FREEZING FISH AT SEA--NEW ENGLAND

Part 10 - Studies of Miscellaneous Handling Problems 1/

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ABSTRACT

This paper deals with miscellaneous studies of the handling problems encountered in the freezing of fish at sea, storing frozen fish on the vessel and ashore, thawing the fish prior to filleting, and cutting the thawed fish and packaging the fillets. Freezing capacity and certain limitations imposed by the brine freezer are discussed along with some problems of storage of round-frozen fish on the vessel. Boxes holding about 410 pounds of fish are suggested for use in moving the fish into cold storage and storing them. Some suggestions for thawing the fish are made. The thawed round fish have proven easy to scale and fillet.

INTRODUCTION

That freezing fish aboard a trawler for subsequent thawing and processing ashore might be practical has been strongly indicated by the results already published by the U. S. Fish and Wildlife Service's Technological Laboratory in Boston, Mass. Fillets prepared from haddock frozen at sea on the experimental trawler Delaware and thawed ashore have proven equal to the best fillets prepared from haddock handled and iced in the usual commercial manner. Freezing fish at sea appears to offer a practical solution to the dream of deep-sea fishermen: always to deliver a capacity load with all the fish of a uniformly high quality and bringing the highest prices.

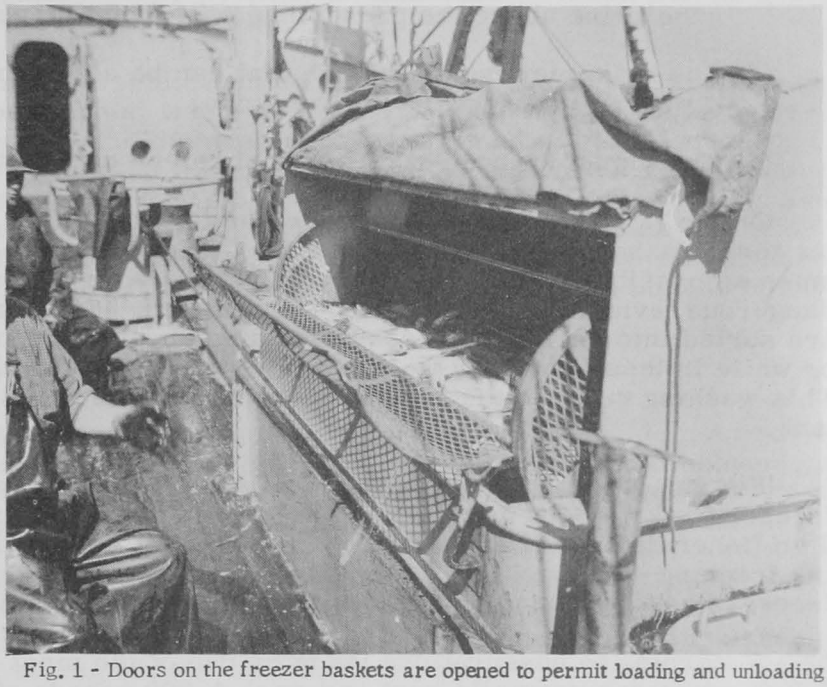

Fig. 1 - Doors on the freezer baskets are opened to permit loading and unloading

For reviews of the related literature and for details of the progress of other phases of this investigation, reference should be made to the earlier reports in this series. The background and the results of the entire investigation were reviewed in the paper by Puncochar and Pottinger (1953).

The installation of refrigeration equipment on the Delaware has not interfered in any way with the normal handling of the fishing nets. However, from the time the fish are on the deck, the procedures employed on the Delaware differ from those employed on a commercial trawler. This paper is a report on miscellaneous studies of the handling problems which are peculiar to (1) freezing fish at sea, (2) storing frozen fish on a vessel, (3) storing these fish ashore, (4) thawing frozen fish, and (5) cutting the thawed fish and packaging the fillets.

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1/ This report is a slightly modified version of a paper read before the Fisheries Symposium, Swedish Institute for Food Preservation Research, Goteborg, Sweden, November 18, 1953.

FREEZING OPERATIONS

The freezing system now in use on the Delaware has been described by Oldershaw (1953 A and B; 1955). The improved freezer being used consists essentially of 11 cylindrical wire-mesh freezer baskets, moving in a tank of refrigerated brine. This tank extends from the floor of the fish hold to about 30 inches above the deck. Each freezer basket is 84 inches long and 24 inches in diameter. These baskets are suspended horizontally between two chains which operate over drive sprockets above the top of the tank and under idler sprockets near the bottom. The freezer baskets move at about 30 feet per minute; 7 or 8 baskets are under the brine at any one time.

