FREEZING FISH AT SEA--NEW ENGLAND
Part 3 - The Experimental Trawler Delaware and Shore Facilities

By C. Butler,* J. F. Puncochar,** and B. O. Knake***

ABSTRACT

A DESCRIPTION OF THE SERVICE'S EXPERIMENTAL TRAWLER DELWARE IS PRESENTED, INCLUDING THE GENERAL CHARACTERISTICS OF THE VESSEL, ALTERATION OF THE FISH HOLD, AND THE REFRIGERATION SYSTEM. ALSO DESCRIBED ARE THE SHORE FACILITIES, WHICH CONSIST OF THE PIER FOR MOORAGE OF THE VESSEL; A PILOT PLANT; A LABORATORY; AND OFFICES. OPERATION OF THE VESSEL AND FREEZING FACILITIES, AND HANDLING OF THE FISH ASHORE ARE DISCUSSED.

THE EXPERIMENTAL TRAWLER

GENERAL: The trawler Delaware being used in the current freezing-fish-at-sea studies by the Technological Section of the Service's Branch of Commercial Fisheries is well known to the New England fishing fleet. A vessel of this type was chosen for very definite reasons. It is our purpose, at this time, to develop fish-freezing and handling methods which are adaptable to the present New England fishing vessels rather than to work out methods of freezing and handling that would require the extensive conversion of these trawlers or the redesigning and building of new fishing vessels.

The characteristics of the Delaware are as follows:

LENGTH OVER-ALL - 147 FEET 6 INCHES
BEAM - 25 FEET
DEPTH - 14 FEET 8 INCHES
DEAD-WEIGHT TONNAGE - 544 TONS
MAIN ENGINE - 7 CYLINDER, 2 CYCLE, 735 HP., 300 RPM.
AUXILIARY LIGHTING GENERATORS - 2 IDENTICAL UNITS:
 4 CYLINDER, 4 CYCLE, 39 HP., 1150 RPM., DIESEL ENGINES, DIRECTLY COUPLED TO D.C. GENERATORS OF 25 KW. CAPACITY OF 1,200 RPM., RATED AT 200 AMPERES AND 125 VOLTS.
TRAWL-WINCH POWER - CONSISTS OF A NEWLY-INSTALLED DIESEL ENGINE, 6 CYLINDER, TWO-CYCLE, 120 HP., 1,200 RPM., DIRECTLY CONNECTED TO A D.C. GENERATOR OF 80 KW. CAPACITY AT 1,200 RPM., RATED AT 320 AMPERES AND 250 VOLTS. THE WINCH, IN TURN, IS DRIVEN BY A 100 HP. ELECTRIC MOTOR.
FRESH-WATER TANK CAPACITY - 11.9 TONS
FUEL-OIL TANK CAPACITY - 63.2 TONS
LUBRICATING OIL TANK CAPACITY - 400 GALLONS
CRUISING RANGE - 8,000 NAUTICAL MILES
SPEED - APPROXIMATELY 10 KNOTS
CREW ACCOMMODATIONS FOR 20 PERSONS

Upon its delivery to the East Boston Laboratory, the vessel required the following alterations and repairs:

1. REMOVAL OF FISH-LIVER-OIL PROCESSING EQUIPMENT, WHICH OCCUPIED HALF OF FORMER GALLEY SPACE.

2. RESTORATION OF GALLEY TO FULL SIZE AND RE-EQUIPMENT WITH NEW RANGE, TABLE, AND CUPBOARDS.

3. RESTORATION OF DECK GEAR TO NEW ENGLAND STANDARD TYPE.

4. REPLACEMENT OF FOREIGN ECHO-SOUNDING EQUIPMENT WITH AN AMERICAN-MADE DEPTH RECORDER AND A DEPTH INDICATOR, BOTH WITH DUAL RANGE - 250 FEET AND 250 FATHOMS.

5. REPLACEMENT OF THE DIESEL ENGINE IN THE DIESEL-ELECTRIC POWER UNIT WHICH DRIVES THE TRAWL WINCH.

* TECHNOLOGIST,
** CHIEF, NORTH ATLANTIC TECHNOLOGICAL RESEARCH,
*** FISHERY ENGINEER,
FISHERY TECHNOLOGICAL LABORATORY, BRANCH OF COMMERCIAL FISHERIES, U.S. FISH AND WILDLIFE SERVICE, EAST BOSTON, MASS.

