# COMPARATIVE KEEPING QUALITY, COOLING RATES, AND STORAGE TEMPERATURES OF HADDOCK HELD IN FRESH-WATER ICE AND IN SALT-WATER ICE

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ABSTRACT

IN AN EXPERIMENT ON ICING REPRESENTATIVE SAMPLES OF HADDOCK ABOARD A FISHING VESSEL IN EQUAL QUANTITIES OF SALT-WATER AND FRESH-WATER ICE, NO SIGNIFICANT DIFFERENCE WAS FOUND IN THE QUALITY OF THE FISH STORED IN THESE ICES. ALL FISH WAS OF EXCELLENT TO GOOD QUALITY UNTIL THE 9TH DAY OF ICED STORAGE, AND OF ACCEPTABLE QUALITY FROM THE 9TH UNTIL THE 13TH DAY OF ICED STORAGE, AFTER WHICH TIME THEY WERE OF UNMARKETABLE QUALITY. THE HADDOCK STORED IN THE SALT-WATER ICE WERE COOLED FASTER AND TO A LOWER TEMPERATURE THAN WERE THOSE COOLED IN THE FRESH WATER ICE. THE SALT-WATER ICE MELTED FASTER THAN DID THE FRESH-WATER ICE AND LEFT THE HADDOCK WITH LESS PROTECTING ICE, AND HADDOCK LYING AGAINST THE PEN BOARDS WERE COOLED AT A MUCH SLOWER RATE THAN THOSES THAT WERE ICED PROPERLY.

## BACKGROUND

The preservation of fish in ice aboard a fishing vessel is a problem of continuing concern to those engaged in the fishing industry. Fresh-water ice, which is used on the majority of fishing vessels in this country, if properly applied, will preserve fish on the vessel for 1 to 2 weeks, depending on the particular species of fish and on the method of icing. The use of an ice that would be acceptable to health and regulatory agencies (Anonymous 1956) and that yet would substantially increase the keeping quality of fish would be of great value, since it would enable the fishing vessels to stay out longer than now is possible and still return to port with fish of marketable quality.

FIG. 1 - HADDOCK BEING ICED DOWN IN A PEN OF THE VESSEL WITH FRESH-WATER ICE.

The storage of fish in salt-water ice, which has a lower melting temperature than has fresh-water ice, would seem to have merit in providing faster cooling and in reducing the storage temperature of the iced fish aboard the vessel. A reduction (1) in the time required to cool the fish initially and (2) in the storage temperature of the fish might well result in an extended storage life. Because of the faster rate of melting of salt-water ice due to its lower latent heat of fusion, lower temperature, and the many factors that influence the icing and storing of fish aboard a commercial fishing vessel, one can not say with certainty whether or not salt-water ice, when used to ice the fish in the same proportions as fresh-water ice

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is now used, will be of sufficient value to warrant the adoption of it by the commercial fishing industry, or whether larger quantities of salt-water ice must be used to obtain proper fish preservation.

Table 1 - Results of Organoleptic Examination of Raw Haddock Stored in Fresh-Water and Salt-Water Ices

| Storage Time in Ice | Type of Ice | Quality Factors | | | | |
|---|---|---|---|---|---|---|
| | | Clarity of Eyes | Color of Gills | Odor Behind Gill Covers | Odor of Gut Cavity | Odor of Meat |
| Days | | | | | | |
| 5 | Fresh-water | Clear | Bright red | Fresh | Fresh | Fresh |
| | Salt-water | Clear | Bright red | Fresh | Fresh | Fresh |
| 7 | Fresh-water | Clear to slightly cloudy | Bright red to pink | Slightly sour | Slightly sour | Slightly sour |
| | Salt-water | Clear to slightly cloudy | Bright red to pink | Slightly sour | Slightly sour | Slightly sour |
| 9 | Fresh-water | Clear to slightly cloudy | Red to pink | Slightly sour | Slightly sour | Slightly sour |
| | Salt-water | Clear to slightly cloudy | Red to pink | Slightly sour | Slightly sour | Slightly sour |
| 12 | Fresh-water | Slightly cloudy | Red to brown | Sour | Sour | Sour |
| | Salt-water | Slightly cloudy | Red to brown | Sour | | Slightly sour |
| 13 | Fresh-water | Slightly cloudy | Red to brown | Strongly sour | Strongly sour | Slightly sour |
| | Salt-water | Slightly cloudy | Red to brown | Strongly sour | Strongly sour | Sour |
| 15 | Fresh-water | Slightly cloudy and sunken | Pink to dark brown | Strongly sour to putrid | Strongly sour to putrid | Strongly sour |
| | Salt-water | Slightly cloudy and sunken | Pink to dark brown | Strongly sour to putrid | Strongly sour to putrid | Strongly sour |
| 16 | Fresh-water | Slightly cloudy and sunken | Brown | Strongly sour to putrid | Strongly sour to putrid | Strongly sour |
| | Salt-water | Slightly cloudy and sunken | Brown | Strongly sour to putrid | Strongly sour to putrid | Strongly sour |
| 19 | Fresh-water | Slightly cloudy and sunken | Brown to dark brown | Putrid | Putrid | Strongly sour to putrid |
| | Salt-water | Slightly cloudy and sunken | Brown to dark brown | Putrid | Putrid | Strongly sour to putrid |