In the evaluation of the commercial possibilities of this freezing system, the rate at which it can handle fish is of prime importance. Any one or more of five factors can limit the capacity of the system to freeze fish:

(1) The rate at which the fishermen can load and unload the baskets.

(2) The minimum time required before the fish are completely frozen.

(3) The maximum sustained rate at which fish can be added without warming the brine above the prescribed operating temperatures.

(4) The maximum weight of fish that can be added in a short interval of time without unduly warming the brine.

(5) The maximum weight of fish that can be held in the system at one time.

On the Delaware the preliminary sorting of the fish in the catch is quite similar to the standard commercial practice. However, the use of forks is avoided as much as possible. Since the fish are frozen in-the-round, the tedious and slightly dangerous eviserating operation is eliminated. For convenience, the round fish are sorted into small wire baskets holding about 65 pounds each. While on the deck or while in these small baskets, the fish are washed with sea water from a deck hose. This washing reduces the accumulation of dirt, seaweed, and other debris in the brine tank.

For the loading and unloading operations, the mechanism is stopped so that a freezer basket opens at a convenient height, 30 to 40 inches above the deck (fig. 1). Two fishermen can easily lift a small basket of sorted fish and empty the fish into the freezing-tank baskets. After the fish are frozen, they are removed from the freezer basket by hand and sent down a chute to the hold.

According to observations made on two of the most recent trips of the vessel, 6 fishermen can normally sort and wash 1,000 pounds of scrod haddock, load these fish into the freezer, and remove an equal weight of frozen fish in less than 17 minutes. Miscellaneous operations, including adjustments in the storage space, require an additional 3 or 4 minutes per 1,000 pounds. In an hour and 15 minutes, which is about the average time for the net to be fishing, the fishermen could easily handle 3,300 pounds of fish both into and out of the freezer.

Pilot-plant studies had indicated that it would be safe to load a freezer basket at a rate of 20 pounds of fish per cubic foot. Thus the baskets in the Delaware's freezer were planned to handle at least 400 pounds of fish each. In trials at sea it was found that even when each basket was loaded with 450 to 500 pounds, the freezing rates were not noticeably affected. Thus the entire mechanism, which has 11 freezer baskets, can hold a maximum of 5,000 to 5,500 pounds of fish at one time.

If too large amounts of fish are placed in the freezer at one time, the temperature of the brine will rise above the prescribed maximum limit of +10° F. The extent of the temperature rise and the time interval until the maximum is reached depend on the size of the fish involved, as well as on their total weight. When 2,000 pounds of scrod haddock were added rapidly to the brine at +5° F., the brine temperature reached a maximum of +10° F. after about 30 minutes. When the same weight of larger fish was added, there was less rise in temperature and the maximum temperature was reached after a longer time.

The characteristics of the refrigeration machinery and of the heat exchangers limit the sustained freezing rate of the system. The plant was designed to freeze 1,000 pounds of fish per hour. In trials at sea the system has been able to freeze only 600 to 775 pounds per hour. Changes and additions already made and being made to the absorption plant and heat exchangers are expected to increase the refrigeration rate to at least the amount originally specified.

The results of pilot-plant studies of the time required to freeze fish, as reported by Magnusson and Hartshorne (1952), have been confirmed by observations on the commercial-scale operations of the Delaware. For convenience aboard the vessel at sea, the fish are separated into only three sizes. Scrod cod, scrod haddock, and other small fish weighing less than 3 pounds are left in the freezer for at least 1½ hours; haddock and cod weighing up to 9 pounds, for 3 hours; whereas fish larger than these are left in the freezer for 4 or 5 hours.

The experimental trials so far indicate that it may be necessary to prepare new brine for each full-scale commercial trip. On the Delaware, brine has been prepared most expeditiously by rotating the system with unopened cotton bags of rock salt in the freezer baskets. When the water was at 60° F., the necessary 7,100 pounds of salt could be dissolved in 3 or 4 hours. When fish are being frozen, the salt content of the brine drops, because sea water adheres to the fish being introduced, while concentrated brine adheres to the frozen fish being removed. It has been found necessary to add about 100 pounds of salt for each 10,000 pounds of haddock frozen.

