or pink-fleshed species lose some of their intensity of color. Any dark-colored areas that were present before the fish was cooked will be considerably more noticeable or pronounced in the cooked fish. Undesirable color changes that have occurred during frozen storage, such as the "rusting" or yellowing of halibut and cod, are accentuated when the fish is cooked. As a result, the color of the thawed and cooked fish gives a better indication of frozen quality than does the color of the thawed raw fish.

### Texture

Frozen fish gradually loses its original succulence, owing to protein changes during storage. These changes cause an undesirable toughening of the flesh that becomes apparent when the fish is thawed, cooked, and eaten. The extent of these changes depends upon the species of fish and upon the conditions of handling, such as the temperature and time on ice before freezing and the temperature (higher than 10° F.) and time in frozen storage. The texture in the cooked fish is therefore a reasonably good indication of the overall quality.

### Flavor and Odor

Really fresh fish has a delicate odor that is characteristic of the species. One of the first noticeable changes that occurs in fish is the loss of this characteristic odor. Undesirable pervasive odors that come from non-oily fish as it is being cooked are indicative of a loss in quality attributable to bacterial-induced changes that may have occurred prior to freezing. The most common cooking odor that comes from fish no longer of the best quality is the odor of trimethylamine. Although this odor is often described as "fishy" because it is associated with fish, it may be present also during the cooking of other protein foods in which bacterial changes have occurred.

An entirely different type of odor may be noted in fish. This odor, described as a rancid one, is a more serious problem with some species than others. If a fish contains only a small quantity of oil (under 1 percent), rancidity is ordinarily of minor importance. However, even such non-oily fish as frozen cod and haddock may develop a rancid odor, sometimes called "salt-fish odor", and reminiscent of that noted in salt cod stored at room temperature. At the other extreme the lake chub, an oily fish, may rapidly develop a very rancid odor in frozen storage.

Fresh fish that have been frozen and placed in storage gradually lose their normal flavor and become flat in flavor. Shortly before the disappearance of the last trace of the normal flavor in fish held frozen in cold storage, a rancid flavor starts to develop. This flavor is characterized by a bitter taste which persists in the mouth long after the fish has been eaten. In the initial stages of rancidity, this flavor may not be objectionable to all persons eating the fish. As a matter of fact, frozen fish so often have become slightly rancid at the time that they are consumed that many persons are unaware that this flavor is not a normal one. As the rancid flavor develops, it becomes more objectionable until a point is reached where the fish become unmarketable. In general, the pattern for the development of rancid flavors is the same as that described under the discussion of rancid odors. Fish that have been too heavily brined are especially susceptible to the development of the rancid flavor. Other flavors and odors foreign to fresh fish may also be present in frozen fish and render the frozen fish poor in quality or inedible. Fuel oil or chemical odors are examples of foreign odors.

Fish that were not fresh when they were processed for frozen storage will be flavorless, stale, or have food-spoilage odors offensive to the senses. Similarly, fish that had unusual or off flavors and odors when they were processed for frozen storage will still have these quality defects when they are taken out of storage, for freezing cannot improve in any way the quality of the original fish. The fresh characteristics of high quality fish, however, can be retained more nearly by proper processing, freezing, and frozen storage than by any other method of preservation. A good general rule for optimum frozen storage is that the lowest temperature economically practicable should always be used. Contrary to the often-heard statement, the use of very low freezing and frozen storage temperatures does not of itself cause the dehydration and discoloration referred to as "freezer burn".

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SECTION 3

# LOCKER PLANTS AND HOME FREEZERS

By Martin Heerdt, Chemist, and Joseph W. Slavin, Refrigeration Engineer*

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## TABLES

## INTRODUCTION

Both lockers and home freezers are designed to aid the homemaker in freezing and storing surplus seasonal foods and in storing foods purchased in quantity at a saving in price. The discussion that follows describes the various types of available equipment so that the reader can use them to the best advantage and tells how to prepare and handle fish for freezing and storage in a locker plant or in a home freezer.

## DESIGN OF LOCKER PLANTS AND HOME FREEZERS

### Locker Plants

The equipment used and facilities provided in a locker plant vary considerably, depending upon the area served, the capacity required, the type of products to be handled, and the prevailing labor supply. A complete locker plant is equipped to process, quick-freeze, and store a wide variety of food products. Most locker plants, however, offer only storage space for frozen foods. On the other hand, some plants furnish only freezing facilities, where food products may be frozen for subsequent storage in home freezer cabinets (figure 1).

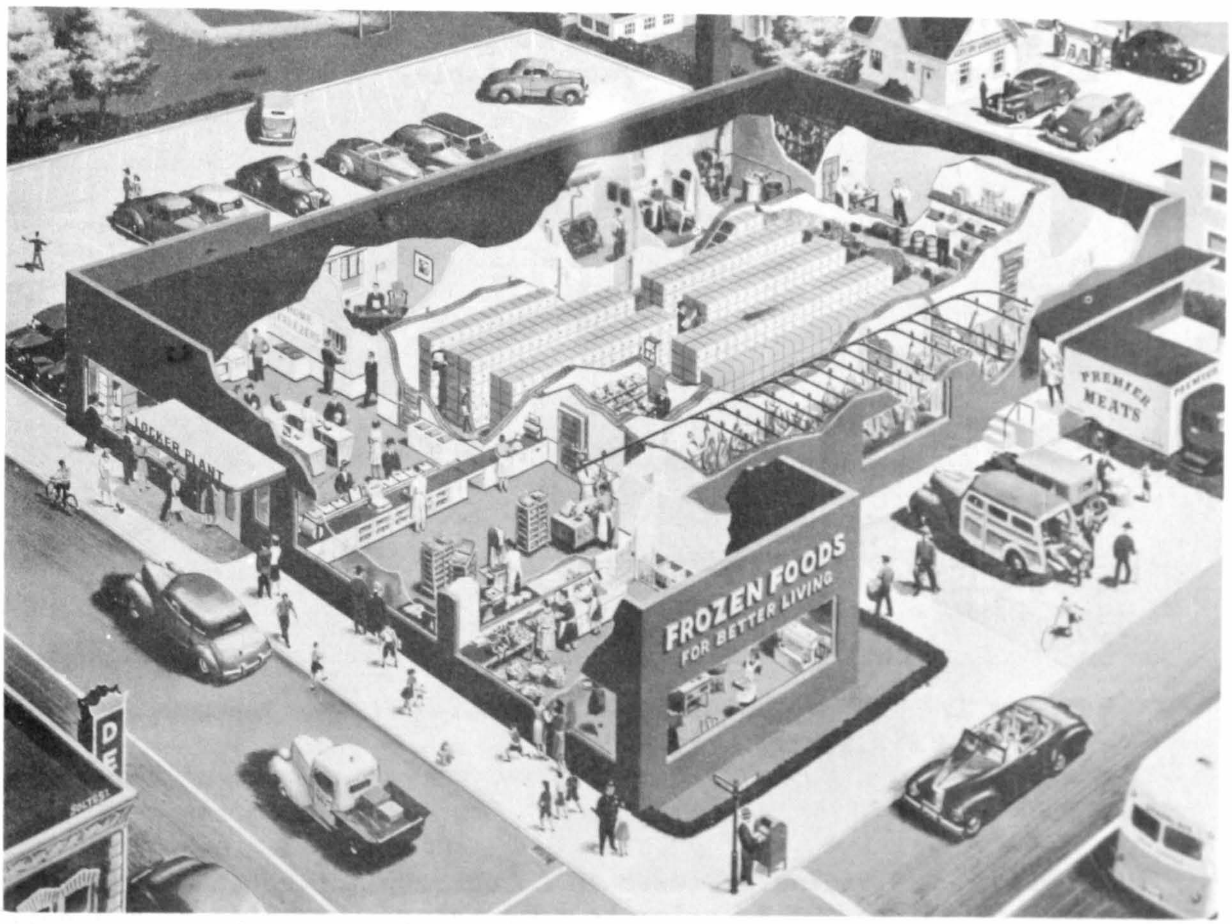



Figure 1.—Locker plant in operation. (Photo courtesy of Armstrong Cork Company)

A large locker plant for processing, freezing, and storing such products as meat and fish must be equipped to furnish the various services that the customer may require. The utmost consideration must therefore be given to the design and construction of the plant and the equipment to be used. Some of these considerations are reflected in the following discussion concerning the design of the processing rooms, chill rooms, freezers, lockers, and cold-storage rooms that comprise the locker plant.

## Processing rooms

In a frozen-food locker plant, a wide diversity of products are handled rather than large amounts of a particular type of product such as are handled in fish- and in meat-processing plants. The comparatively small amounts of fish processed in the locker plant do not warrant the large expense necessary for automatic processing equipment, such as fish filleting and skinning machines. The mechanical machinery in most locker plants processing fish is restricted to power-driven saws and to hand scaling machines.

Washing tanks, filleting tables, and glazing tanks are necessary and are usually available. In a small locker plant, the washing and the glazing tanks might well be combined with the filleting tables. The processing equipment should be arranged to provide a smooth flow of products from the washing tank to the wrapping table. A suggested plant layout is shown in figure 2.