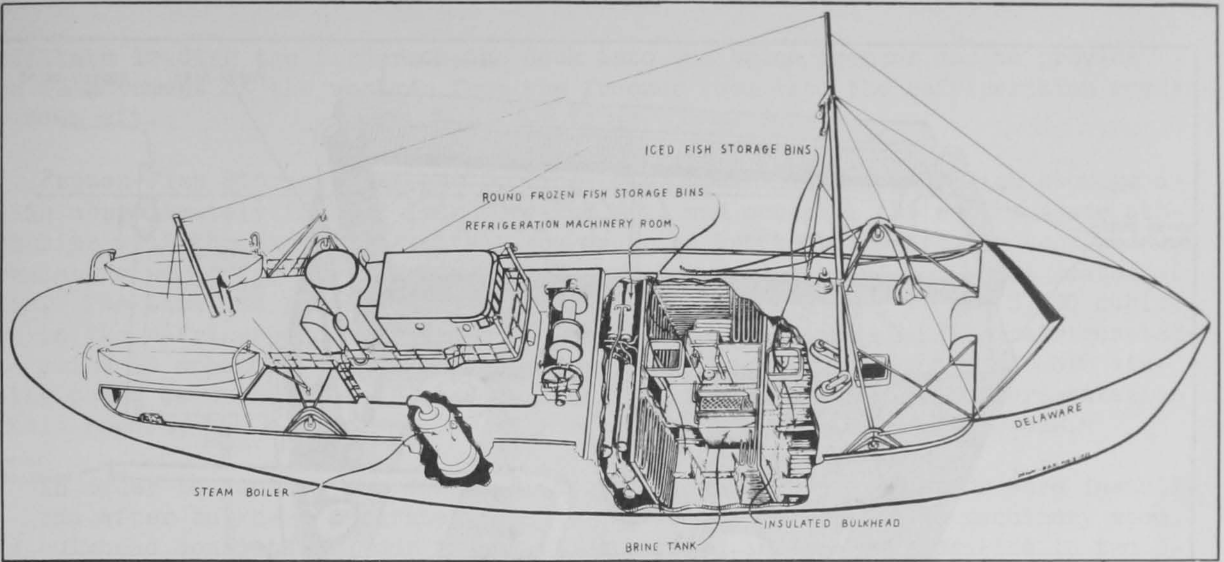

FIGURE 1 - CUTAWAY VIEW OF THE DELAWARE, SHOWING LOCATION OF THE REFRIGERATION SYSTEM AND STORAGE BINS.

ALTERATION OF THE FISH HOLD: The fish hold of the Delaware was originally about 36½ feet long with a total volume of 8,200 cubic feet. In this space was constructed (for the freezing-fish-at-sea project) a refrigeration machinery room and a frozen-fish storage space (Figure 1).

The refrigeration machinery room consists of the area formerly occupied by the after fish-pen section. This room is about 5 feet wide and occupies the entire cross-section of the fish hold immediately in front of the fuel-storage tanks, for a total of 1,300 cubic feet.

The balance of the fish-hold area (forward of the bulkhead installed to make the refrigeration machinery room) was divided equally by means of a second insulated bulkhead to provide, in the after portion, frozen-fish storage space. A brine-freezer unit was also installed in this frozen-fish storage area, which is approximately 15 feet long and has a total capacity of 2,800 cubic feet. The frozen-fish storage area, exclusive of the space occupied by the brine-freezer tank and the work areas essential to its use, will provide frozen-storage space for approximately 100,000 pounds of round fish.

The forward portion of the divided fish-hold area was left in an unaltered condition to provide space for the icing of gutted fish in the usual method. This space now totals approximately 3,000 cubic feet and can carry up to 132,000 pounds of iced, gutted fish.

THE REFRIGERATION SYSTEM: The refrigeration system aboard the M/V Delaware may be considered to have four main parts:

1. THE BRINE TANK FOR FREEZING ROUND FISH.
2. THE COOLING-COIL SYSTEM IN THE FROZEN-FISH STORAGE HOLD.
3. THE REFRIGERATION PLANT.
4. THE REFRIGERANT EVAPORATORS FOR COOLING THE BRINE AND THE ALCOHOL-TYPE MEDIUM IN THE COOLING-COIL SYSTEM.