STORAGE OF FISH ON THE VESSEL

For various reasons, the present arrangements on the Delaware do not provide the maximum possible storage space for frozen fish. For experimental convenience and for general safety in the experimental work, the ammonia absorption system and the evaporative coolers were located in a room separate from the main machinery of the vessel (Butler, Puncochar, and Knake 1952). In a vessel intended solely for commercial operations, the refrigeration machinery could be advantageously located elsewhere in the vessel, principally in the main machinery room. From the experience and the information gathered on the Delaware, further space-saving arrangements would bring the total storage space on a commercially-operated vessel to 50 percent or even 75 percent more than on this experimental vessel.

As now arranged, the Delaware has a maximum of 3,800 cubic feet of cold-storage space. When frozen fish were simply dropped into the storage spaces, the average density of the fish was at least 30 pounds per cubic foot. With very little extra time and effort being taken in the arrangement of the fish in the hold, the density was increased to 33 pounds per cubic foot. Several trials indicated that there is very little difference between the volume of storage space required by the different sizes and species of fish.

On the Delaware the fish are now sent directly from the freezer basket down a short chute to an opening in one of the two hatches. In this opening is a moveable arrangement which directs the frozen fish into any of four directions. Semipermanently installed chutes then carry the fish to the proper pen sections. It has proven

unnecessary for anyone to work in the refrigerated holds until the holds are about two-thirds full. Thereafter, as the last third of the load accumulates, 1 or 2 men must occasionally arrange the frozen fish to assure loading each section to its capacity. The total time spent in the hold is only a small fraction of the time required to ice down a comparable load of eviscerated fish.

All frozen fish delivered by the Delaware have been removed in canvas baskets common to the Boston Fish Pier. These hold 150 to 175 pounds of iced fish per load. The weight of frozen fish loaded by an experienced crew averages about 85 pounds per basket. A crew of 3 men in the hold, 1 at the hatch, 1 on the winch, and 1 or 2 on the dock could maintain a rate of unloading of 100 baskets per hour. With 2 hatches being unloaded simultaneously, the maximum that can be unloaded by this method is about 17,000 pounds per hour.

Fig. 2 - Frozen fish delivered by the Delaware are unloaded into large boxes for for holding in frozen storage.

The unloading of large catches of fish has been complicated by the crew's natural aversion towards staying for long periods in the refrigerated holds. Also the work is hampered by a fear of the hard-frozen fish falling from the basket back into the hold. For their protection, the men in the hold wear hard-top hats of the type worn by construction workers.

The ultimate solution to the problem of removing the frozen fish from the storage space seems to be a continuous conveyor lowered to the level of the fish. However, the relatively small quantities delivered so far and the cost of any experimentally constructed conveyor have prevented a testing of this assumption.

It was intended to maintain the frozen-storage holds at 0° to $+5^{\circ}$ F. In practice, the temperature has often approached $+10^{\circ}$ F. When such high temperatures were encountered on a trip, the fish packed a little closer, being over 33 pounds per cubic foot. Whenever the temperatures rose and later fell, or when the fish entering the hold were not completely frozen, there was a tendency for the fish in the bottom of the hold to freeze together. When proper freezing and storage temperatures were employed, this problem was eliminated.

STORAGE OF FISH ASHORE

If fish frozen at sea are thawed and processed within a few hours after the vessel unloads, there is, of course, no need for cold storage ashore. However, it is anticipated that a large portion of the fish frozen at sea will be stored at least for a few days and possibly for several weeks. These fish will then be withdrawn from storage as they are needed to maintain a more or less constant processing rate in the filleting plant. This will provide for the most efficient use of a permanently employed processing crew.

About 70 percent of the frozen fish delivered by the Delaware has gone directly into a cold-storage warehouse located on the Boston Fish Pier. A temporary platform was installed from the regular platform of the warehouse to the edge of the dock. At first boxes which held 110 to 130 pounds were used to move the frozen fish into the warehouse. Eight of these boxes were loaded on a "flat," which was moved on a four-wheel hand truck. Generally, these boxes were emptied in the cold-storage room, and they were used many times during the unloading operation. Between 35 and 45 man-hours were required to transfer 10 tons of frozen fish from the dock into cold storage. Additional labor was required later when the fish were removed. This procedure was soon discontinued, primarily because of the excessive labor requirements. Furthermore, it was difficult to build high piles of loose fish, and therefore the storage space was not efficiently used.

The frozen fish delivered by the last few trips of the Delaware were moved and stored in specially-built larger boxes (fig. 2). The most satisfactory box, 30 by 37 by 23 inches inside dimensions, capable of holding about 410 pounds of fish frozen at sea, was designed to fit on one of the common-type wooden pallets. When properly stacked, these boxes make efficient use of the full height of the storage rooms. The boxes are fairly rugged and can withstand moderately rough treatment. They are sufficiently tight to serve as convenient tanks for thawing the fish in water. Leaving the fish in the boxes has saved much expensive labor in the cold rooms. When these specially-designed boxes were employed, warehouse personnel devoted only 11 man-hours to place 10 tons of frozen fish in cold storage. After only 3 or 4 uses, the savings in labor and in storage charges would equal the cost of the boxes.

