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Freezing Shrimp At Sea

H. E. CROWTHER, *Chief, Technological Section, Branch of Commercial Fisheries, Fish and Wildlife Service, Washington, D. C.*

ONE OF THE MAJOR PROJECTS in the Fish and Wildlife Service's present technological program is freezing fish at sea. By means of this research work it is hoped to determine whether it is possible to freeze fish in the round at sea and later at a shore plant defrost, fillet, package, and refreeze the fillets and still obtain a high quality product. Such a process, to be practical, must be workable not only from a technological and mechanical viewpoint but it must be economically sound. Experiments now in progress at Boston are providing information which will permit a definite recommendation to the fishing industry on the feasibility of the process.

Specifically, the main purpose of this paper is to describe briefly the work being done at Boston and to pass on to those interested in the shrimp industry the information gained thus far in fish freezing work which may be applicable to shrimp.

Present Refrigeration Methods Used on Shrimp Boats

Shrimp boats in the Gulf of Mexico may be divided into two general classes, according to their size and area of operation. The small boats, ranging in lengths from 25 to 55 feet concentrate on the shallow, inshore waters. The larger vessels from 50 to 80 feet in length fish the off-shore waters and can remain at sea for as long as 10 days. Many of the vessels in the 50 to 80 foot class and capable of fishing in any part of the Gulf and are often found in the distant Campeche area.

Crushed ice is practically the only means of refrigeration available to a majority of the shrimp boats. On long trips, such as those to Campeche, ice may be the item which determines the length of the trip. Fishing time on the grounds is limited because provision must be made for the 3 or 4 days required for the voyage to the plant, so fishing must cease when the ice supply reaches a low point. Travel to and from distant fishing grounds is not only costly but involves the chance of loss of the entire catch of shrimp through spoilage if delay occurs. One possibility of extending the length of the trip is to use some form of mechanical refrigeration to retard the melting of the ice or to replace the ice entirely as a refrigerant. Some boats have installed such equipment but they are few in number.

The most recent approach to solving the refrigeration problem is the use of freight boats or mother ships to pick up the shrimp from trawlers on the fishing grounds and freeze the headless shrimp at sea in 5 pound cartons. Several boats of this type are now in operation and apparently are having some

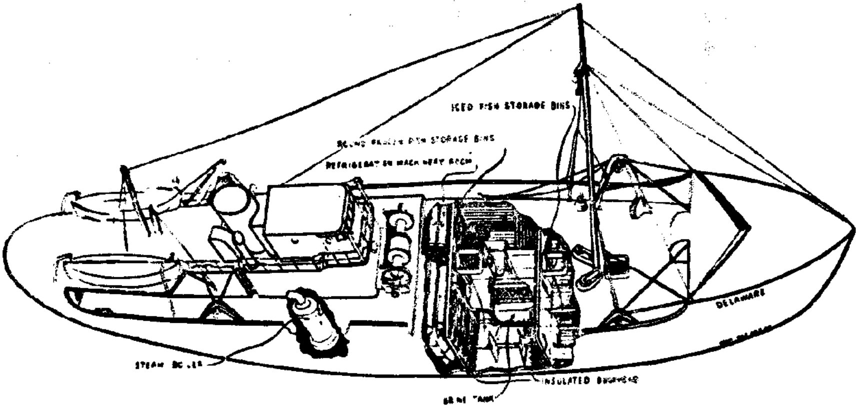

FIGURE 1—Cut-away view of the *Delaware* showing location of the refrigeration system.

success. These boats may also be used to carry ice and other supplies to the shrimp fishing boats.

For the majority of shrimp boats now in operation, however, ice appears to be the only available means of refrigeration. If some practical low cost method of freezing the shrimp at sea on the individual boats could be found it would have many advantages, such at (1) eliminating black spots; (2) eliminating spoilage; (3) permitting continuous fishing until a full load is obtained without dependence on melting ice; and (4) above all, insuring the production of only top quality shrimp. No definite recommendation is made at this time regarding such refrigeration equipment but perhaps the information obtained from the Boston operation will indicate some possibilities which are worthy of investigation.