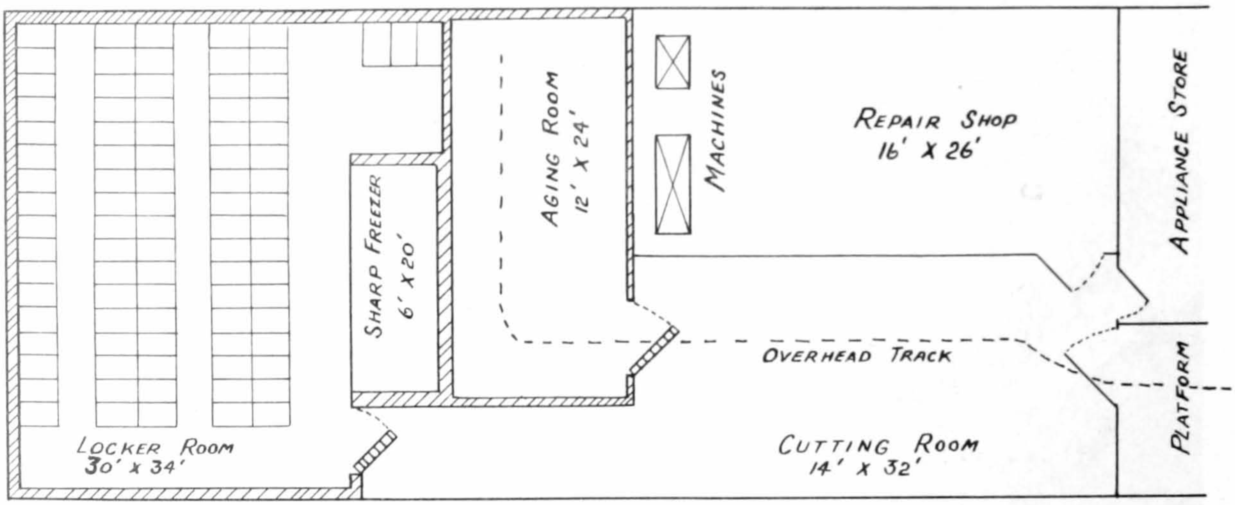



Figure 2.--Floor plan of locker plant. (Photo courtesy of Industrial Refrigeration)

## Chill rooms

Chill rooms are ordinarily used in a locker plant to hold meat at temperatures of 35° to 40° F. prior to processing. The size of the chill room varies with the particular installation and the volume of products to be handled. The refrigeration effect is usually furnished by a blower-type unit cooler employing Freon 12. Fish to be stored in chill rooms are packed in wooden boxes with a sufficient amount of ice to keep the temperature of the fish at 32° F. Some of the factors to be considered in the design of a chill room, in the calculation of refrigeration requirements, and in the selection of refrigeration equipment are given in Fishery Leaflet No. 427 of this series.

## Freezers

Freezing fishery products in locker plants is accomplished by use of a low-temperature (-20° F.) refrigerated room, a sharp freezer employing low-temperature refrigerated plates, or a small blast freezer. The last two methods of freezing are the most desirable because of the rapid freezing afforded. A description of the commercial freezing methods used to freeze fishery products is given in Fishery Leaflet No. 427. The following discussion will be restricted therefore to the application of the sharp- and blast-type freezer in a locker plant, where the small amount of product handled, the limited space, and the ease of operation are important factors.

### Sharp Freezers

The sharp freezers used in a locker plant are of the walk-in or cabinet type.

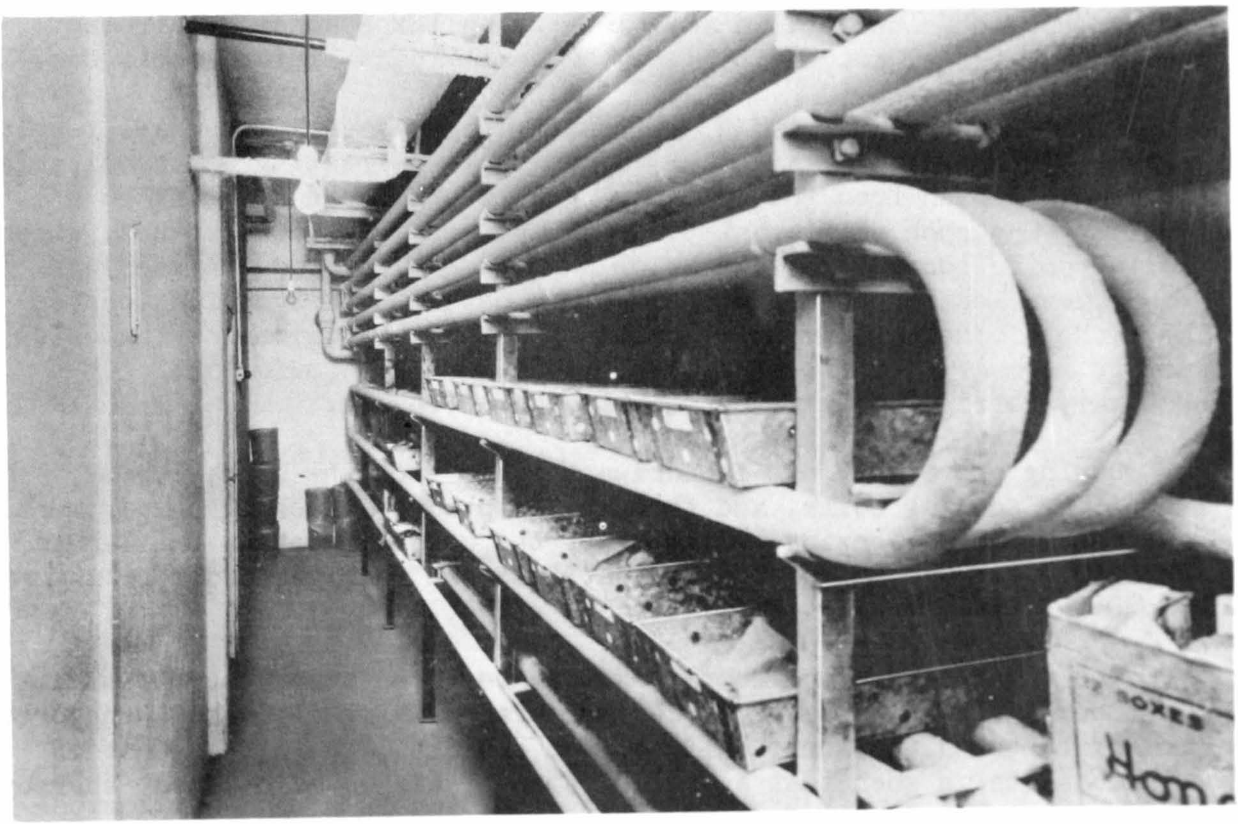


Figure 3.--Sharp freezer. (Photo courtesy of York Corporation, York, Pa.)

The walk-in sharp freezer consists of refrigerated plates or, in some cases, bare pipe coils arranged so as to form shelves located in an insulated room (Fishery Leaflet No. 427). The products to be frozen are placed directly on the refrigerated plates or on metal trays, which are then placed on either the refrigerated plates or the bare pipe coils forming the shelves. A shelf temperature of -20° F. provides quick and satisfactory product freezing. The inability of this freezer to freeze small loads efficiently, the large space required, and the high initial cost are some of the disadvantages that should be considered however before this type of freezer is selected for use in a small locker plant.

The cabinet-type sharp freezer consists of a metal-locker storage cabinet containing shelves comprised of refrigerated plates. These cabinets are located adjacent to the locker storage units. The products to be frozen are placed on the refrigerated shelves. When the necessary freezing time has elapsed, they are removed to the desired locker for storage. This freezing cabinet provides quick and efficient freezing for small amounts of fishery products. It is widely used in many small and large locker plants for freezing fish, meat, and other food products.

Blast Freezers

Blast freezing rooms (Fishery Leaflet No. 427) were employed to some extent in the first frozen-food locker plants. The defrosting problem encountered, however, in addition to the large space requirements, high initial cost, and inefficiency at small loads limited their use.

Improvements in freezing equipment within recent years have resulted in the development of many small, compact blast-freezing units suitable for use in frozen-food locker plants, where available space is at a premium. One such unit consists of a baked-enamel steel cabinet, with cooling coils located in the bottom compartment, a product-freezing compartment located in the center, and a centrifugal-type fan located above the product-freezing compartment. This unit maintains the cold-storage room at the proper temperature in addition to furnishing the necessary refrigeration effect for product freezing.

During operation, the fan draws the air from the storage room, around the cooling coils, and through the product-freezing compartment. From the product-freezing compartment, the cold air enters the fan and is discharged out the top of the cabinet into the refrigerated room in order to provide the necessary refrigeration effect.

The product-freezing compartment is serviced through two cabinet-type doors. Products to be frozen are placed in metal baskets supported from brackets on the inner walls of the cabinet. The arrangement of these baskets is such that a uniform flow of air is maintained, thereby insuring quick and satisfactory freezing of the product.

## Lockers

Lockers used in commercial locker plants are made of stainless steel, galvanized metal, or steel with a baked-enamel finish. Arrangements of the lockers in tiers 6 feet high with at least a 4-foot aisle between the rows permits easy loading and unloading of the products.