With the foregoing considerations in view, the Bureau of Commercial Fisheries Technological Laboratory in East Boston, Mass., conducted the following study in which representative quantities of haddock were iced in equal amounts of (1) fresh-water ice and (2) salt-water ice (3 percent salt by weight; melting temperature, 29.5° F.) aboard the Bureau's exploratory fishing trawler Delaware.

## OBJECTIVES

The specific objectives of the experiment were:

1. To determine the keeping quality of haddock iced and stored aboard a fishing vessel (employing the manner traditionally used in the haddock fishery) in:

   a. Crushed fresh-water ice

   b. Crushed salt-water ice (3 percent salt by weight)

2. To determine the cooling rates and storage temperatures of haddock stored in these ices.

## EXPERIMENTAL PROCEDURES

Briefly, the experimental procedures were (1) obtain the haddock at sea, (2) eviscerate and wash them, (3) divide them into two groups, (4) ice one group with fresh-water ice and the other with salt-water ice, (5) measure the changes in temperature of the two groups during storage, and (6) organoleptically determine the change in quality of the two groups during storage. The details of the experiment are given in the subsections immediately following.

PREPARATION OF THE ICES: The ices were made in 300-pound blocks in a commercial ice plant.

Fresh-Water Ice: Ordinary crushed ice as used at present by New England fishing vessels was obtained in 50-pound bags.

Salt-Water Ice: Forty pounds of 100-degree salinometer brine was added to each ice-freezing pan, and water then was added to make 300 pounds of solution. The pans were lowered into the freezing medium, and air tubes were used to agitate the water. After the water had been well agitated, a dispersing agent consisting of 150 grams of carboxymethylcellulose (CMC high viscosity, type 70 1/) was added to each freezing pan. Once the CMC was dispersed (this required agitation for 15 minutes), the air tubes were removed, and the mixture was allowed to freeze without

1/HERCULES POWDER CO., INC., WILMINGTON, DEL.

further agitation. The temperature of the brine (12° F.) used for freezing the solution of salt water was not low enough to freeze the ice sufficiently hard within the period of time allotted so as to permit crushing. The blocks of salt-water ice therefore were brought to the pilot plant of the laboratory where they were cooled for several hours in a blast freezer and then stored at 0° F.

FIG. 2 - ICING DOWN THE TOP TIER OF HADDOCK WITH SALT-WATER ICE.

Pieces of ice chipped from the outside edges and center of a block were allowed to melt, and the salt content was determined with a salinometer. Distribution of the salt was quite uniform throughout the block. Pieces of the finely crushed ice made from the blocks of salt-water ice were melted; the salt content, which then was determined with a salinometer, was 2.8 percent.

On the day of departure of the Delaware, these blocks of ice were easily crushed by a portable ice crusher, which blew the flakes directly into the hold of the vessel.

FIG. 3 - HADDOCK ICED IN THE PENS OF THE VESSEL WITH FRESH-WATER ICE. NOTE THE THERMOCOUPLE WIRES LEADING TO THE INDIVIDUAL FISH.

HANDLING THE FISH ABOARD THE VESSEL: The haddock used in this experiment were caught on the northeast part of Georges Bank in the spring of 1956. The fish, after being landed on the vessel, were eviscerated, washed, and stowed in the respective ices, in two pens located in the midsection hold. Each pen was iced with only one type of ice. Icing was done by the fishermen, under the supervision of the writers, following the procedures customarily employed in the haddock fishery (fig. 1).