Preliminary Results of Freezing Fish at Sea

The vessel used in the fish freezing work in New England is the modern trawler, *Delaware*, which is approximately 148 feet in length and has a capacity for carrying over 300,000 pounds of iced fish. Several years ago it was one of the larger vessels of the commercial fishing fleet of Boston.

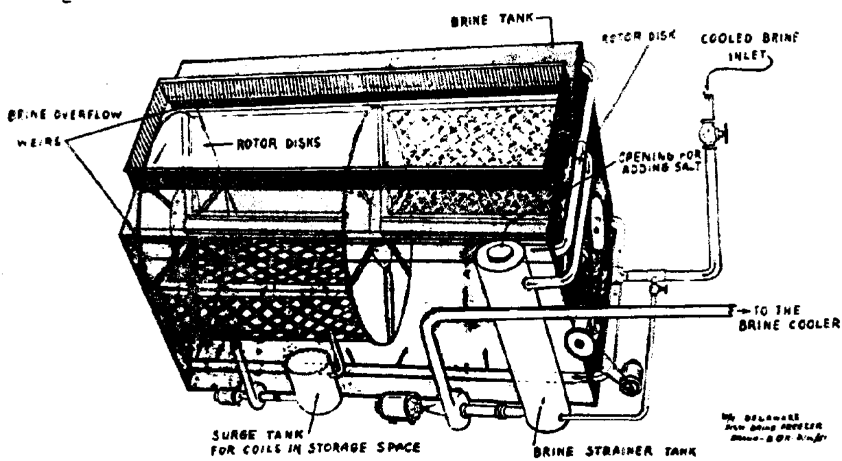

FIGURE 2—Brine freezer tank showing rotor and brine circulating equipment.

Today, the outward appearance of the *Delaware* remains the same but a substantial change has been made in the hold of the vessel, as may be seen from the sketch of the *Delaware* showing a cutaway view of the hold (Figure 1) An insulated partition has been placed so as to divide the hold equally. One half of the hold now contains bins for icing fish—identical with the method now used commercially for holding cod, haddock and similar fish in crushed ice. In the other half of the hold a brine freezing tank containing a rotary freezing apparatus (Figure 2) has been installed. The sides and ceiling of this half of the hold have been insulated and lined with refrigerating coils to help convert this entire half of the hold into a storage room for frozen fish.

The fish caught in the otter trawl and landed on the deck of the vessel are immediately placed in the V-shaped wire mesh sections of the rotary freezing apparatus shown in Figure 2. The entire rotating mesh basket containing the fish is submerged in 80% saturated NaC1 brine which has been chilled to a temperature of approximately 5° F. Immersion in a liquid, such as brine, provides the most efficient means of removing heat from the fish, or in other words, freezing them. The purpose of the rotating action of the basket is to make certain that the cold brine is in continuous contact with the fish. If a stationary basket were used the floating action of the fish in concentrated brine would cause the fish to pack so closely that the cold brine would not come in contact with the fish in the center. In the rotating basket the fish are continually changing position and the brine must flow around them.

The time required to freeze fish in a brine solution depends on a number of factors. Obviously, the most important of these are the temperature of the brine and the size of the fish. In order to report on some of the preliminary results obtained in Boston a very large haddock, 4 inches in diameter and weighing about 10 pounds, will be taken as a starting point. If the 10-pound haddock is immersed in flowing brine held at 0° F., freezing will progress at the rates shown in Figure 3. It is to be noted that during the first hour one inch of the outer layer of the fish was frozen, while during the second hour only a 7/16-inch layer was frozen. The progress of freezing continues to decrease as the distance from the outer surface increases. During the fourth and final