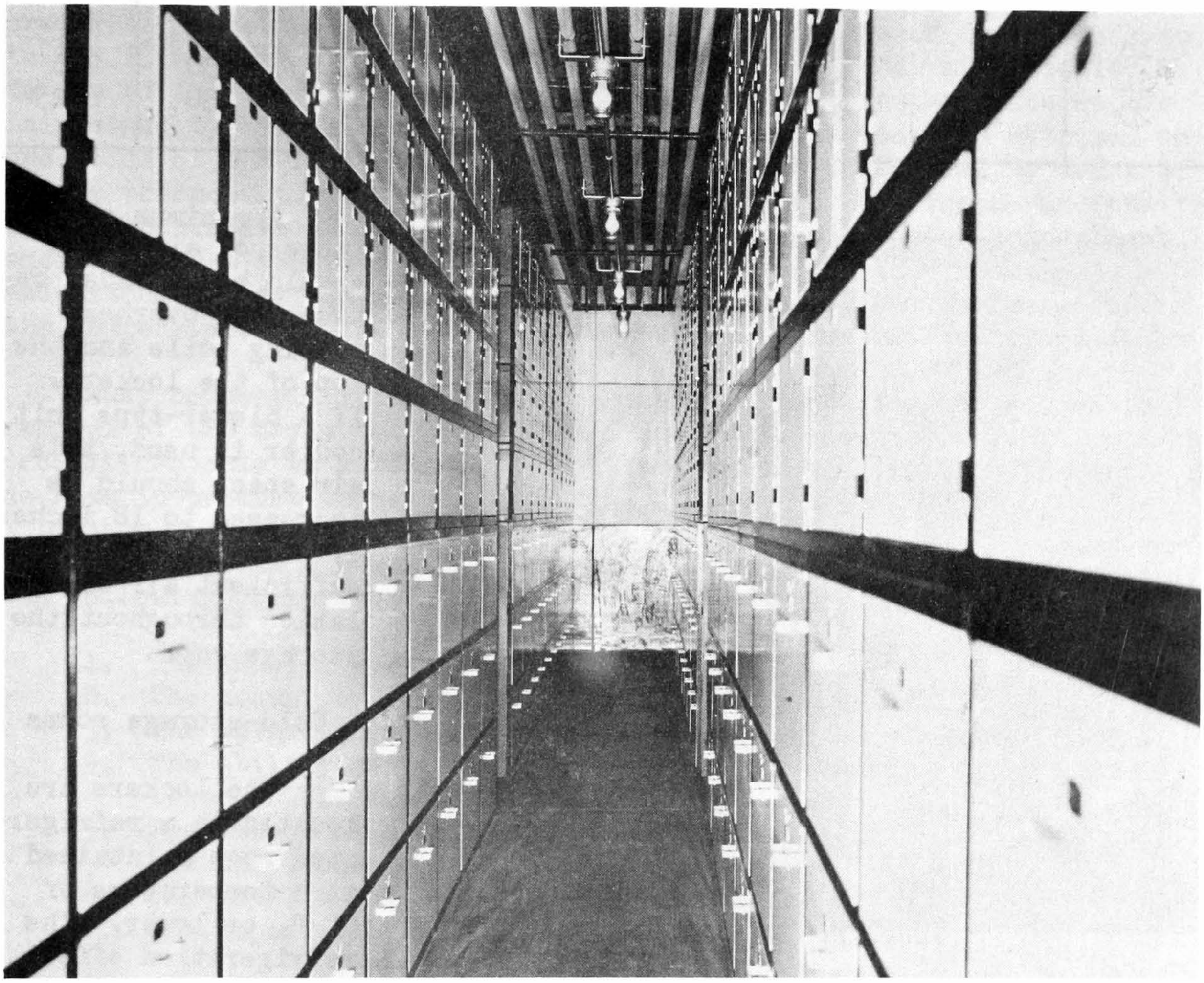


Figure 4.--Looking down the aisle of a locker room. (Photo courtesy of Industrial Refrigeration)

The lockers on the upper part of a tier are usually provided with doors. These lockers contain about 6 cubic feet of storage capacity, which allows space for the storage of 120 pounds of fish sticks or 300 pounds of fish fillets.

The lower lockers are usually of the drawer type and provide approximately the same amount of storage space as do the upper lockers. Table 1 shows some of the more popular sizes of lockers that are used in commercial locker plants.

Table 1.--Locker dimensions 1/

| Door lockers | | | | Drawer lockers to match | | | |
|---|---|---|---|---|---|---|---|
| Width | Height | Depth | Volume | Width | Height | Depth | Volume |
| Inches | Inches | Inches | Cubic ft. | Inches | Inches | Inches | Cubic ft. |
| 18 | 18 | 30 | 5.62 | 18 | 22 | 30 | 6.25 |
| 24 | 15 | 30 | 6.25 | 24 | 20 | 30 | 7.5 |
| 20 | 17 | 30 | 5.9 | 20 | 20 | 30 | 6.25 |

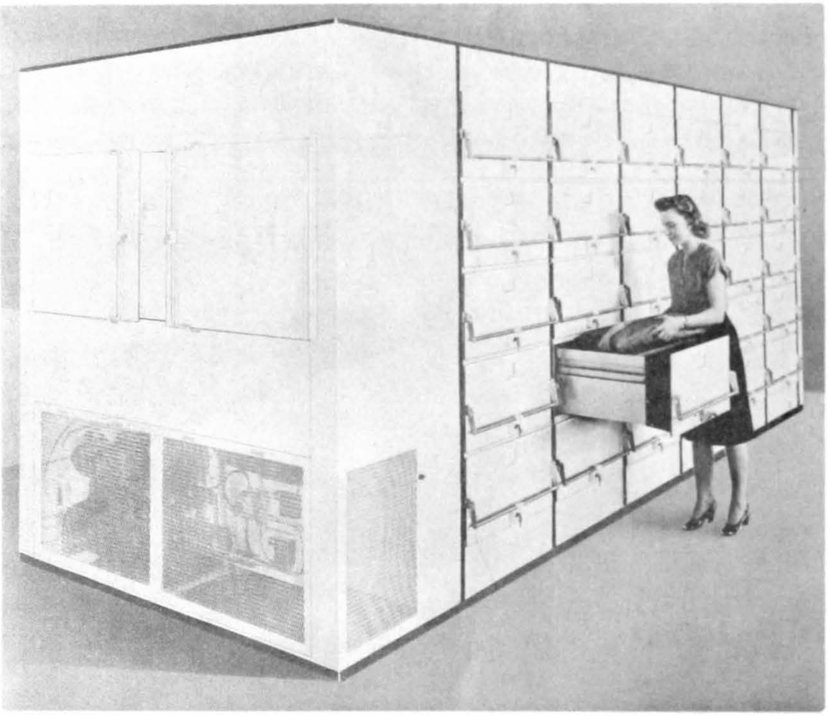


Figure 5.--Complete locker unit. (Photo courtesy of Industrial Refrigeration)

A minimum of 12 inches of air space should be provided between the overhead cooling coils and the top of the lockers. If a blower-type unit cooler is used, this air space should be increased to 18 inches or more to allow for sufficient air circulation throughout the storage room.

Cold-storage rooms

The lockers are located in a refrigerated room maintained at a temperature of 0° F. or lower. The refrigeration effect is usually provided by expanding Freon 12 through refrigerated plates, bare pipe coils, or finned-pipe coils--all of which are supported from the ceiling. In many cases, a blower-type unit cooler furnishes the necessary refrigeration. A conventional-type, hot-gas defrosting system permits quick, easy defrosting of the refrigerated surfaces. In defrosting the pipe coils, the operator should place a canvas over the top of the lockers to prevent water from seeping into them.

A small Freon-12 reciprocating compressor driven by an alternating current induction motor is used to pump the refrigerant through the pipe coils. The factors affecting the design of the cold-storage room, the selection of refrigeration equipment, and the calculation of refrigeration

1/ From the American Society of Refrigerating Engineers' "Air Conditioning Refrigerating Data Book," Applications Volume, Fifth Edition, 1954-1955.

requirements are discussed in Fishery Leaflet No. 427.

## Home Freezers

### Household refrigerators

Household refrigerators are of two principal types. Both types ordinarily have two compartments, one for the storage of fresh foods at 35° to 45° F. and the other for the storage of frozen foods at 0° to 10° F. In one of the types of household refrigerators, these temperatures are maintained by circulating Freon through pipe coils that are attached to the underside of the frozen-food compartment and are controlled by means of a single thermostat. In the other of the two types, the fresh- and the frozen-food compartments are separated by an insulated wall, each compartment is encircled by a separate set of pipe coils through which Freon circulates, and either one or two thermostats are provided. If there are two thermostats, the temperatures of the two compartments can be controlled individually.

Many household refrigerators employ some means for the automatic removal of the day's accumulation of frost. Maximum storage life in the product can only be attained if defrosting operation results in little or no rise in product temperature.

In selecting a household refrigerator, the homemaker should consider the following factors:

1. The initial cost.
2. The amount of storage space.
3. The method of defrosting, whether automatic or manual.
4. The ability of the unit to maintain temperatures of 0° F. or lower in the freezing cabinet.
5. The method of controlling the temperature in the fresh-food and the frozen-food storage areas.
6. The total amount of storage space in proportion to floor space.
7. The dependability of the refrigeration equipment.

### Household freezers

The necessity for storage of large supplies of frozen foods by consumers located considerable distances from the market or by those desirous of purchasing frozen foods from the wholesaler has resulted in wide use of home-freezer cabinets with capacities of 4 to 60 cubic feet for frozen-food storage. The models having capacities of 10 to 20 cubic feet are the most popular.

These cabinets are predominantly of the chest type, consisting of an aluminum or steel (with a baked-enamel finish) compartment for freezing and storage. Refrigeration is obtained from a hermetically sealed condensing unit that is located under the bottom insulation or in a recess in the side of the cabinet in the smaller-size cabinets, or in an enclosure attached to one end of the insulated cabinet in the larger-size cabinets. Freezing is accomplished by circulating Freon 12 or Freon 22 through pipe coils attached to the outside surfaces of the metal forming the food compartment. Insulation, 4 inches thick, of either glass fiber or mineral wool, forms a complete envelope around the sides, ends, and bottom of the inner food-storage compartment. This insulation is covered by steel with a baked-enamel finish, which forms the outer shell of the cabinet. This outer shell is sealed with various forms of wax, tar, and plastisole in order to provide high resistance to the penetration of water vapor through the outer shell of the cabinet. The cabinet is serviced by a hinged cover sealed by a gasket attached to the top. This cover consists of two pieces of preshaped steel, with a baked-enamel finish, on both sides of a suitable insulation material. The thickness of insulation is generally less than that used on the sides and bottom of the food compartment.

Quick freezing in the home freezer cabinet is provided by placing the product on the refrigerated surface forming the bottom of the storage compartment, as was described in the cabinet previously discussed, or by placing the product on shelves consisting of refrigerated plates. These shelves are usually located in one end of the storage compartment.

## HANDLING OF FISH IN LOCKER PLANTS AND HOME FREEZERS

### Determination of Quality

Much of the fish stored in lockers or in home freezers are caught by sports fishermen. For this reason, the fisherman should acquaint himself with good practice for handling his fish after they are caught so that their fresh quality may be retained until served. This practice is described in the following subsection "Preparation for Freezing." The preparation is the same whether the fish is to be eaten fresh or frozen.