Brine Freezer: The brine freezer tank is 5 by 5 by 10 feet, constructed by 1/2-inch welded steel plates (see Figure 2). The tank is mounted on steel channels secured to the pen-board stanchion posts. The location of the tank is between No. 2 and No. 3 hatch and on the center line of the vessel at the finished floor level in

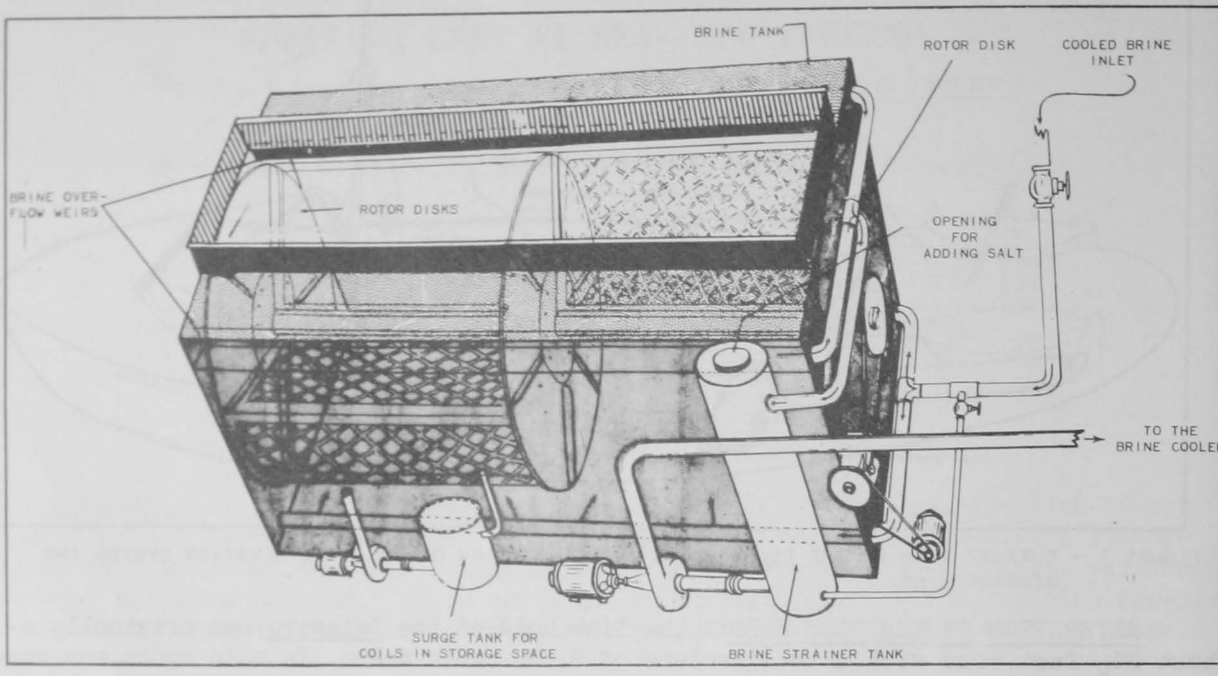

FIGURE 2 - BRINE-FREEZER TANK SHOWING ROTOR AND BRINE CIRCULATING EQUIPMENT.

the refrigerated fish-storage area (see Figure 1). Inside the rectangular tank proper there is mounted (on suitable bearings) a rotor 4 feet 8 inches in diameter fastened at each end of the tank. The rotor is divided into two sections of equal length. Each of the sections is further divided into six V-shaped segments. These segments provide support for V-shaped baskets which are constructed of welded angle-iron frames and covered with expanded metal lathe. Twelve baskets, six in each section, make up the complete rotor in the brine-freezer tank. The baskets are secured to the discs at the ends of each segment of the rotor and are equipped with a rounded-surface lid on the curved top. Fish to be frozen are loaded through the lid opening; the lid is then secured with a metal clamp. These baskets are designed in such a manner that they may be removed from the rotor individually, if necessary.

The drive mechanism for rotation of the rotor in the refrigerated brine consists of a large pulley driven by a triple V-belt from a gear-reduction unit, which is in turn V-belt driven from a 2-hp. motor. The speed of rotation for the rotor is about 3 rpm.

Located at the after corner on the port side of the brine tank is a cylindrical strainer unit 20 inches in diameter by 5 feet in height into which the brine overflow from the brine tank discharges. The outlet from the bottom of the strainer tank is coupled directly to a centrifugal pump driven by a 2-hp. motor and by means of which the brine is circulated back to the brine cooler in the refrigeration machinery room, aft.

On the top of the brine tank there is a walkway (approximately 15 inches wide) on each side to accommodate workmen engaged in loading and unloading the fish at the brine freezer. The actual opening of the tank is approximately 2½ by 10 feet. A light-weight metal cover is provided to minimize sloshing of the brine out of the tank with the roll of the vessel and to eliminate the possibility of foreign matter falling into the tank when the equipment is not in use.