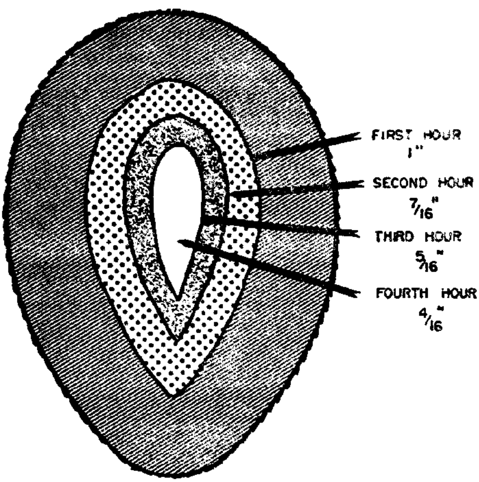

FIGURE 3—Diagram of cross section of Haddock showing freezing rates when held in circulating brine at 0° F.

hour only a ¼-inch layer was frozen. A small fish 2 inches in diameter should freeze in one hour since the radius, or the distance from the outer layer to the center, is only 1 inch. Freezing in air would be much slower than freezing in brine of the same temperature. Taylor[1] has reported that a fish 4 inches thick would require 8.8 times as long to freeze in air as in brine of the same temperature.

The rates of thawing a fish 4 inches in diameter in circulating water at 65° F. is shown in Figure 4. A comparison of the rate of thawing with the rate of freezing will show that at comparable temperatures a fish will freeze faster than it thaws. This is explained by the fact that the frozen layers of fish flesh are better conductors of heat than are thawed layers of equal size.

When freezing in brine is mentioned the first thought which comes to mind is penetration of the salt. It seems logical that a concentrated brine would immediately impart a strong salty taste throughout any fish flesh with which it comes in contact. At high temperatures the brine does penetrate fast but at low temperatures such as 0° F. even the layer of flesh just beneath the skin does not show any appreciable increase in salt content. Normal haddock flesh which has not been exposed to brine has a sodium chloride content of about 0.2 per cent. Haddock frozen in concentrated brine at 5° F. has a sodium chloride content of about 0.6 per cent in the ¼-inch layer next to the skin. When this haddock is thawed in fresh water the salt content drops to 0.4 per cent. This concentration approaches the normal salt content of the fish.

Preliminary Results on Freezing Shrimp in Brine

The results given above are for fish. If shrimp were immersed in the chilled brine what would happen? Very preliminary tests with headless jumbo shrimp in calcium chloride brine (40 percent by-weight) at a temperature of -3° F. showed that the shrimp would be completely frozen in 5 minutes. Headless shrimp approximately 3 inches long ⅝ inches wide and 1 inch thick were frozen to a depth of one-eighth of an inch in two minutes; nine-thirty-seconds of an inch in 4 minutes; and to the center in 5 minutes. The temperature of the

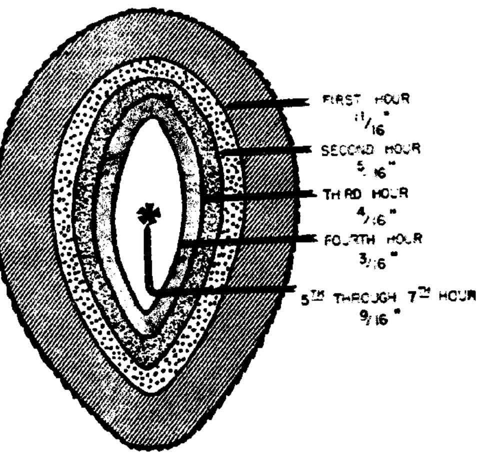

FIGURE 4—Diagram of cross section of Haddock showing thawing rates when held in circulating water at 65° F.

[1] Taylor, Harden F., "Refrigeration of Fish," U. S. Bureau of Fisheries Document No. 1016 (1927).

shrimp when placed in the brine was approximately 65° F. The results of these very preliminary tests indicate that the shrimp will not stick together on freezing and will be rather easy to handle. Previous freezing tests indicate that if shrimp are to be frozen in brine the heads should be left intact in order to avoid direct contact between exposed flesh and the brine. Freezing shrimp with the heads on has the advantage of permitting the shrimp to be immersed in the freezing solution immediately after capture instead of being held on deck at unfavorably high temperatures until it is convenient to carry out the heading operation.