The pens were filled with fish, one tier at a

time, in rotation. One tier of fish (approximately 500 pounds) was iced with about 250 pounds of ice in the first pen, then a tier of fish was started in the second pen. After one tier of fish had been iced down in each of these two pens, the next tier of fish was started in the first pen. This procedure was followed until each pen had been filled with four tiers or about 2,500 to 2,500 pounds of fish (fig. 2).

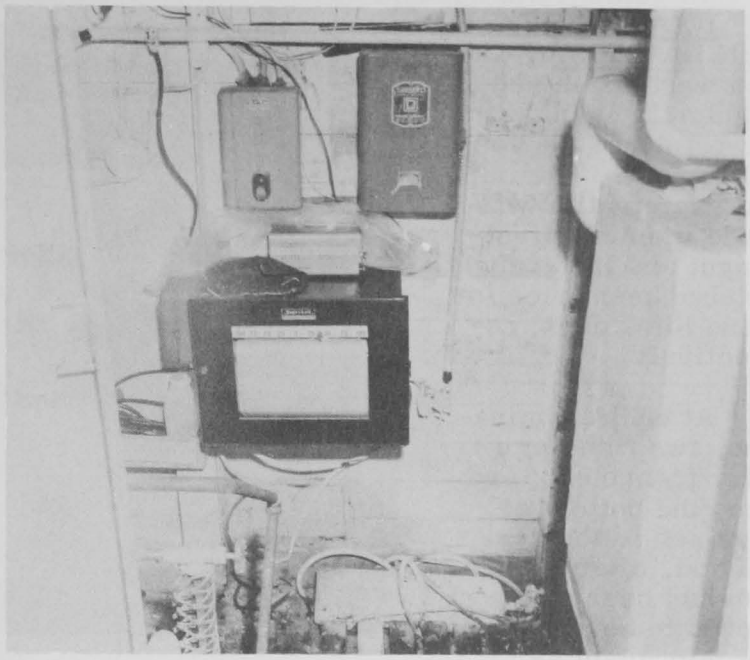

FIG. 4 - POTENTIOMETER USED TO RECORD THE TEMPERATURES OF THE HADDOCK STORED IN THE VARIOUS ICES.

TEMPERATURE MEASUREMENTS: As each tier of fish was being iced, a copper constantan thermocouple was inserted as near as possible into the center of the thickest section of the meat just back of the vent of at least one medium-size fish--average weight of 3 to 4 pounds (fig. 3). The temperatures of these fish were recorded on a 8-point recording potentiometer installed in a compartment adjacent to the engine room (fig. 4). The power to operate the recorder was supplied through a direct current-alternating current inverter. The accuracy of the potentiometer was checked periodically with a mercury thermometer and was found to be $\pm$ 0.5° F. (fig. 5).

FIG. 5 - CHECKING THE TEMPERATURE OF THE HADDOCK WITH A MERCURY THERMOMETER.

HANDLING THE FISH ASHORE: To obtain information representative of the quality deterioration that occurs during prolonged storage on ice, we left the fish aboard the vessel at the dock as long as possible (10 days). The first fish caught were held in ice in the hold of the vessel for 15 days; and the last fish caught, for 12 days.

Fifteen days after the first catch was brought aboard the vessel, 300 pounds of fish from the bottom of each pen were transferred to wooden boxes in the laboratory pilot plant in order to free the vessel for duty at sea. These boxes were constructed with "pen" boards on one side to permit the removal of samples of fish from the top and the bottom (fig. 6). The respective

positions of the top and the bottom fish in the pens were maintained as the fish were transferred to the boxes and were iced with the appropriate type of ice.

EXAMINATION OF THE RAW FISH: The fish were examined at regular intervals after the return of the vessel to port. The initial examination was made when the first-caught and last-caught fish had been in ice for 5 and for 2 days, respectively.