At the after end of the brine-freezer tank and immediately below the No. 3 hatch at the approximate level of the top of the tank there is located a work platform to facilitate loading the fish from the deck into the brine freezer and to provide ease in movement of the workmen from the freezer room into the refrigeration machinery room aft.

Frozen-Fish Storage Area and Cooling-Coil System: The frozen-fish storage area is approximately 15 feet long fore and aft, and occupies the entire space athwartships with the exception of the area occupied by the brine-freezer tank and the circulating pumps for the brine and the alcohol-type medium of the refrigerated coils. The tank and pumps occupy approximately 800 cubic feet of the 3,600 cubic feet in the refrigerated storage area. The liquid medium used in the refrigerated-hold coils is ethanol. Other liquids with a low freezing point and suitable viscosity could be used. For this reason and for our convenience in the presentation of this report, the alcohol medium will be referred to as the "antifreeze."

In order to isolate the frozen-fish storage space, two bulkheads were installed. The after bulkhead separates this area from the refrigeration machinery room. This bulkhead consists of four inches of cork-board insulation installed in two 2-inch layers with moisture-vapor barrier paper laid up in hot asphalt on the warm (after) side of the cork. The protective surface on the cold side of this bulkhead is $1\frac{1}{2}$-inch tongue-and-groove planking. A second such layer of planks laid with white-leaded joints provides the protective surface on the warm side of this bulkhead. Vertical studs, 4 by 6 inches on 16-inch centers, provide an additional strengthening feature.

A removable plug, approximately 5 by 4 feet, is located in the after bulkhead into which there is constructed a standard refrigerator door, approximately 24 by 56 inches, that opens from the refrigeration machinery room into the refrigerated storage area at the work-space level under the No. 3 hatch.

The forward bulkhead of the refrigerated storage space is built on the penboard stanchion line across the vessel at a point 15 feet forward of the after bulkhead. Details of construction were similar to those described for the after bulkhead except that the vertical stud reinforcement feature was omitted. In this bulkhead there is also a small refrigerator door which opens into the iced-fish storage area at the work-space level of the brine-freezer tank.

The refrigeration system for the frozen-fish storage area consists of a series of $1\frac{1}{4}$-inch coils of pipe with return bends on 4-inch centers. These sets of coils are bolted approximately 2 inches out from the wood surfaces and are secured to them on the after bulkhead, the forward bulkhead, the deckhead, and the port and starboard surfaces in this area. There are, however, no cooling coils on the deckhead above the brine-freezer tank. The total length of the refrigerated coils in the room is about 2,400 feet.

On the forward end of the brine tank on the port side, there is mounted a centrifugal pump driven by a 1/2 hp. motor. This unit supplies the propulsion force to circulate the "antifreeze" liquid used to provide the refrigeration in the frozen-fish storage area.

One-inch moisture-resistant plywood partitions on the stanchion posts on both sides above the brine-freezer tank create a series of storage bins into which the frozen fish may be segregated as to size and species. Doors are provided in these partitions for access to each of six such bins. Through use of the existing vertical penboard-stanchion supports between the three pens on each side of the brine-freezer tank, a positive separation can be obtained in the frozen fish, if necessary. A further separation can be made through the use of additional penboards placed horizontally at levels of approximately five feet from the finished floor in the refrigerated storage space. On the port side of the brine-freezer tank there is provided a wood-partition protection for the two centrifugal pumps and motors, for the strainer unit, and for the connecting pipes of the two circulation systems.

Based on past experience elsewhere with brine-frozen fish, there appears to be no need to provide battens to keep the fish from direct contact with the refrigerated coils, since the fish, upon removal from the brine, will be at the approximate temperature of the storage room coils, namely 5° F. In order to minimize any possible shifting of the frozen stacked fish in rough weather, the frozen fish will be sprayed with fresh-water which, in turn, should freeze and bind the fish together.

Refrigeration Machinery: The refrigeration machinery room is located between the frozen-fish storage area and the main engine room.

Access to this area from the main engine room is through a small watertight door installed in the watertight bulkhead between the fuel-storage tanks. The forward bulkhead contains the refrigerator door leading to the frozen-fish storage area and brine tank.

An absorption refrigeration system was installed. The absorption-type system was chosen over the conventional compressor system since this type of refrigeration equipment costs less to install and operate; requires much less electric power, an important factor aboard ships; is believed to occupy proportionately less space; and avoids the necessity for "staging" the system to obtain continuing maximum refrigeration capacity at the low temperature levels. The several parts making up the absorption-system plant are shown on the left hand side of Figure 3.