Strictly fresh fish appear to have just been taken alive from the water and have:

1. Almost no odor.
2. Eyes that are bright, clear, and shiny.
3. Gills that are bright red, covered with clear mucous, and possessed of a fresh odor.
4. Skin colors that are bright.
5. Mucous on the skin that is clear in color.
6. Flesh that is firm so that impressions made by the fingers do not remain (very fresh fish are stiff or rigid).
7. Belly walls that are intact.
8. A vent that is pink in color and not protruding.

Stale fish have:

1. An odor that is stale, sour, or putrid.
2. Eyes that are dull, wrinkled, and sunken.
3. Gills that are brown or gray, covered with cloudy mucous, and possessed of a sour and offensive odor.
4. Skin colors that are faded.
5. Mucous on the skin that is cloudy or ropy.
6. Flesh that is so soft and flabby that impressions made by the finger remain.
7. Belly walls that are ruptured, with viscera protruding in some species.
8. A vent that is brown in color and protruding.

## Preparation for Freezing

### When caught

Fish begin to spoil as soon as they die. The sports fisherman who wishes to preserve his fish for freezing or for eating fresh can delay spoilage, however, if he:

1. Stuns the fish as it is landed.
2. Removes its gills.
3. Eviscerates it.

A fish will be stunned if it is struck on the head with a blunt instrument such as the handle of a gaff hook. The gills can then be removed by the aid of a sharp knife, which also severs the blood vessels and permits the blood to drain from the fish. The fish may be eviscerated by slitting it open along the belly from the vent to the gills and by pulling out the viscera. These operations eliminate the routes and sources of bacterial spoilage and prolong fresh quality. A few species of fish may be frozen in the round. These species are mentioned under "Dressing and gutting" and in tables 3 and 4. Because cleanliness is so important, any remaining viscera or kidney and blood should be scraped and brushed from the fish. The fish should then be washed inside with water or wiped with a damp cold cloth.

Removing the source of spoilage is not enough, however, for the fish must also be chilled as a safeguard against the rapid growth of spoilage bacteria. To chill the fish, the fisherman should place crushed ice in the belly cavity and all around the fish; or if a refrigerator is available, he should wrap the fish in waxed paper and place it in the meat keeper or adjacent to the cold coils.

### At the locker plant

#### Fish

Fish for freezing should be kept in ice or in a refrigerator until they are placed in the freezer. Prolonged holding of the fish prior to their being frozen will decrease their quality. Fish may be frozen (1) as whole fish, either round or dressed, or (2) as chunks, steaks, or fillets.

Washing and scaling.—All round or dressed fish are washed in cold water to remove the mucous secretion from their skin before they are processed and packaged. Fish are usually scaled, unless the scales are very small or the skin of the fish is going to be removed, as in the preparation of skinned fillets. Scales may be removed from a fish by scraping it gently from the tail to the head with the dull edge of a knife or similar utensil (figure 6). The fish is usually held under water by the tail as it is being scaled. Electric hand-held scalers are available for use in scaling fish in quantity, but they are not ordinarily found in locker plants.

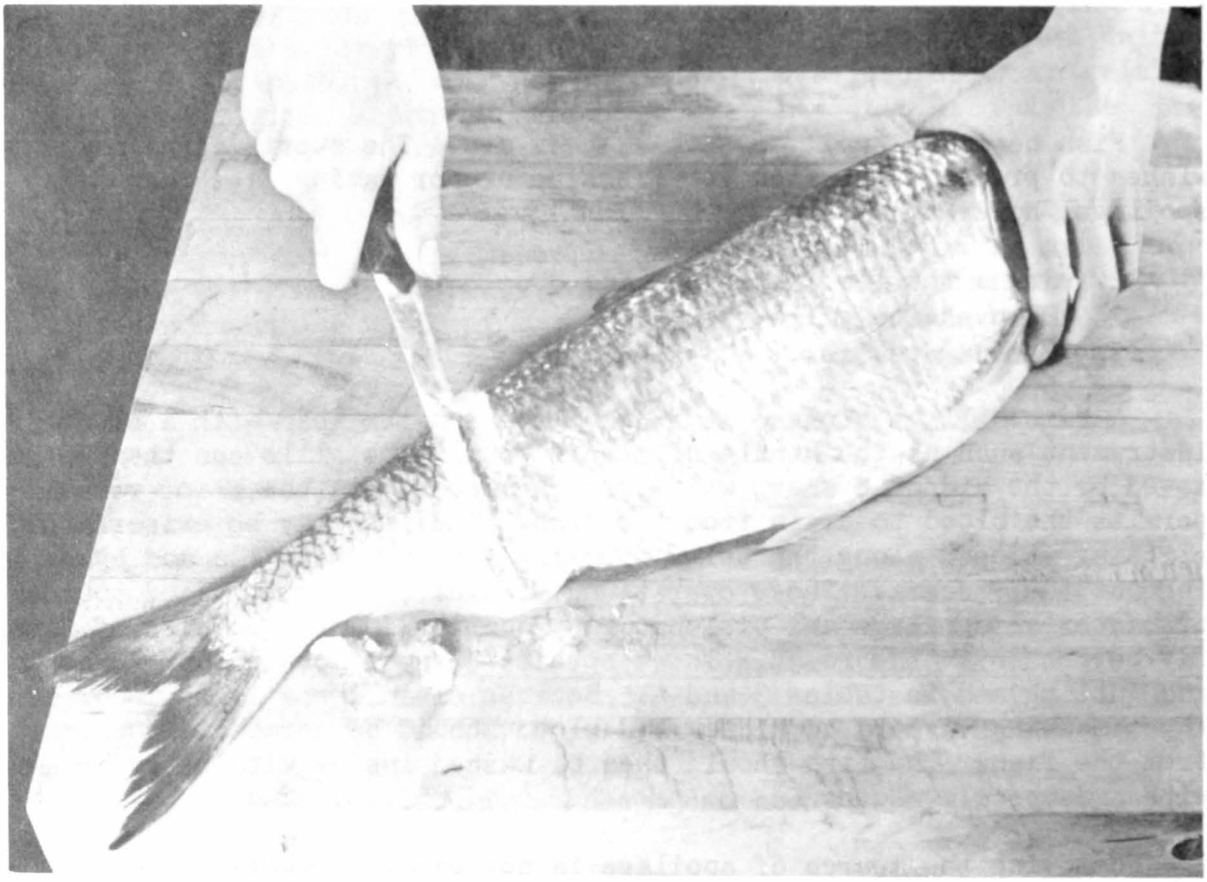
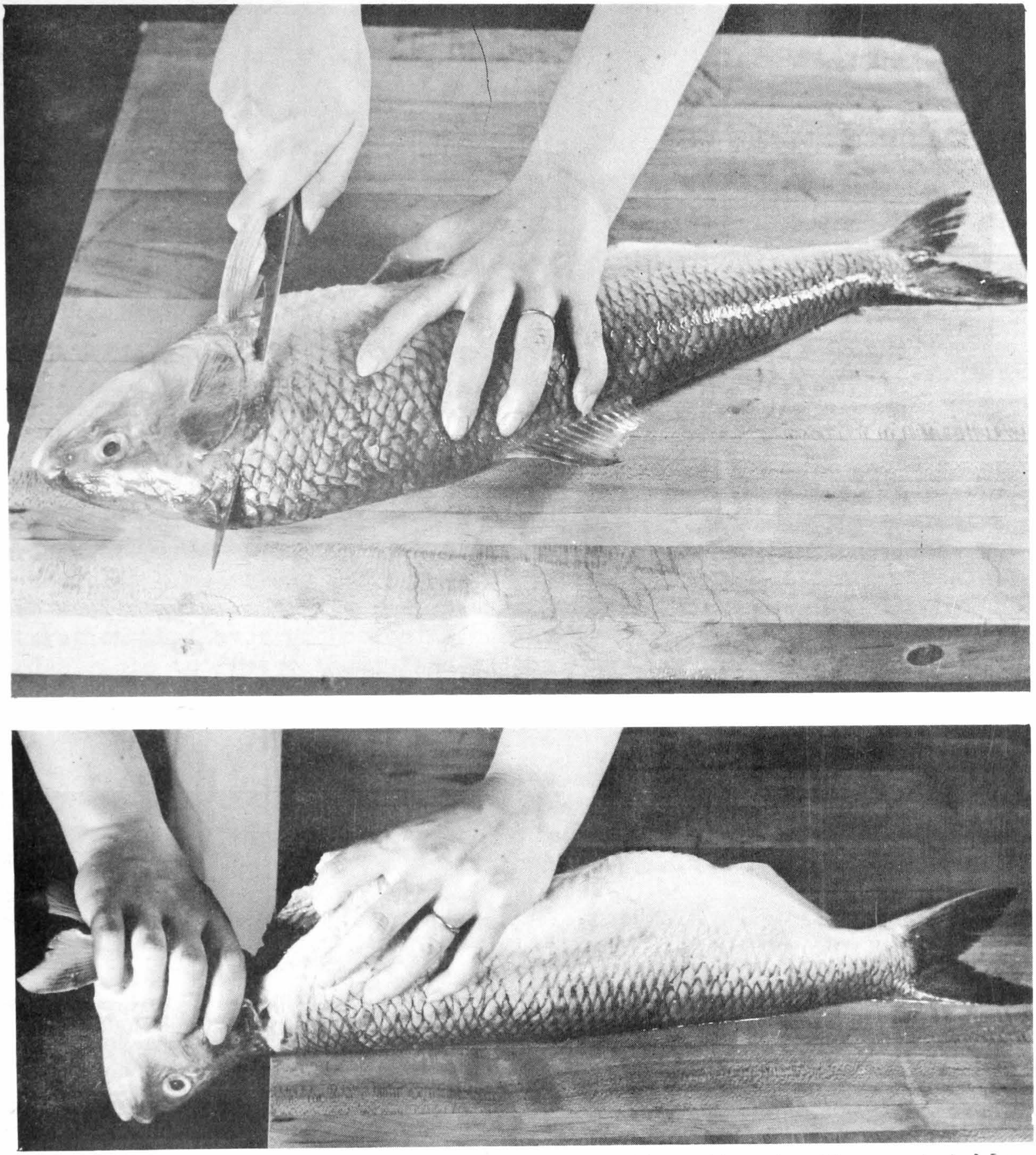


Figure 6.--Scaling fish

Dressing and gutting.--Most homemakers who store fish in lockers or home freezers prefer to eviscerate and dress their fish before the fish are frozen so that they will be ready for cooking when removed from the freezer (figures 7 and 8). This method makes meal preparation possible with a minimum of time and effort. Fish, such as herring, that are caught while feeding may become soft and predigested along the belly walls if they are not eviscerated after being caught. These fish usually have a longer frozen-storage life and taste better after storage if they are eviscerated before being frozen. Fresh- and salt-water smelt, however, can be successfully frozen and stored in the round because their quality is not seriously influenced by not removing their small intestinal tract or by cooking and serving them in the round. Fish that are to be frozen in the round should be frozen promptly after they are landed.