Refrigeration System

Now that the possibilities of brine freezing of shrimp have been described, the next logical question is, what chills the brine. There are two principal

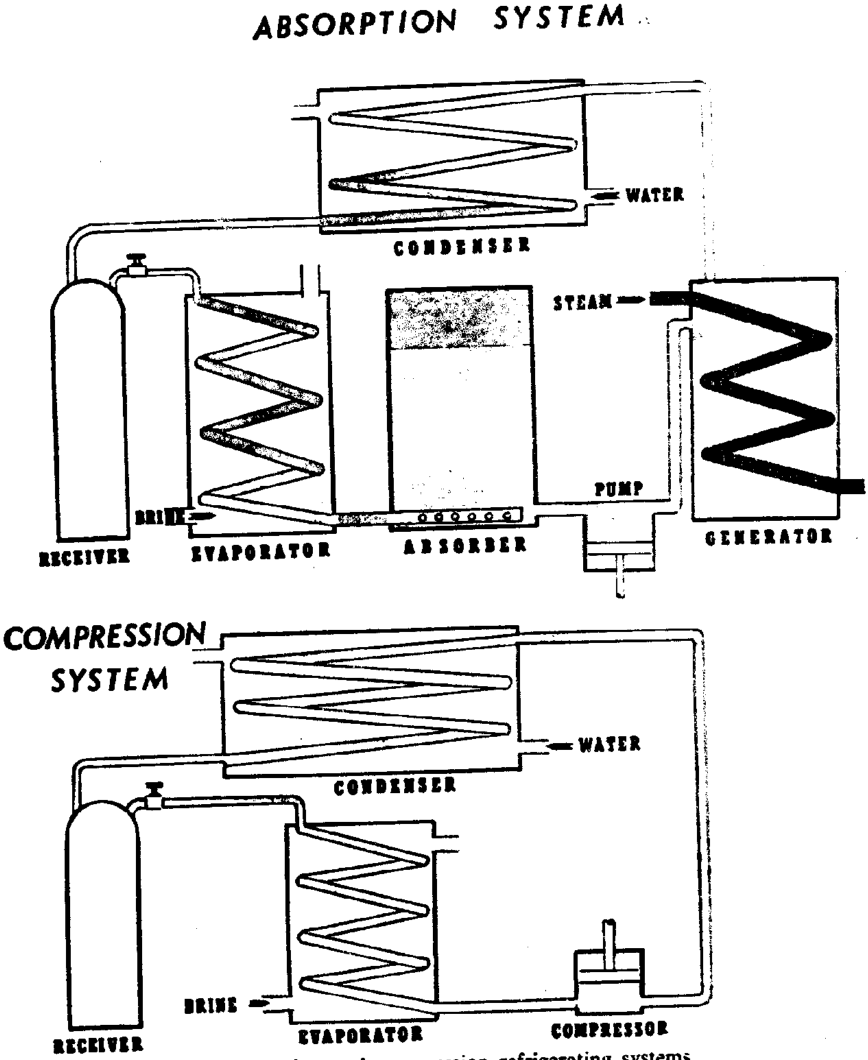

FIGURE 5—Outline of absorption and compression refrigerating systems.

methods of mechanical refrigeration,—the compression system and the absorption system. The compression system is the better known by far and is the more widely used of the two both in commercial and household units—but the absorption system does have certain advantages.

After considering both the favorable and unfavorable features of both systems, the absorption system was chosen for installation on the *Delaware.*

The same reasons for choosing this refrigerating system for the *Delaware* may make the use of the absorption system feasible on the large individual shrimp boats. First will be explained in very general terms the difference between the compression and absorption systems. This can best be done by the use of sketches of the two very elementary units shown in Figure 5.