A brief explanation of the manner in which the system operates is as follows: The source of power in the absorption system is supplied by steam from a low-pressure boiler located in the main engine room aft of the refrigeration machinery compartment (see Figure 1). The steam enters the system (Figure 3) at the generator in which there is maintained a specified amount of concentrated aqueous-ammonia solution by means of an automatic-level control valve. The heat energy supplied by the steam vaporizes the ammonia and the water in the generator. These constituents pass off to the specially designed distillation column. As the water and ammonia vapors pass up through the successively cooler zones in the column, the water vapor is condensed (water has the higher boiling point). The condensed water ultimately drops to the bottom of the distillation column, and is returned to the generator. The ammonia vapor, passing upward, becomes more and more concentrated. At the top of the column, liquid ammonia is supplied from the ammonia condenser through a reflux meter. The passage of the ammonia vapor over this liquid ammonia insures that any vapor passing upward from the column will constitute approximately 99.95 percent ammonia. The ammonia vapor passes from the distillation column to the condenser where it is cooled and condensed to liquid by means of coils supplied with running sea water as a coolant. The liquid ammonia from the condenser passes downward, as indicated, to the ammonia receiver (shown on the right-hand side of the drawing). However, a sufficient portion is diverted to the distillation column to supply its need for liquid ammonia. The liquid ammonia is supplied from the receiver to the brine and "antifreeze" coolers in accordance with the refrigeration needs. The evaporation of the liquid ammonia in the heat exchangers' tubes provides the refrigeration for the circulating brine and "antifreeze." The ammonia vapor then passes on to the absorber unit.

The absorber is a specially-designed heat exchanger of the shell-and-tube type in which sea-water supplies the cooling medium. The absorber shell is charged with a weak aqua-ammonia solution into which the vaporized ammonia from the brine and "antifreeze" coolers is absorbed. The enriched aqua-ammonia solution is next drawn from