Remove head by cutting above collarbone and breaking backbone at table edge.

Figure 7.--Removing head.

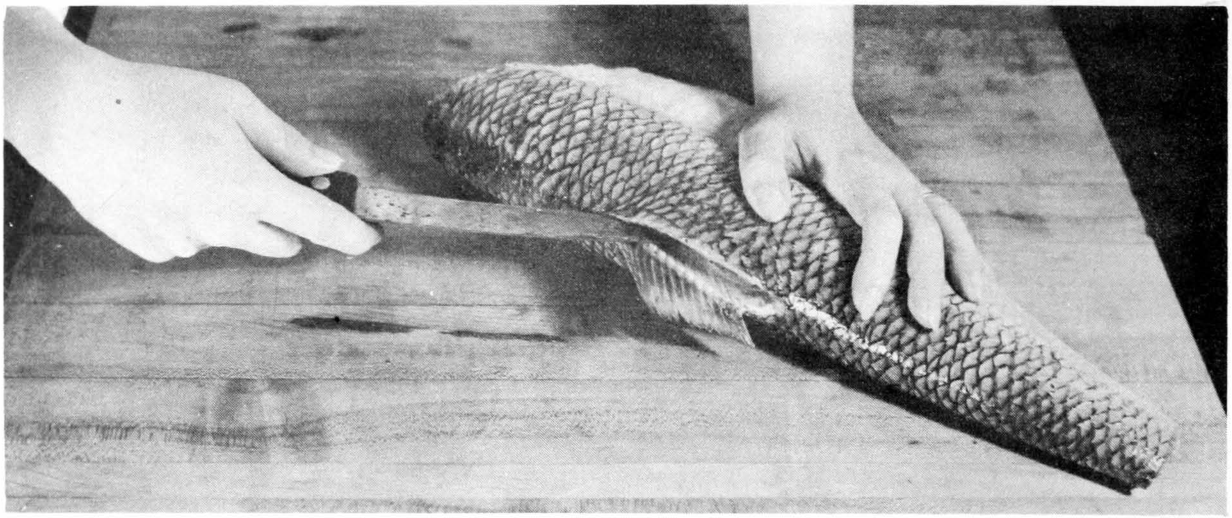


Figure 8.--Removing fins.

Tables 2 and 3 indicate the recommended methods of preparing the most common species of fresh- and salt-water fish. The words dressed, chunks, steaks, or fillets all indicate that the viscera have been eliminated.

Whole versus meal-size units.--The freezing of very large whole fish is not recommended because, generally, the entire fish must be thawed and used at once, and in most cases, a very large fish provides more than enough food for one family meal (Heerdt, Bucher, and Stansby 1949). Institutional users who serve smorgasbord or family style, however, find that freezing whole fish is practical. For this use, large fish--particularly the various species of salmon--can be handled in the round without dressing them provided that they are frozen within a short time after being caught.

It usually is advantageous to freeze fish in meal-size units. For home consumption, the use of meal-size units has two distinct advantages. A considerable saving in storage space is realized by removing the waste portions (head, viscera, backbone, fins, and tail); and only that amount of fish to be used at one time is taken from the freezer and thawed.

Fish dressed for package freezing have a larger area of flesh exposed to the air than do round fish. To prevent undesirable changes in flavor, color, and moisture content during frozen storage, one must take greater care in preparing such fish for storage than in preparing round fish, but if adequate precautions are taken, a satisfactory product can be obtained with most species. With a few species, however, such as pink salmon, the alteration in flavor and color is so marked during cold storage that it is desirable to freeze these fish in the round or in large chunks or to pack them in containers in order to avoid exposing any greater surface to air than is absolutely necessary.

For cutting individual or meal-size units such as fillets, steaks, or chunks (figure 9), a sharp, narrow-bladed butcher or boning knife is recommended. A cutting board about 30 inches long by 16 inches wide can be used to advantage in these operations.

Fillets are prepared as follows:

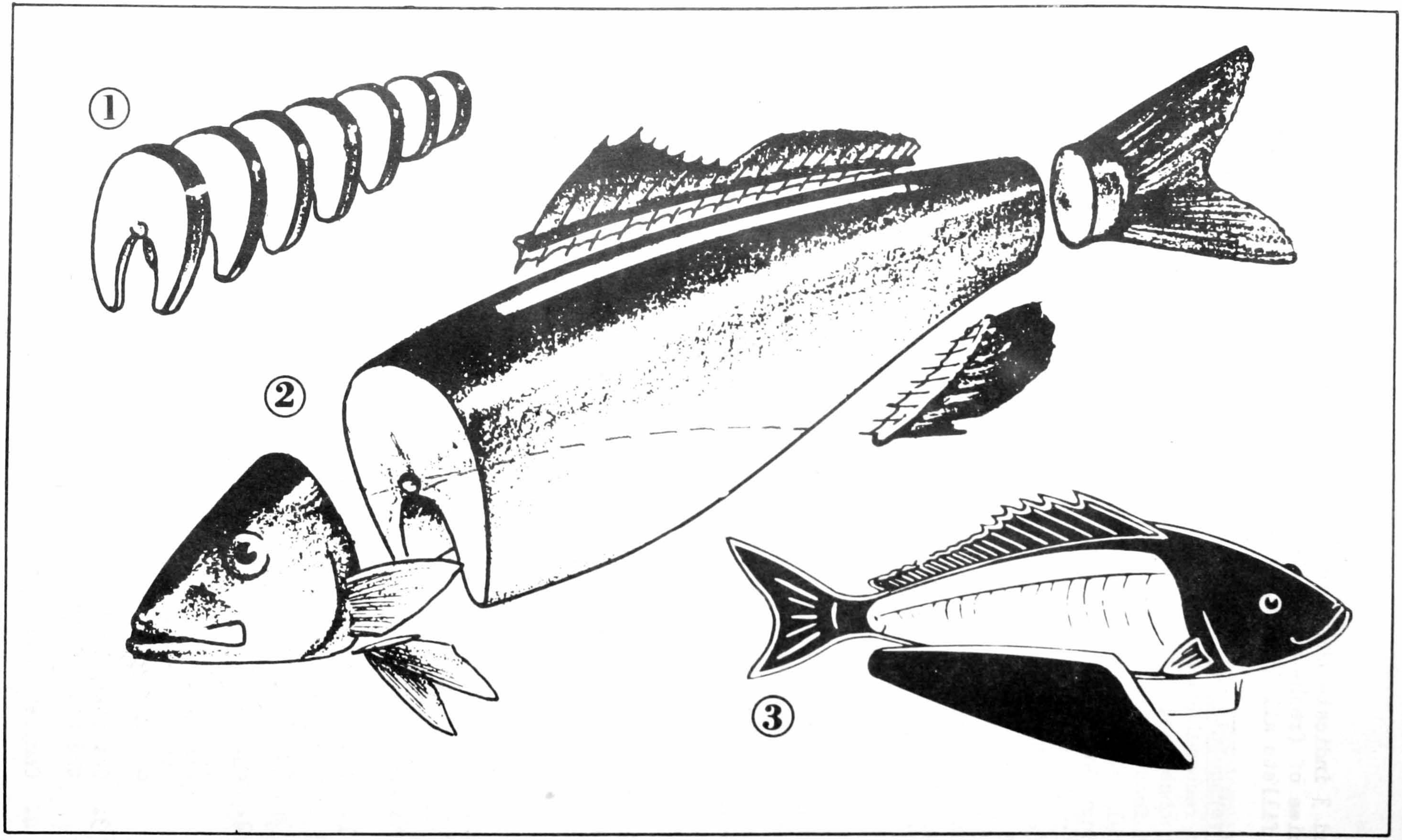
1. With the fish lying on its side, hold the knife diagonally, close to the head, cut down and in toward the head to the bones (figure 10a).

2. Pull the fish to the left and cut forward (figure 10b). [The knife is passed just above the backbone and is held firmly against it in such a way as to leave the dorsal fins (those growing above the backbone) and a very narrow strip of skin adhering to the bone.]

3. Cut flesh loose from spine along the back with the tip of the blade (figure 10c).

4. Complete the final cut on the first side (figure 10d).

Figure 9.--Cuts of fish.




1. Steaks

Cross sections of large dressed fish.

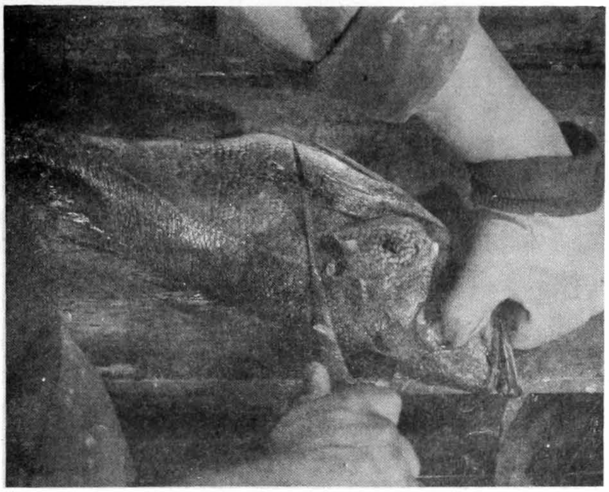
2. Dressed

Head, viscera, scales, fins, and blood clots removed. If head, fins, or scales are intact, fish is drawn or eviscerated.