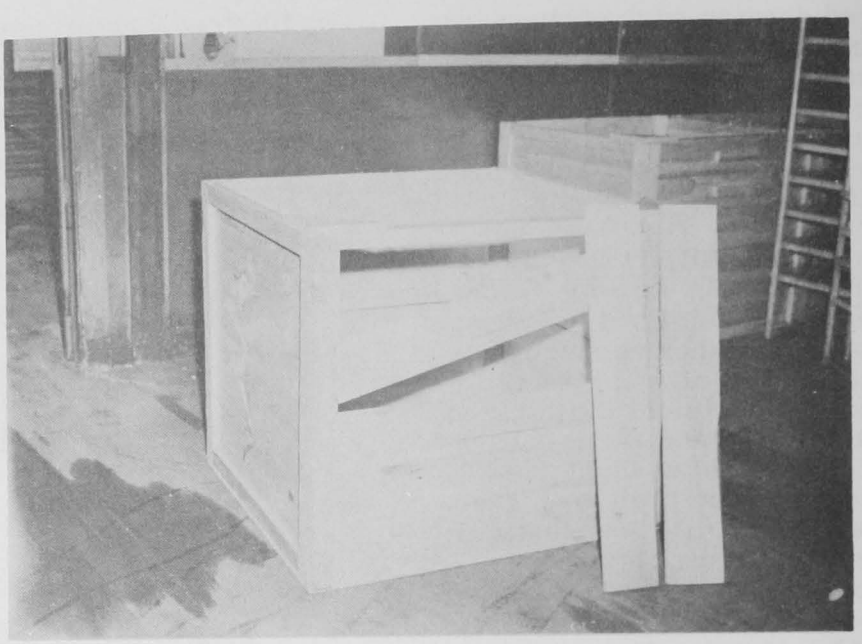

FIG. 6 - FISH BOX WITH SLIDING "PEN" BOARDS.

At each examination, two fish were taken from the top and from the bottom of each pen in the vessel and, after the fish had been transferred to boxes in the pilot plant ashore, from the top and bottom of each box. These raw eviscerated fish were examined for the following quality factors:

1. Clarity of eyes.
2. Color of gills.
3. Odor behind gill covers.
4. Odor of meat.

In these examinations the inspectors did not know the type of ice in which the fish has been stored.

EXAMINATION OF THE COOKED FISH FILLETS: At each examination, fillets prepared from four raw eviscerated fish stored in each of the ices were wrapped tightly in aluminum foil to prevent the fillets from drying out and were baked in an oven at 400° F. for 20 minutes. The aluminum-foil packages then were opened, and the odor of the escaping vapors was noted.

Portions of the cooked fillets were tasted by a panel consisting of 6 to 8 members of the laboratory staff accustomed to making such tests, and were rated for appearance, odor, flavor, and texture.

## RESULTS AND DISCUSSION

KEEPING QUALITY: Raw Fish: The results obtained from the examinations of haddock stored in fresh-water and in salt-water ices are shown in table 1. These results indicate that very little difference in the quality of the fish stored in each of the two ices was noted by the examiners.

Cooked Fish Fillets: Results obtained in examining the cooked fish fillets for appearance, odor, flavor, and texture showed that the ratings of odor, flavor, and texture were the most significant. The taste-panel scores for these quality factors are shown in table 2.

The averages of the scores for all the quality factors presented in table 2 are shown in figure 7. These curves show that the fish stored in the fresh-water and

salt-water ices decreased in quality at about the same rate. The fish stored in both ices were of good to excellent quality until the 9th day of iced storage and of fair to borderline quality from the 9th until the 13th day of iced storage after which they were considered unmarketable. Therefore no extension of the keeping quality of the fish resulted from the storage of the fish in salt-water ice.

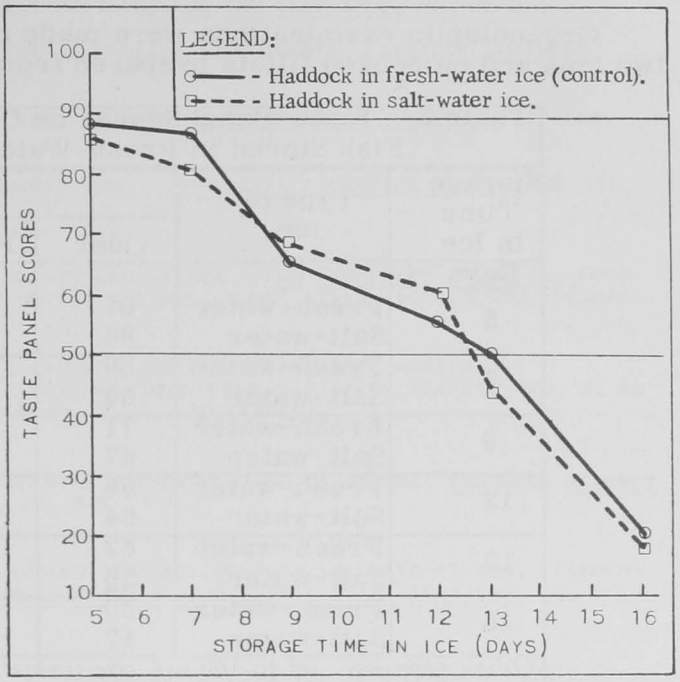


FIG. 7 - AVERAGES OF TASTE PANEL SCORES FOR COOKED FILLETS.