Compression System

To make the systems easier to visualize, an ordinary pressure tank or receiver is taken as the starting point. As with any gas or liquid under pressure, when the expansion valve is opened and the gas released it expands rapidly and exerts a cooling effect. If released rapidly the expanding gas will cause metal or similar material in contact with it to cool to a temperature well below the freezing temperature of water. Therefore, as the expansion valve of the receiver is opened the expanding gas cools the coils of the evaporator, which in turn cools the brine in which the coils are submerged. This is the brine which is used to freeze the fish. After the gas leaves the evaporator it is pulled by suction into a mechanically operated compressor which subjects the gas to pressure. The compressed gas then passes into the condenser where it is chilled and condensed into a liquid. The liquid under pressure then goes to the receiver or original pressure tank and is ready to begin the cycle again.

Absorption System

In the absorption system the liquid pressure tank (receiver) and the evap-

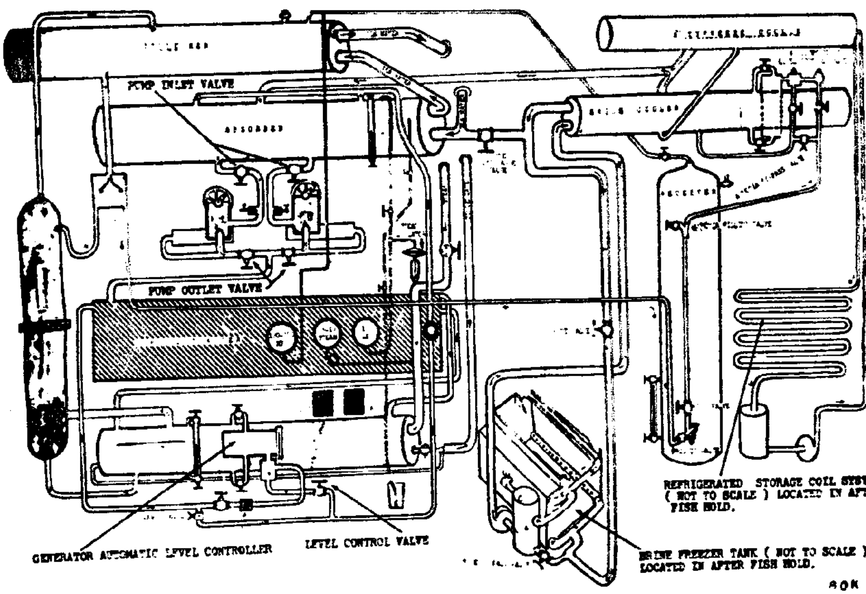

FIGURE 6—Diagrammatic view of the absorption refrigerating system installed on the *Delaware.*

orator, or brine cooling tank, are identical with that of the compression system, but here the similarity ends. Instead of going to a compressor the ammonia gas is discharged into a tank of water, known as the absorber. Since ammonia has the property of being absorbed very rapidly by water the ammonia gas is converted into strong aqua ammonia or ammonia water. The strong ammonia solution is drawn off at the bottom of the tank by a small pump and forced into a generator or heating tank. In this tank the steam coils which wind through the tank heat the strong aqua ammonia and boil off the ammonia gas. The gas then passes through a cool condenser and becomes a liquid. The liquid flows to the pressure tank or receiver and is ready to begin another cycle.

The main difference between the two refrigeration systems is the method of increasing the pressure between the evaporator and the condenser. In the absorption system this is accomplished by heat while in the compression system electricity or other mechanical means are used.

The two systems shown in the sketch have been oversimplified to facilitate a comparison of the principles involved. The complete absorption system as installed on the trawler, *Delaware,* is shown in Figure 6.

Advantages and Disadvantages in the Absorption System

On an overall basis, the operating costs of the two systems are approximately the same. The exact cost depends on the cost of the steam and electricity available. In regard to ease of operation our experience has shown that the absorption system requires considerably more attention than the compression system. This is one of its main disadvantages. The three principal advantages of the absorption system and the basis for our decision to use this system on the trawler, *Delaware,* are (1) lower initial cost, (2) less hold space involved, and (3) much less electric power required.