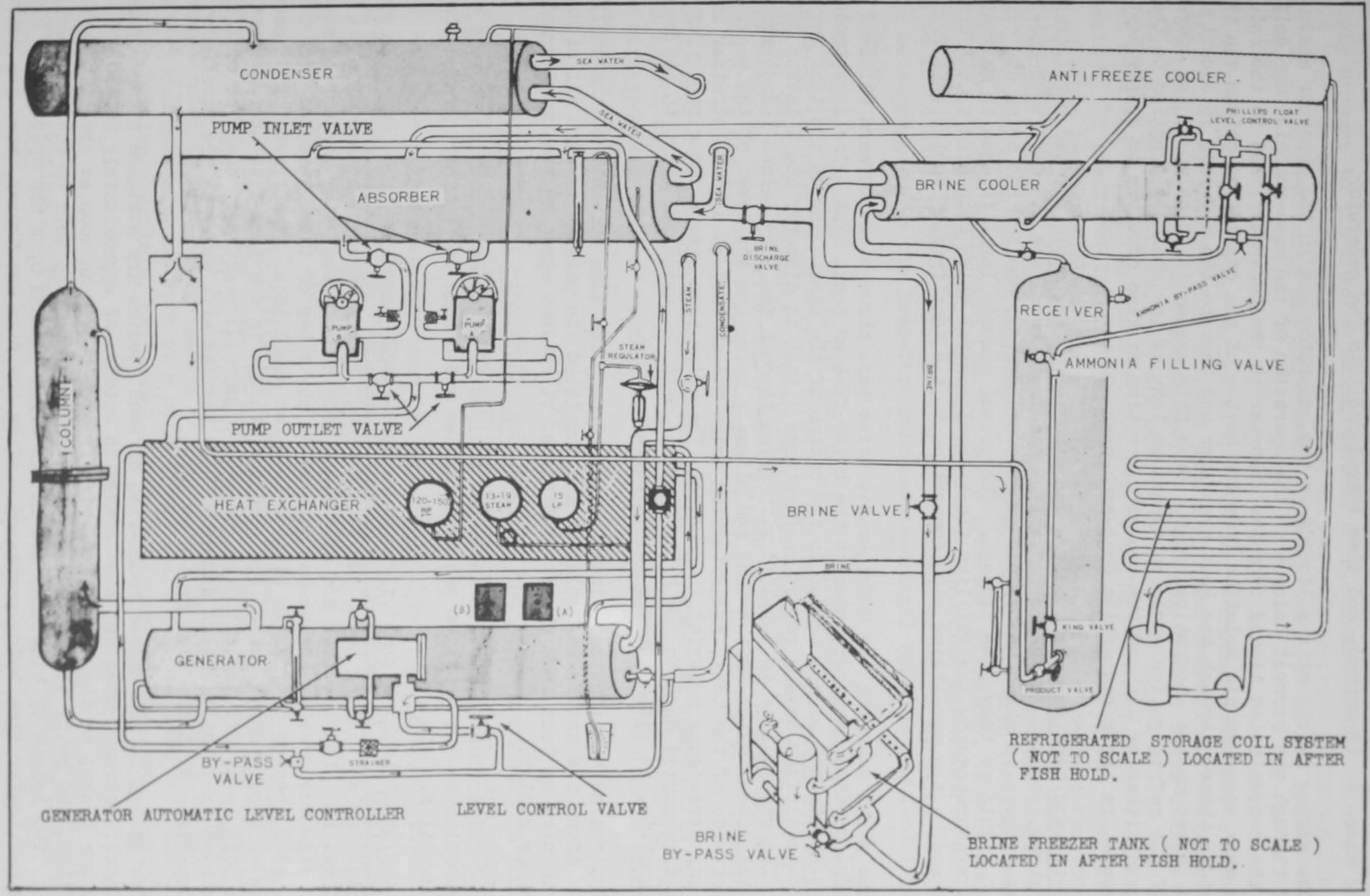

FIGURE 3 - DIAGRAMMATIC VIEW OF REFRIGERATION SYSTEM.

the absorber by the specially designed pump, passed through a counterflow heat exchanger where it is warmed, and then introduced into the generator.

The proper levels of the liquids in the generator and in the absorber are maintained through the correct balance in the operation of the aqua-ammonia pump delivering the concentrated liquid from the absorber to the generator, and in the return of the weak aqua-ammonia solution from the bottom of the distilling column via the generator, thence through the heat exchanger and back to the absorber in a cool condition to resume the absorption cycle. Once this system is in balance, the operation of the refrigeration cycle continues so long as the steam is supplied to the unit, and either or both of the two refrigeration systems continue to supply heat for removal in their respective heat-exchanger coolers.

Brine and "Antifreezer" Coolers and Circulating Systems: The two refrigerant evaporators, located in the refrigeration machinery room, are standard tube-and-shell-heat exchangers in which the liquid ammonia evaporates, cooling the brine and "antifreeze" liquid as they pass through. The proper ammonia level in each is maintained in the evaporators by the Phillips float-level control valve connected to the brine cooler and by the equalizing pipe connection to the "antifreeze" cooler (see Figure 3).

The pipes carrying the refrigerated brine pass through the forward bulkhead of the refrigeration machinery room to the brine-freezer tank. The brine is introduced through two 4-inch pipes located in the bottom of the tank. Inside the tank each of these 4-inch pipes have a row of perforations 1 inch in diameter and 6 inches on centers. The return line is supplied with brine through two 6 by 6-inch launders mounted at the sides inside of the tank and slightly below the top level of the tank. On the port side of the tank, the returning brine passes through a large strainer unit where any extraneous material is removed. The brine then enters the circulating pump and is transported back to the brine cooler. Salt, to bring the brine to the desired concentration, is added through this strainer.

The cooled "antifreeze" liquid passes through the same bulkhead to the cooling coils. After the antifreeze solution has completed its passage through all of these pipes to pick up heat from the storage space, it returns again to the refrigerant-evaporator cooler.

The refrigeration load to these two coolers is adjusted to provide 20 tons of refrigeration per 24 hours to the brine system and 5 tons to the refrigerated-area cooling-coil system.

OPERATION OF THE VESSEL AND FREEZING FACILITIES: The Delaware is being operated, insofar as fishing technique is concerned, in the standard manner of a New England trawler. When the fish are discharged from the cod end, they are sorted according to size and species and washed just as on any other of these vessels. For our tests, each species of fish is divided into two equal lots. The first lot of each species so separated is gutted and iced for storage in the iced-fish storage portion of the hold in accordance with regular good commercial practice. Each lot of fish is assigned an identification number. These samples will serve as the "controls" for comparison with the fish frozen in brine.