COOLING RATES AND STORAGE TEMPERATURES: The cooling rates of eviscerated haddock stored in fresh-water ice and in salt-water ice are given in figure 8. Examination of these cooling curves shows that icing with salt-water ice resulted in quicker cooling and cooling to a lower temperature than did icing with fresh-water ice.

The top curve (fig. 8) which shows the cooling rate of a fish lying against the pen board, demonstrates very strikingly what occurs when the fish are not completely surrounded by ice. Over 18 hours was required to cool this fish to 32° F. as compared with about 4 hours for a well-iced fish.

The temperatures of the fish, 24 hours after they were iced initially and during storage aboard the vessel, are shown in table 3. These temperatures show that (1) the fish in the bottom of a pen were as cool as or cooler than those in the top of the same pen, (2) the rise in temperature of the fish in the top of a pen was greater than was the rise in temperature of those fish stored in the bottom of the same pen, and (3) the fish stored in salt-water ice rose to a higher temperature than did the fish stored in the fresh-water ice. This higher temperature was due to the faster melting rate of the salt-water ice, which resulted in less ice to protect the fish. Therefore, in order to keep the haddock stored in salt-water ice at temperatures close to the freezing point of the salt-water ice, sufficient quantities of salt-water ice must be used to make up for the faster melting of this ice; additional work on the quantities of salt-water ice that must be used to maintain the fish at the proper temperature level will be conducted in the future.

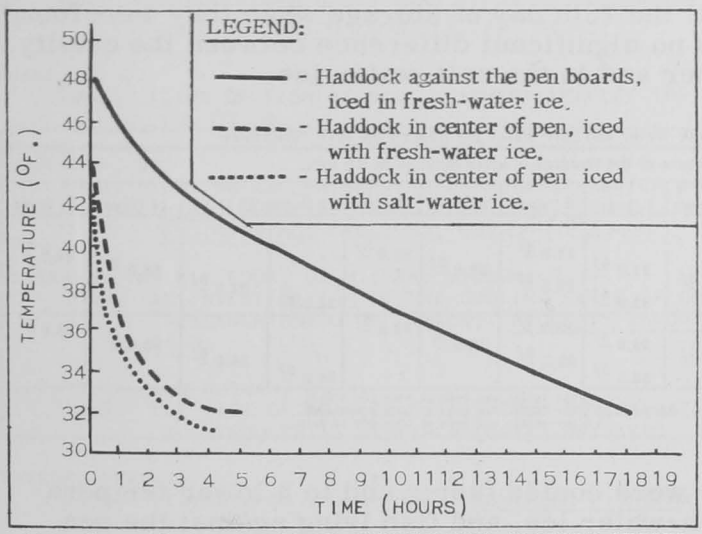


FIG. 8 - COOLING RATES OF EVISCERATED HADDOCK STORED IN FRESH-WATER AND SALT-WATER ICES. (AVERAGE WEIGHT 3 TO 4 POUNDS.)

## SUMMARY

Tests were conducted to determine (1) the keeping quality and (2) the cooling rates and storage temperatures of representative lots of eviscerated haddock stored aboard a fishing vessel in equal quantities of fresh-water and salt-water (3-percent salt by weight) ice when iced in the manner traditionally used in the haddock fishery.

aboard a fishing vessel in equal quantities of fresh-water and salt-water (3-percent salt by weight) ice when iced in the manner traditionally used in the haddock fishery.