A few trials have been made on the use of a variety of paper and fiber bags for handling and storing fish frozen in brine at sea. So far no bag has proven inexpensive, sturdy, easy to handle, and sufficiently resistant to water. A possible advantage to the use of bags or other small containers would be that the fish could be handled, unloaded, and even thawed in convenient units of 40 to 80 pounds. This assumes that the frozen fish would be placed in the bags by the fishermen, preferably at sea.

Most of the frozen fish landed by the Delaware was stored in still-air cold-storage rooms held at 0° F. After six months in this storage, a slight but noticeable odor resembling rancidity developed on the surface of some of the frozen haddock. A few of the small haddock at the top of the stacks showed signs of desiccation after nine months of storage. Less than two percent of the fish stored for one year were not usable. In well-stacked lots of loose fish and in lots of fish left in boxes, the losses were even less. More serious desiccation and rancidity occurred in lots of frozen haddock stored in the cold-storage room of the laboratory. The room is refrigerated by circulated air. Storage of fish in this room in an uncovered box for over one month resulted in excessive losses due to desiccation.

THAWING OPERATIONS

The results of laboratory and pilot-plant investigations of thawing fish frozen at sea have already been reported in considerable detail (Magnusson and Hartshorne 1952). On the basis of these investigations, it was recommended that the frozen fish be thawed by immersion in well-circulated fresh water at about 60° F. When complete thawing was required in semicommercial-scale operations, scrod haddock were left in water at 60° F. for 2 hours. For these fish to thaw sufficiently to permit filleting, $1\frac{1}{2}$ hours in the water was adequate. Haddock and cod weighing 9 pounds were ready to fillet after 3 or $3\frac{1}{2}$ hours in water at 60° F. As might be expected, the rate of thawing was found to be nearly directly proportional to the difference between the water temperature and 30° F. To thaw frozen fish in water at 45° F. required approximately twice as long as at 60° F. At 88° F. the thawing time was half that at 60° F.

Several tests were made to determine the effects of thawing water temperatures above 60° F. on the quality of the thawed fish. Haddock thawed in water at 72° F.--if they were cooled before being filleted--were found to be as good in all respects as similar haddock thawed at 60° or 50° F. Noticeable adverse effects were noted on haddock thawed at 80° F. for over an hour. After haddock were in water at 85° F. for about 40 minutes, the skin separated easily from the meat. The meat of the haddock appeared to be partially cooked when the fish were thawed in water at 95° F.

In several tests the fish were kept in the thawing tank for 3 to 5 times as long as was required to complete thawing. In no case did the fillets exhibit any odors or flavors attributable to deterioration of the viscera. This was true though fish were in water at 80° F. for 4 hours or at 40° F. to 45° F. for 20 hours. There are some indications that excessive time in the thawing water even at 60° F. may make cod and haddock less suitable for smoking. More information is needed on this problem, however.

Fig. 3 - Hoisting thawed round fish from the thawing tank.

The methods and the tank successfully used in the laboratory for semi-commercial-scale thawing have been described (Magnusson 1952). This tank--35 inches wide, 95 inches long, and 35 inches deep, with 3 wire-mesh baskets of 14-cubic-feet capacity each--has been used often to thaw 1,100 pounds of frozen haddock (fig. 3). The water in the tank has been kept moving with a $\frac{1}{3}$ hp. centrifugal pump or with a propellor-type mixer of the same power. Both have proven effective at providing the very necessary circulation of water past the fish. An overhead hoist and a monorail system facilitate transporting the baskets from the unloading platform to the thawing tank and later back to the platform.

Transportation of the frozen fish from the cold-storage warehouse to the processing plant offers no unusual problems. Fish frozen at sea have been easily transported by truck in bulk or in the storage boxes. When the load of frozen fish was covered with a tarpaulin, there was no serious thawing during the 30 to 90 minutes required to travel from the cold-storage warehouse to the laboratory pilot plant.

Recent trials have demonstrated that under certain circumstances the frozen fish can be satisfactorily thawed in the 410-pound-size boxes described in an earlier section of this paper. Although such boxes are not watertight, a moderate stream of water can keep them full. This procedure is practical only if the normal supply of water is neither so warm as to harm the fish nor so cold as to require too much time, water, and space to thaw them. When the fish are thawed in boxes, special effort is necessary to agitate the fish frequently to prevent "packing," which slows the thawing process.