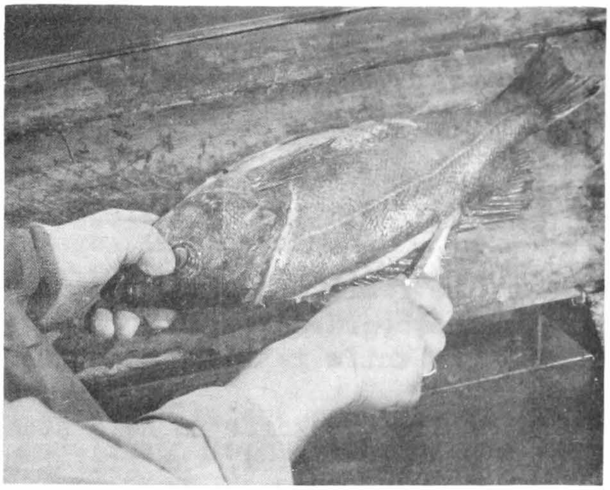
3. Fillets

Meaty sides of fish cut lengthwise away from the bone.

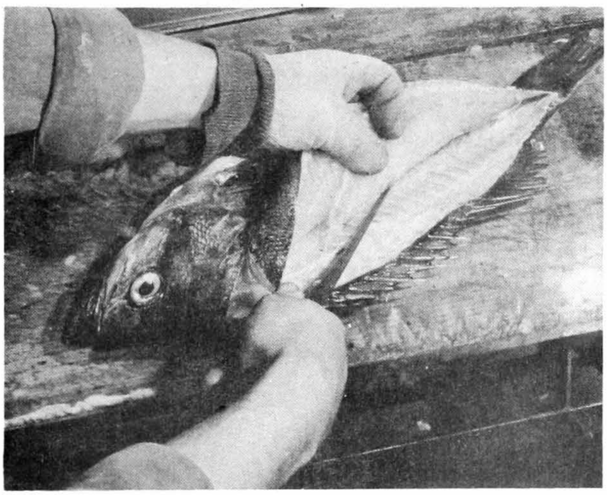
Figure 10.--How to fillet rockfish



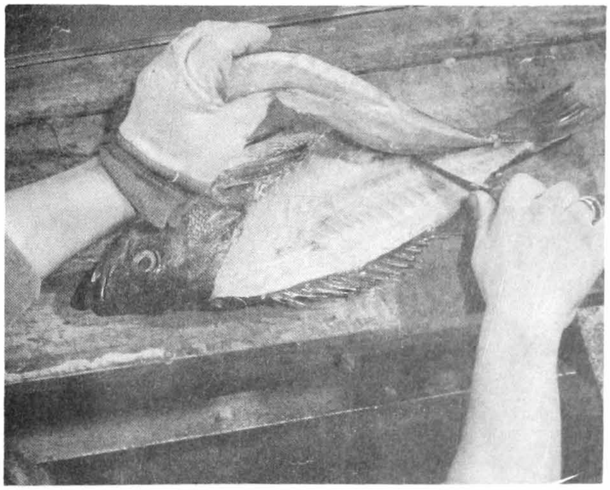
(a) Hold fish with head away from you to begin first cut on left hand side.



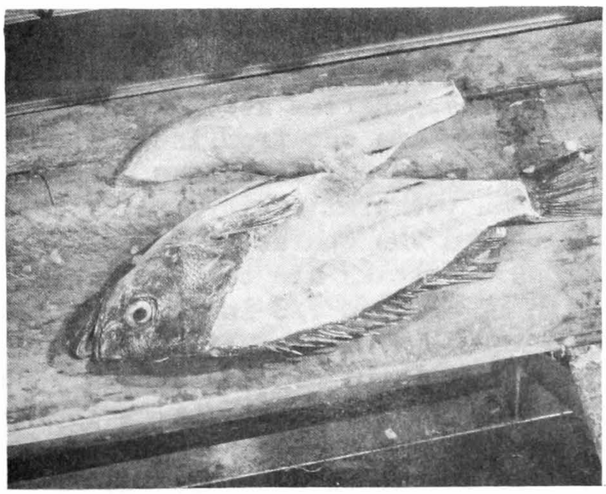
(b) Pull the fish to the left and cut forward.



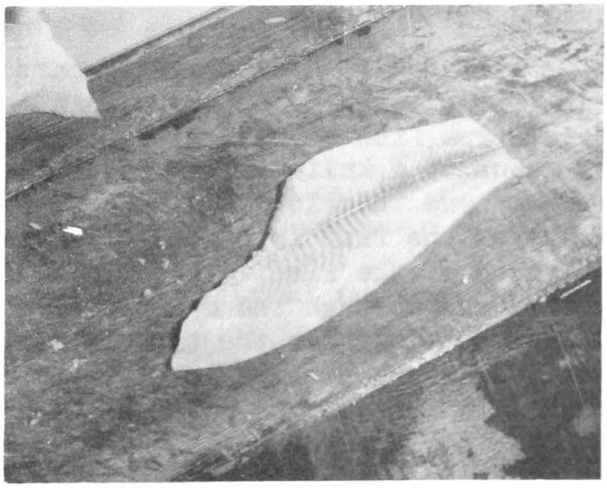
(c) Same action as (d)



(d) Completion of final cut on first side.



(e) Fillet and skeleton of rockfish.



(f) Rockfish fillet.

With most varieties of fish, a fillet prepared in this manner should be practically free from bones.

After the fillets have been obtained, the skin is sometimes removed. This operation is done as follows:

1. The fillet is placed on the cutting board with the skin against the board.
2. The knife is inserted between the skin and the flesh at the tail end.
3. While the knife is held steadily (flat side against the skin) with the right hand, the fillet held by the free flap of skin is pulled toward the knife blade with the left hand (do not saw); at the same time, the knife is run slowly forward in contact with the skin, with care being taken not to cut through it (figure 11).

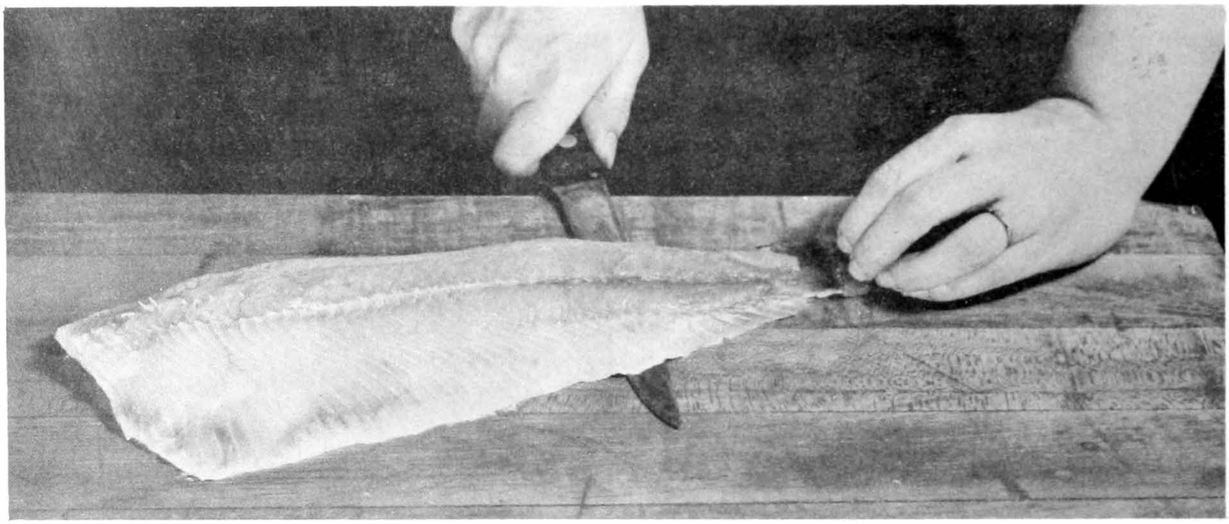


Figure 11.—Skinning the fillet.

With a little practice, the skin can be removed in one piece without the fillet being mutilated.

Fillets are ordinarily prepared from fish of small to medium size, one fillet weighing not more than 1 to 1½ pounds, whereas steaks are prepared from fish of medium to large size. Steaks are cut from the whole fish by means of a knife or saw after the viscera, head, and fins have been removed and the blood has been washed from the visceral cavity. If a knife is used, the fish is placed with its back toward the operator, and with the head of the fish to the right. Sections or steaks are cut by slicing across and through the backbone of the fish at 3/4- to 7/8-inch intervals. As the section near the tail is approached in steaking, the fish is too small in cross section to yield good steaks. It therefore is customary to cut fillets from this small section rather than to continue cutting steaks.

Chunks are cut in the same manner as are steaks except that the thickness of each piece is considerably greater--ordinarily 4 to 6 inches.

Chunks are cut in a size adequate for an entire meal, and individual servings are prepared after the fish has been thawed or cooked. Cutting fish into chunks is advantageous where it is possible to estimate closely the amount to be consumed at one time. Chunks require less wrapping paper per pound of fish than do individual steaks, and as they have less exposed flesh, discoloration and other changes are minimized. Chunks require a long thawing time and are more suitable for boiling or baking, whereas steaks require a short thawing time and are more suitable for frying or broiling.

It may be advisable to give the steaks or fillets a preliminary brine treatment before they are wrapped and frozen in order to reduce drip upon subsequent thawing. This brine treatment is especially desirable for cuts of non-oily fish, such as cod and flounder. Commercial practice indicates the desirability of a 30-second dip in salt solutions of the following strengths: 2½-percent salt solution (1/3 cup of salt to 1 gallon of water) for croaker, flounder, sole, and mullet; and 5-percent (2/3 cup of salt to 1 gallon of water) for barracuda, cod, cusk, haddock, hake, halibut, pollock, rockfish, ocean perch, sablefish, and whiting. The salt employed should be free from impurities that would adversely affect the quality of the fish; however, ordinary table salt may be used.