Organoleptic examinations were made on raw eviscerated haddock stored in the two ices and on cooked fillets prepared from these fish. The results of these exam-

Table 2 - Taste-Panel Scores on Cooked Fillets Prepared from Fish Stored in Fresh-Water and Salt-Water Ice

| Storage Time In Ice | Type of Ice | Quality Score 1/ | | | |
|---|---|---|---|---|---|
| | | Odor | Flavor | Texture | Average |
| Days | | | | | |
| 5 | Fresh-water | 87 | 93 | 90 | 90 |
| | Salt-water | 86 | 89 | 87 | 87 |
| 7 | Fresh-water | 89 | 87 | 90 | 90 |
| | Salt-water | 84 | 83 | 86 | 84 |
| 9 | Fresh-water | 71 | 61 | 66 | 66 |
| | Salt-water | 67 | 69 | 69 | 68 |
| 12 | Fresh-water | 56 | 57 | 57 | 57 |
| | Salt-water | 64 | 70 | 57 | 64 |
| 13 | Fresh-water | 62 | 52 | 46 | 53 |
| | Salt-water | 56 | 40 | 36 | 44 |
| 16 | Fresh-water | 20 | 23 | 13 | 19 |
| | Salt-water | 17 | 17 | 20 | 18 |

1/FISH SCORING: 90 TO 100 WAS CONSIDERED EXCELLENT; 80 TO 89, VERY GOOD; 70 TO 79, GOOD; 60 TO 69, FAIR; 50 TO 59, BORDERLINE; 25 TO 49, POOR; AND BELOW 25, INEDIBLE. SCORES OF 50 OR ABOVE INDICATE THAT THE FISH WERE MARKETABLE; SCORES BELOW 50 INDICATE THAT THE FISH WERE NOT MARKETABLE.

inations indicate that (1) the fish stored in fresh-water and salt-water ice were of good to excellent quality until the 9th day of iced storage, after which time they were of fair to borderline quality until the 13th day of storage when they were found to be unmarketable, and (2) there was no significant difference between the quality of the fish stored in the the fresh-water and in the salt-water ice.

Table 3 - Temperature of Haddock stored in Fresh-Water and Salt-Water Ice Aboard the M/V "Delaware"

| Location of the Iced Fish | | Temperature of the Haddock 1/ after Storage in Ice for: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Ice | Tier 2/ Number | 1 Day | 2 Days | 3 Days | 4 Days | 5 Days | 6 Days | 7 Days | 8 Days | 9 Days | 10 Days | 12 Days | 13 Days | 14 Days | 15 Days |
| | | (°F.) | | | | | | | | | | | | | |
| Fresh-water | 1 | 32.0 | 32.5 3/ | 32.5 3/ | 32.0 3/ | 32.0 3/ | 33.0 4/ | 32.0 4/ | 32.0 4/ | 32.0 5/ | 32.0 5/ | 34.5 6/ | 32.5 6/ | 33.0 6/ | 32.5 6/ |
| | 2 | | | | | 33.0 4/ | | 33.0 5/ | 32.5 5/ | | | | | | |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |
| Salt-water | 1 | 31.0 | 32.0 3/ | 31.5 3/ | 31.5 3/ | 31.0 3/ | 32.5 4/ | 33.0 4/ | 32.0 4/ | 32.5 5/ | 32.5 5/ | 36.0 6/ | 36.0 6/ | 35.0 6/ | 33.5 6/ |
| | 2 | | | | | 33.5 4/ | | 33.5 5/ | 32.5 5/ | | | | | | |
| | 3 | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | |

1/AVERAGE WEIGHT OF HADDOCK WAS 3 TO 4 POUNDS.
2/TIER NO. 1 WAS THE BOTTOM TIER OF FISH, TIER NO. 2 THE SECOND FROM THE BOTTOM, AND SO ON.
3/DAY OF ARRIVAL OF VESSEL AT DOCK.
4/DAY VESSEL HAD BEEN AT DOCK FOR 3 DAYS.
5/DAY VESSEL HAD BEEN AT DOCK FOR 5 DAYS.
6/DAY VESSEL HAD BEEN AT DOCK FOR 10 DAYS.

The fish stored in salt-water ice were cooled faster and to a lower temperature than were the fish stored in fresh-water ice, and fish lying against the pen boards were cooled at a slower rate than were fish properly iced. Owing to the greater loss of ice, the fish stored in the top of a fish pen, in the hold of the vessel, rose in temperature faster than did the fish stored in the bottom of the same pen. Similarly, owing to the faster rate of melting and the resulting greater loss of ice, fish stored in salt-water ice, after being initially cooled to a lower temperature than the fish stored in the fresh-water ice, eventually rose to a higher temperature than did the fish stored in the fresh-water ice. Therefore, in order to maintain the fish in the salt-water ice at a temperature close to the melting point of this ice sufficient quantities of ice must be used to make up for the faster melting.

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