The second lot of washed round-fish of each species are assigned a corresponding identification number and then loaded in batches of approximately 200 to 250 pounds per basket to the pre-cooled brine-freezer tank. As soon as the 12 baskets are filled, the rotor is placed into operation and the fish held in the brine until frozen. The length of time they are in the brine depends upon the species and size of the particular fish being processed. After the fish are frozen, they are removed from the baskets and stored in the refrigerated-storage space which has been previously brought to the holding temperature of 5° F. Each lot of fish as it is removed from the brine freezer is segregated in the hold in order to retain its identity for subsequent tests and comparisons with its "control" in the gutted-iced-fish hold.

Preliminary trial runs indicated that the brine freezer will have a total capacity of approximately 2,500 to 3,000 pounds of round fish and will require from one to three hours for the freezing cycle. Based upon the estimated average catch of fish per haul (1,500 pounds), six baskets in the rotor can be filled from the first haul and during the course of the next dragging operation these fish will be freezing. If the first lot of fish has not completely frozen by the time the second haul has been completed, due to large sizes or for other reasons, the fish may remain in the baskets while the second lot of fish is loaded and during the beginning of the freezing phase. Through this arrangement it is possible to allow as much as three hours for the freezing of a given lot of fish with little, if any, dislocation of the continuous freezing cycle provided, of course, that no unusually large hauls of fish are made. In the event that more fish are landed on deck than can be immediately frozen, that part of each lot set aside for freezing in the round will be segregated in the iced-fish hold and iced until the freezing facilities are available.

The refrigeration system has been designed and built to preclude changes in the brine-tank temperature in excess of two to four degrees under normal operating conditions. Although the brine temperature in the system may rise from two to four degrees when the unfrozen fish are introduced, the capacity of the system is such that within a few minutes the temperature will be lowered to its operating level.

After the vessel has completed the fishing and freezing operation at sea, it will return to the dock at the East Boston Fishery Technological Laboratory where the corresponding lots of iced-gutted fish and round-frozen fish will be removed for processing ashore.

SHORE FACILITIES

PIER, PILOT PLANT, LABORATORY, AND OFFICES: The shore facilities at the East Boston Laboratory include moorage for the vessel, a laboratory, a pilot plant, and offices (see Figure 4).

The pier, constructed of wood piling with wood decking, is approximately 15 feet wide and 400 feet long. The depth of the water, from the 50-foot mark on the pier to the end of the pier, is great enough to provide safe moorage for the Delaware at any tide stage. The main ship channel through Boston harbor is located within 300 feet of the end of this pier.

The fish-processing facilities ashore, at a distance of approximately 150 feet from the shore end of the pier, include sufficient space and equipment for (1) the holding (not freezing) of up to 10,000 pounds of frozen fish in a low-temperature storage room; (2) the water-thawing of frozen fish in 1,000-pound lots; and, (3) the cutting and packaging of fish on a pilot-plant scale. In the same building there are the fishing gear loft, the vessel stores space, and other essential auxiliary facilities.

In the adjacent building, the Administrative Offices are located on the ground floor. The testing laboratory, together with other office space, is on the third floor.