There is generally a slight increase in the weight of the fish during the thawing operation. The slime, any dirt, and a few scales are washed off, but a compensat-

ing quantity of water is absorbed. When the frozen fish had been kept in still-air storage, the net gain in weight during thawing generally ranged between 1 and 2 percent. If the fish had been poorly stored, for instance in an air-blast refrigerated room, larger increases in weight resulted during thawing.

CUTTING AND PACKAGING

After fish frozen at sea have been thawed, they can be transported, handled, and processed in essentially the same way as iced eviscerated fish taken directly from a trawler. In fact, if a thawed haddock is eviscerated and its gills are removed, the resulting dressed fish compares well with the freshest available dressed haddock at time of landing. The viscera taken from the thawed fish are generally intact and in fresh condition. If the thawed fish are not cut immediately, the viscera starts to soften and deteriorate. The freezing and the thawing operations cause the gills to turn a muddy brown. Therefore, the color of the gills is not a good criterion of the freshness of these fish.

Except when the viscera were saved for some special experiment, the thawed fish have not been eviscerated before being processed into fillets. The whole round fish, full of viscera, have proven easy to scale and to fillet. Processing-plant employees who have worked with fish frozen on the Delaware unanimously agree that it is easier to scale the thawed round fish than the customary eviscerated fish. A great majority of these employees also reported that the thawed fish was the easier of the two to fillet. The fish frozen at sea and thawed quickly in circulating water exhibit a desirable firmness. Often the fish taken from a thawing tank appears to be in a mild state of rigor mortis. This is not a rigor due to salt; it is simply the firmness of a very fresh fish.

If the thawed fish are too warm when they are filleted, some of the advantages of freshness and firmness are lost. Whenever the temperature of the fish has ex-

Table 1 - Comparative Data on Processing of Iced Eviscerated Haddock and Thawed Round Haddock

Size of Haddock	State of Haddock	Initial Weight (from 1,000 Pounds of Whole Round Fish)	Time Required to Scale	Time Required to Fillet	Weight of Fillets with Skin on
		Pounds	Man-Hours	Man-Hours	Pounds
Small (caught in October)	Iced eviscerated (gills in)	903	0.70	3.2	429
	Thawed round (replicate 1)	1000	0.71	3.5	445
	Thawed round (replicate 2)	1000	0.74	3.3	425
Medium (caught in July)	Iced eviscerated (gills out)	839	0.49	1.6	380
	Thawed round (replicate 1)	1000	0.50	1.5	390
	Thawed round (replicate 2)	1000	-	-	371

ceeded 60° F., the meat has been unnecessarily soft, and therefore the fish has been difficult to handle and cut. This problem has been solved by spraying the fish with cool water or sprinkling ice on them. A simpler solution has been to remove the fish from the water when thawing was only 80- or 90-percent complete. This procedure has the added advantage of saving thawing time and equipment.

Data have been secured on the times required to scale and to fillet both round fish and iced eviscerated fish. The yields of fillets from both have also been compared. Data for two such series of trials made in a cooperating commercial plant are given in table 1. It will be noted that rates of processing and the yields of fillets for iced eviscerated fish and for thawed round fish are not significantly different. Both the frozen fish and the iced eviscerated fish used in these trials were delivered by the Delaware. It is believed that if frozen fish were compared with fish handled and iced on a regular commercial trawler, there would be a definite processing rate

and yield advantage in favor of the frozen fish. For example, the frozen fish are delivered to the filleting table at the same weight as when they are caught, whereas there apparently is quite an appreciable shrinkage of eviscerated fish during storage in ice on the trawler.

The fillets prepared from haddock frozen at sea tend to be firmer and darker than fillets from iced eviscerated fish. The difference in color is most noticeable on freshly cut samples. After they have been held a short time under ice or in frozen storage, the color difference is reduced or eliminated. The results of consumer-type taste-panel tests (Pottinger, Holston, and McCormack 1952) indicate that freezing fish at sea for subsequent processing ashore can produce a uniform, high-quality, marketable, and delectable fillet.

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SINGLE FISH STICKS SOLD IN NEW YORK CITY

Fish sticks are being sold by the individual stick in a number of New York City markets. The merchant sells the individual breaded sticks, both cooked and uncooked, from bulk packages. Sales are reported to be brisk.

--N. F. I. Flashes, December 17, 1954.