Table 2 summarizes the advantages and disadvantages of the various methods used in storing fish for home use in refrigerated lockers. In general, preparation of the fish as chunks is the optimum method because the entire piece is edible except for the backbone, only a minimum of surface is exposed, and refrigerated space is conserved. Fish chunks are suitable for baking or boiling without further preparation, or they can be cut into steaks for cooking in other ways. Small fish, however, cannot be prepared in this way and should ordinarily be pan dressed. Each of the other methods described is advantageous in certain instances, but if a single method is to be employed, cutting the dressed fish into chunks, size permitting, will give the best results.

Table 3 gives information on recommended cuts of fresh-water fish. Table 4 shows the recommended cuts for salt-water fish and gives the percentage of salt in brine dips, and the cold storage life, in months, based on the method of packing.

## Shellfish

Shrimp, crab, oysters, scallops, clams, and mussels can be successfully frozen. Bivalve shellfish should be washed in clean water to eliminate sand before they are opened. Opening of bivalves is accomplished by inserting a slender bladed knife between the shells so as to sever the adductor muscle from the shell. Sometimes the bill of the shell may have to be chipped away to permit inserting the knife. When scallops are being shucked, only the adductor muscle or "eye" as it is called is saved. Residual sand in raw shellfish meats may be washed away under a spray of clean cold water or by stirring the meats in a 2½-percent brine solution and draining them. Only containers that can be sealed are suitable for shellfish.

Table 2.--Comparison of various methods of preparing fish for storage in refrigerated lockers

| Method | Size and type of fish | Advantages | Disadvantages |
|---|---|---|---|
| Whole fish in the round | Very small to large size fish. Fish with short storage life. | Keeping quality good. | Much waste material is stored in locker; entire fish must be thawed and consumed at one time. |
| Eviscerated or pan dressed | Small to medium size fish. Fish with short storage life. | Keeping quality good. Less waste is stored in locker than if whole fish is used. | Some waste material is stored in locker; entire fish must be thawed and consumed at one time. |
| Chunks | Medium to large size fish. | Fish keep well. Very little waste is stored in locker. | Not adapted to very small fish. |
| Steaks | Medium to large size fish. | Very little waste is stored in locker. Flexible in that any amount can be withdrawn at one time. | Steaks do not keep as well as do larger cuts. Requires careful packaging. |
| Fillets | Small to medium size fish. | No waste is stored; all bones are removed. | Requires special skill in preparing. |



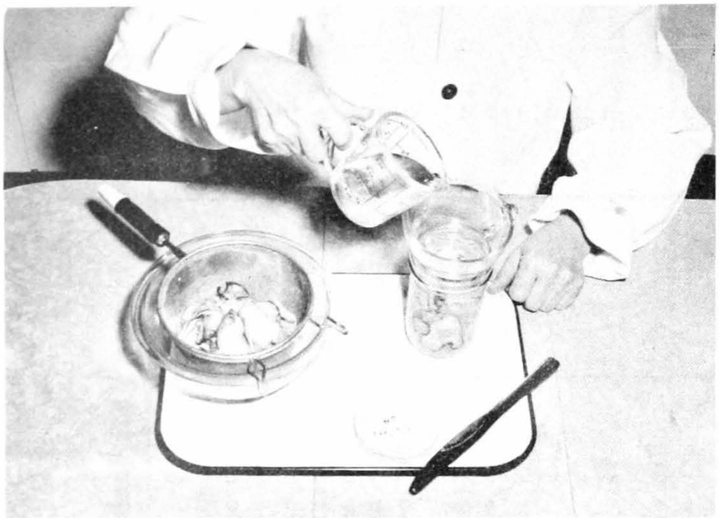
Table 3.--Recommended methods of preparing fresh-water market fish for storage in refrigerated lockers

| Species | Producing region | Season | Recommended method |
|---|---|---|---|
| Blue pike | Great Lakes | May and June; November and December | Fillets |
| Buffalofish | Mississippi River | February to November | Chunks |
| Carp | Mississippi River, Great Lakes, all coastal streams | All year | Chunks |
| Lake herring | Great Lakes | November and December | Dressed heads on |
| Lake trout | Great Lakes | All year, principally April, May, and November | Chunks |
| Pickerel | Great Lakes | March and April | Chunks |
| Sauger | Great Lakes | September and October | Fillets |
| Sheepshead | Mississippi River and Great Lakes | April, May, and June | Chunks |
| Smelt | Great Lakes | January, February, and March | Round or pan-dressed |
| Suckers | Mississippi River and Great Lakes | April to October | Fillets |
| Whitefish | Great Lakes | June, July, and August | Chunks |
| Yellow perch | Great Lakes | April and September | Round or pan-dressed |
| Yellow pike | Great Lakes | April and May; September and October | Chunks |

Table 4.--Recommended methods of preparing and packaging salt-water market fish for storage in refrigerated lockers

| Species | Producing region | Season | Recommended cut | Concentration of salt in 30-second brine dip | Cold storage life based on method of packing, for average storage temperature of 0° F. | |
|---|---|---|---|---|---|---|
| | | | | | Wrapped in moisture-vaporproof material | With 2½-percent brine in glass jars |
| | | | | Percent | Months | Months |
| Cod | New England, Mid-Atlantic, and Pacific | All year | Fillets | 5 | 9 | - |
| Cusk | New England | All year | Fillets | 5 | 9 | - |
| Flounder | Atlantic and Pacific | All year | Fillets | 2½ | 9 | - |
| Haddock | New England and Mid-Atlantic | All year | Fillets | 5 | 9 | - |
| Hake | New England and Mid-Atlantic | All year | Fillets | 5 | 9 | - |
| Halibut | North Pacific and North Atlantic | April-September | Steaks | 5 | 9 | - |
| Herring (sea) | Atlantic and Pacific | All year | Round or dressed | No dip | - | 6 |
| Mackerel | New England, Mid-Atlantic, and Pacific | June-February | Fillets | No dip | 3 | 6 |
| Mullet | Gulf and South Atlantic | All year | Fillets | 2½ | 6 | - |
| Pollock | New England and Mid-Atlantic | All year | Fillets | 5 | 9 | - |
| Rockfish | Pacific | All year | Fillets | 5 | 4 | - |
| Ocean perch | New England | All year | Fillets | 5 | 6 | - |
| Sea trout (gray) | Atlantic | April-November | Dressed or fillets | No dip | 6-8 | - |
| Sablefish | Pacific | June-November | Chunks or steaks | 5 | 9 | - |
| Salmon: | | | | | | |
| Chum | North Pacific | October-November | Chunks or steaks | No dip | 6 | 9 |
| Chinook | Pacific | April-September | Chunks or steaks | No dip | 6 | 9 |
| Pink | North Pacific | July-September | Chunks | No dip | 1/ | 6 |
| Silver | Pacific | June-October | Chunks or steaks | No dip | 6 | 9 |
| Red | Pacific | July-August | Chunks or steaks | No dip | 6 | 9 |
| Smelt | Atlantic and Pacific | All year | Round | No dip | - | 6 |
| Snapper (red) | Gulf and South Atlantic | All year | Chunks | No dip | 6 | - |
| Striped Bass | Atlantic | All year | Dressed or fillets | No dip | 6-8 | - |
| Whiting | New England and Mid-Atlantic | May-October | Chunks | 5 | 9 | - |

1/ Freeze in round or in large chunks; then either ice glaze and wrap or pack in glass jars only. Wrapping in paper without an ice glaze has been found unsatisfactory.



(a)

(b)

(c)

Figure 12.--Packing shucked oysters in freezer jar.

The containers that have proved satisfactory include polyethylene, pliofilm, or cry-o-vac bags that can be heat sealed or tied tightly, freezer jars, and containers that have tight-fitting lids. Waxed cylindrical cartons and waxed tubs with press-in lids are not satisfactory. Surface discoloration in storage can be avoided by covering the shellfish with water, a $2\frac{1}{2}$-percent brine, or if clams are being frozen, clam liquor saved from the shucking operation (figure 12a). The shellfish should be kept submerged in the liquid. This can be accomplished by inserting crumpled waxed paper under the jar lid (figures 12b and c).

Shrimp may be frozen, either raw or cooked, for storage in lockers and home freezers. Raw shrimp are prepared for storage by breaking off and discarding the head portion. The remaining tails with the shell intact are then washed and packed in freezer jars or sealable bags with or without a covering of water or $2\frac{1}{2}$-percent brine. Water or brine as a packing medium excludes air and extends the frozen-storage life of the product. If a frozen cooked product is desired, the raw shrimp are headed, the shell is peeled from the tail portion, and the raw edible meat is boiled in 5- to 10-percent brine for 4 to 15 minutes, depending upon the size of the shrimp. Cooked shrimp are packed in the same manner as are raw shrimp. Toughening of cooked shrimp in frozen storage can be delayed somewhat by covering them with water or brine.

Crab must be cooked before they are frozen. In this process, the live crab are cooked in boiling water or 2½- to 5-percent brine for 10 to 20 minutes--depending upon their size--are cooled immediately afterward in cold water, and are drained. The cooked crab, when cold, can be packaged in the shell in frozen-food-type cellophane, polyethylene, pliofilm, or cry-o-vac bags, and the bag can be heat sealed or closed with a tie or a clamp.

If shucked crabmeat is desired, the top shell, gills, and viscera are discarded, the crab is broken in half, and the body meat is shaken from the bottom shell. (This method of removing body meat does not apply to blue crab, the meat of which must be picked out.) Meat from the claws and legs may be removed by cracking them with a mallet and shaking them over a pan. Crabmeats are packed the same as are cooked shrimp. Toughening can be retarded by covering with water or 2½-percent salt brine.