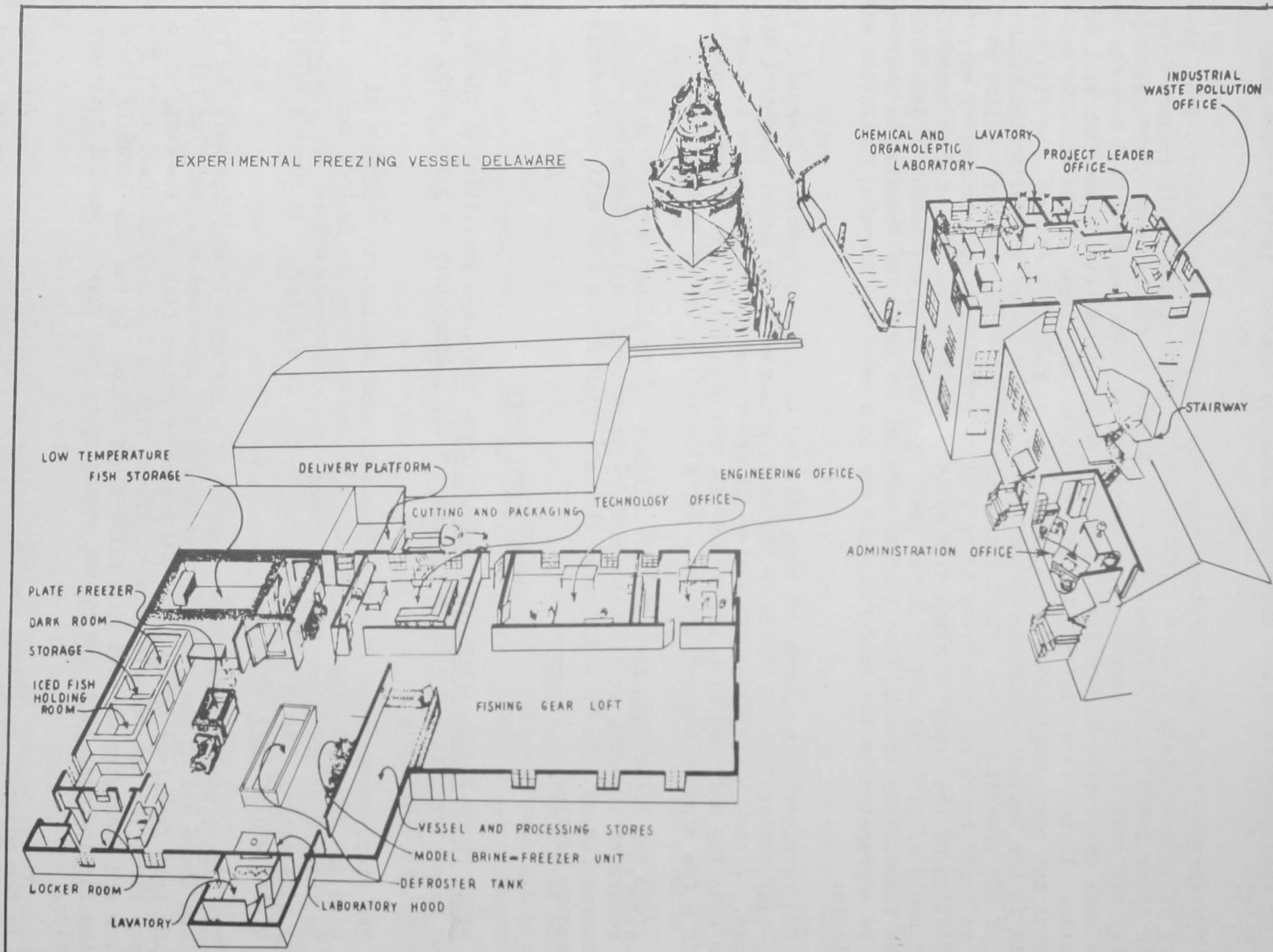

FIGURE 4 - CUT-AWAY VIEW OF THE FISHERY TECHNOLOGICAL LABORATORY, EAST BOSTON, MASSACHUSETTS, SHOWING OFFICE, LABORATORY, AND PILOT-PLANT FACILITIES; THE DOCK; AND THE EXPERIMENTAL TRAWLER DELAWARE.

HANDLING FISH ASHORE: The frozen fish aboard the Delaware upon their return to port are trucked from shipside to the low-temperature storage room in the pilot-plant building. These fish may be removed and water-thawed as required for filleting and packaging in the pilot plant where equipment and space for one scaler, two cutters, and one packager are available. Alternatively, the thawed fish may be trucked to a commercial filleting plant immediately after thawing. In either instance the packaged fillets, except small lots for special experiments, are frozen and stored in commercial cold-storage plants. A cold-storage box with sharp freezing capacity of 200 pounds and storage capacity of about 600 pounds of fish is used for special experiments on small lots.

Iced fish landed from the Delaware may be cut and packaged in the pilot plant or trucked directly to a commercial plant for filleting, packaging, and freezing.

Representative samples of fillets from the iced fish and from the thawed fish are taken to the laboratory for physical, chemical, and taste-panel evaluation. These results on the fish at the initial stage of processing then serve as a reference point for evaluation with subsequent samples from the corresponding lot in frozen storage. Each examination and evaluation is made semi-monthly for nine months.

PACKAGING FROZEN FISHERY PRODUCTS

The low temperatures which are required for proper storage of frozen fishery products and frozen foods in general will cause extreme desiccation or drying out unless special preventive precautions are taken. The humidity of the air in a frozen-storage room is quite low. On the other hand, the air immediately surrounding the frozen food is practically saturated with moisture. The dry air in circulating through the room will pick up any moisture that is available. Any exposed or improperly packaged food products in the room will thus lose moisture, in the form of water vapor, and will rapidly develop a dry, spongy and discolored surface. The tissues become tough due to denaturation or irreversible changes in the protein. This condition is known as "freezer burn." The package is of prime importance in order to prevent this drying. Care is needed to package the food properly in containers which have a very low or - ideally - a zero rate of water-vapor transfer, so as to keep the moisture where it belongs - within the package.

--Fishery Leaflet 324