The cost of the absorption system installed on the *Delaware* was $17,000, exclusive of wiring and power. A compression system of the same capacity was quoted at approximately $37,000 without wiring or power. And, contrary to general belief, $20,000 in some governmental agencies is the difference between operating and not operating. Some refrigeration engineers have told us that in order to maintain low temperatures a two stage system is necessary, and this would require at least two compressors. If this is true the cost would be considerably higher than $37,000.

As installed on the *Delaware,* relatively little horizontal space is required for the absorption system, for the equipment is so arranged that the condenser, absorber, and heat exchanger are mounted above the other units of equipment. The fore and aft horizontal space occupied, including working space for the operator, is only 5 feet. This is an important factor aboard a fishing vessel for every foot of hold space is valuable.

To operate the 25-ton absorption system on the *Delaware,* only a very small amount of electric power is used—the major source of power being supplied by a steam boiler. If a 25-ton compression system had been used, at least a 37 hp. electric motor would have been required, as determined by calculation. Refrigeration companies recommended at least a 50 hp. unit. In contrast with this the total electrical power used in the absorption system is approximately 2.5 hp. On the *Delaware,* as with most fishing vessels, the capacity of the generator is limited, consequently the installation of a sizeable motor would also require an additional generator, which is both costly and requires additional space.

No reliable information has been found regarding the operating efficiency of small absorption systems, such as would be suitable for use on small shrimp boats. One manufacturer has offered the information that absorption units of less than 10 tons capacity would not be as efficient as comparable size compression units. This has not been confirmed.

Split Absorption System

In addition to the complete absorption installation there is one method of using the absorption system on small boats which may be worth considering. It is the split absorption system. In this system, which has been used experimentally on refrigerated cars, only one half of the system is installed aboard the vessel, while the other half is operated ashore. The refrigerating equipment on the boat consists of only an ammonia pressure tank, evaporator coils, and a tank of water. At sea, when the boat requires refrigeration, the ammonia in the pressure tank is simply released through an expansion valve into coils to produce the cooling effect and is then passed into a tank of water, where it is absorbed to form aqua ammonia. The shore plant, which may serve many boats, removes the strong aqua ammonia from the boat, puts it through the heating cycle to boil off the ammonia gas from the solution and then condenses the gas to form liquid ammonia. The liquid ammonia is then used to recharge the system on the boats.

A report on a test of this system in railroad cars is described in an article which appeared in the June 1947 issue of *Quick Frozen Foods.*

For boats which will be at sea only a few days the split absorption system may be feasible. For those on long trips of 10 days or more, the size of the ammonia and water tanks required may occupy so much more space that the system would not be feasible. For example, to maintain a temperature of 0° F. in an insulated railroad car approximately 1000 pounds of liquid ammonia and 500 gallons of water were required for each 24-hour period. One advantage the split absorption system would have over ice is that the system need not be turned on until refrigeration is needed. However, the biggest advantage by far is that the system is practically fool-proof and has no moving parts on the vessel installation.

At this point a word of caution is in order. The purpose of this information on refrigeration is merely to offer suggestions as to what might be done aboard shrimp boats. Before any type of refrigerating equipment is installed on any type of fishing boat a competent refrigeration engineer should be consulted.

Future work on the freezing-fish-at-sea project will undoubtedly provide definite information which is applicable to the freezing of shrimp. The relatively small size of shrimp together with the limited amounts caught during a 24-hour period should make freezing shrimp at sea a feasible operation.

Exploratory Fishing for the Little Tuna (Euthynnus alletteratus) Off the Atlantic Coast of the United States

C. B. CARLSON, *Fishery Engineer, U. S. Fish and Wildlife Serivce, College Park, Maryland.*

Introduction

INTEREST in the utilization of little tuna (*Euthynnus alletteratus*) began during World War II when several companies prepared packs from incidental