## Protection during Frozen Storage

If fish are placed directly in the refrigerated locker without suitable protective treatment or packaging, several undesirable changes will take place during cold storage. A gradual loss of moisture will occur until the fish are shrunken and dried. This dehydration not only causes an unsightly appearance and alteration in texture but also results in loss of weight and flavor and accelerates the development of rancidity. If fish are not protected from the air of the cold storage room, discoloration and strong rancid odors and flavors develop.

### Ice glaze

Large whole or dressed frozen fish are usually glazed or dipped in cold water to form a protective layer of ice on the outside of the fish. This ice glaze effectively seals the fish and prevents it from coming in contact with the oxygen of the air; any evaporation that takes place comes from the ice glaze and not from the fish itself (Fishery Leaflet 429, section 3). Fish that are glazed in this way should be dipped in water or sprayed periodically during the storage period to replace ice lost through evaporation. It is more convenient, however, to wrap the glazed fish in some suitable moisture-vaporproof material to prevent the loss of glaze and thus eliminate the necessity for reglazing.

The glazing of frozen fish is usually not convenient for the homemaker, but it can be accomplished by freezing the fish, then placing a pan of water in the locker or home freezer until the temperature of the water reaches 33° to 40° F., dipping the fish in the cold water, and removing the fish and letting a film of water freeze on it. The dipping operation should be repeated two or three times until a heavy glaze is formed.

## Moisture-vaporproof wrapping materials and bags

The selection of the appropriate wrapping materials and the use of the proper method of applying them are very important in the successful storage of frozen fish (Fishery Leaflet 429, section 3). Ordinary waxed paper (paraffin coated) is not recommended because it does not retard the loss of water vapor adequately. Furthermore, the wax coating cracks at the folds and permits considerable moisture to escape. Transparent cellophane of the frozen-food type with anchored-moisture-vaporproof and heat-sealing coatings in both sheet and bag form is very good for packaging fillets, steaks, and chunks. If an overwrap is used to cover the cellophane, protection is obtained against tearing. Other transparent sheet- and bag-packaging materials that are very good include frozen-food types of polyethylene, pliofilm, and cry-o-vac. Freezer-weight aluminum foil is also very good for wrapping fillets, steaks, and chunks because it is resistant to water vapor and can be molded to fit the contour of the piece of fish (figures 13, 14, and 15).

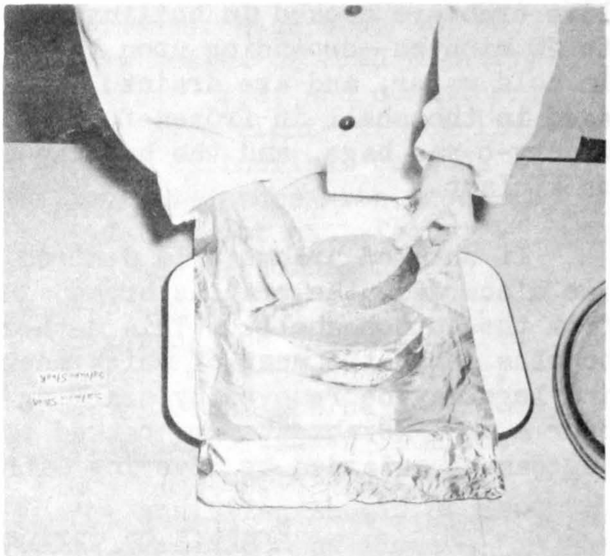


Figure 13.--Placing steaks on foil.

Figure 14.--Folding the foil

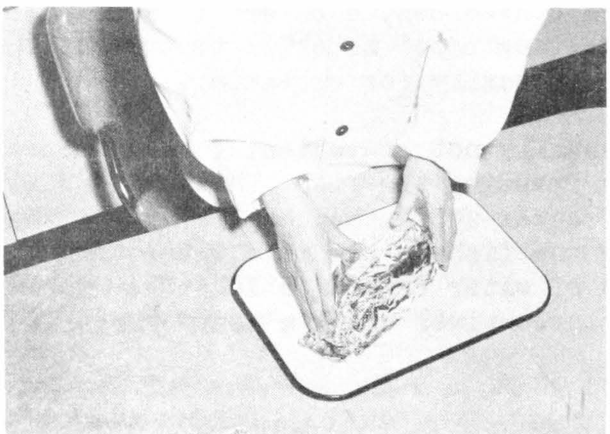


Figure 15.--Molding foil to contour of steaks.

In packaging fish, one should wrap the product tightly in order to remove a maximum amount of air from within the package. A very small volume of air is sufficient to cause considerable discoloration and rancidity. It is advisable to use a generous amount of wrapping material to provide overlaps at the ends of the package. These overlaps can be folded over and fastened with locker tape or tied with string.

### Containers

Glass freezer jars, metal cans, and soft plastic cartons fitted with airtight covers meet all of the requirements of a container for frozen foods. Steaks, fillets, very small whole or round fish, and shellfish should be carefully packed in the container to within 1½ inches of the top for quarts, and 1 inch of the top for pints. Enough water should then be added to fill the spaces between and around the fish and to just cover the product. Entrapped air bubbles may be removed with the aid of a spatula or blunt knife. The lid is then fastened tightly into place to assure an airtight seal. The ice, when frozen, serves to keep the air that is enclosed in the container away from the fish, and the seal on the container prevents the evaporation of water. Round containers, compared to those of a square shape, have the disadvantage of being uneconomical of space in the locker. Freezer jars are of heavy construction and resistant to sudden temperature changes. They will not break when their contents are frozen, if the recommended headspace is provided.

## Freezing Fish in Locker Plants and Home Freezers

### Locker plants

If the locker plant in which the food is to be stored is equipped with a sharp freezer or a blast freezer, the fish and shellfish should be frozen in it before being placed in the locker. These freezers are capable of rapidly cooling the fish down to 0° F. They are essential in freezing the fish before it has a chance to spoil and in preventing the formation of the large ice crystals that result from very slow freezing.

Locker-plant operators usually require the fish to be packaged and labeled as to its identity before it is placed in the freezer. Following this rule prevents loss of food parcels. In some plants, the locker operator loads and unloads the freezer for the patrons. In using a sharp freezer or a blast freezer, one should place the fish in intimate contact with the metal shelf or plate or directly in line with the flow of air so as to obtain as rapid freezing as possible.

If a freezer is not available in the locker plant, the fish or shellfish may be frozen in the locker itself in small quantities of 5, 10, or 15 pounds at a time, depending upon rate of freezing and the available space in the locker. If larger amounts are frozen, the rate of freezing will be very slow. To freeze fish in relatively still air, one should keep the packages or containers separate from the other frozen fish in the locker.

Fish can be sharp or blast frozen in 8 to 12 hours, depending upon the capacity of the freezer, whereas 24 to 48 hours will be required for freezing fish in the locker, depending upon how much is being frozen at one time. The use of the freezer prevents the undesirable warming of frozen fish already in the locker, which occurs when unfrozen packages are added. Once fish have been frozen to 0° F., they can be stacked in the locker with other frozen fish.

### Home freezers

The methods used in freezing and storing fish and shellfish in a home freezer are similar to those used in freezing and storing them in a locker. The home freezer usually has more space, however, and some are divided into freezer and storage sections. The amount of fish that can be frozen in a home freezer is limited to what can be placed in direct contact with a refrigerating surface at any one time (Shelor and Woodroof 1954). In a chest-type freezer, this amount is about 12 percent of the total capacity, whereas in an upright type, this amount is about 23 percent. The area available for freezing fish is confined to the refrigerated shelf surface in an upright freezer and usually to the bottom surface in a chest-type freezer. Fish and shellfish freeze most rapidly in flat cartons laid flat against the refrigerated surface. When these cartons are stacked two deep, they require eight times as long for freezing. Some chest freezers have a freezing section with walls that contain refrigerating coils. Fish can be frozen on both the floor and the walls of this section provided that the packages are placed in tight contact with the walls. Here again, freezing capacity is limited to the packages that can be placed in contact with the refrigerated surface.

Household refrigerators that have a frozen-food storage compartment can be used for freezing fish as well as for short-time storage of frozen fish. Freezing capacity is limited to the packages that can be placed in contact with the horizontal refrigerating surface.

## Storing Fish in Locker Plants and Home Freezers

Before frozen fish are stored--and again periodically during storage--the temperature of the room in which the lockers are located or the temperature of the home-freezer cabinet should be checked. If a thermometer is not provided in the locker room, a small dial thermometer called a refrigerator-and-deep-freeze thermometer may be purchased for this purpose.

Low temperature and high humidity in storage are necessary to obtain maximum storage life from a given species of fish. Toughening, loss of flavor and color, and development of rancidity in a given species of frozen fish will occur much more rapidly in storage at temperatures above 0° F. than in storage at those below 0° F. Fluctuating temperatures provide storage conditions for fish that are little better than those at a temperature equal to the maximum that prevails during the temperature-fluctuation cycle (Pottinger 1951). Storage in rooms of low relative humidity (dry air) causes excessive drying of the frozen fish unless good protective packaging is provided.

If the fish that are placed in the locker or home storage cabinet are labeled, dated, and stored in rows, in rectangular wire-mesh baskets, or on shelves, desired items are easily found, and the taking of the inventory is facilitated. All of the fish in storage will be available for use at any time, and none of the fish need become unpalatable from having been held too long in storage.

## Thawing Frozen Fish and Shellfish

Fish fillets and steaks, which are thin in cross section, can be baked or fried from the frozen state if desired. A longer baking or frying time is required, however, because additional heat is needed (Osterhaug and MacFarlane 1955).

The fish should be thawed in the film or bag in which it is packaged. Overnight thawing in the lower part of a refrigerator is simplest and best if the meal can be planned a day in advance. With less advance notice, one can conveniently thaw frozen fish in 6 to 8 hours at room temperature. Use of a fan to blow air over the package will reduce the thawing time to only 3 to 4 hours at room temperature. If even less time is available, frozen fish may be thawed in running cold water in 1½ to 2 hours or less provided the fish is in a sealed package so that the water does not come in contact with the fish.

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