for dairy products, one for fruits and vegetables, one for meats, and a fourth for frozen foods, each would have its own Refrigerant 12 condensing unit with associated cooling units. This provides maximum protection of perishables in case of mechanical failure of any important component. A better arrangement will provide one or more standby condensing units. By proper piping and valving, the standby unit can be connected to substitute for any unit which has failed.

Unit installations are those in which a single condensing unit is applied to each fixture, an arrangement preferred by some engineers.

Cooling units. The choice of cooling units for the refrigerated rooms is somewhat controversial in the marine field. During and since World War II, there has been a growing tendency to use packaged forced-air cooling units with finned tubes to speed and reduce the cost of the installation. The choice has also been prompted by the safe non-toxic halogenated hydrocarbons. Automatic defrosting, where average room temperatures are about 34 F and above, is considered practical. Air distribution should be worked out so that the force of the air blast is directed above the food and allowed to diffuse downwardly, returning to the cooling unit for recirculation. One or more of the units may be installed in a room after careful consideration of air distribution.

If finned tube forced air units are used for temperatures below 34 F, some positive means of defrosting must be provided. Hot gas, electric and water defrost are successful if properly applied and used.

When wall coils are used, paneled baffles should be installed over them to prevent the produce from contacting the low temperature surfaces and to promote positive air circulation. In designing direct-expansion wall coils, the circuits must not be so long that excessive superheat of the expanded refrigerant results. On the other hand, a shortage of cooling surface results in excessive differences between refrigerant and room air temperature, with consequent dehydration of stored products. The proper layout of wall coils requires that the expansion of the refrigerant be upward in the first series of coils and downward in the last coil to assure correct oil return to the compressor. Where coils are connected into a common overhead suction main, the piping from the coil can be arranged, which will avoid collecting the oil draining from the suction line. Where suction lines must be run along or under the deck, a trap should be placed at the end of the run where the line rises to the compressor. If possible, the line should slope to the trap.

Controls. The most reliable system is one with a minimum of automatic apparatus which affords the utmost in simplicity. For marine applications, liquid controls should be of the automatic expansion type. Either constant pressure or thermostatic type valves are suitable; the latter is preferable for most applications. Rolling, pitching, trim, and list of vessels make it difficult for float valve controls to function correctly. Expansion valves, being spring operated, are not affected by these conditions. Capillary tubes are commonly used in unit refrigerators and will function on board vessels. If a float type control is unavoidable, its vertical plane of operation should be fore-and-aft rather than athwartship. Float controls are unsuitable in vessels with propulsion machinery aft or which normally trim aft.

Temperature controls using thermostats, low pressure controls, evaporator regulating valves, and solenoid valves perform satisfactorily in ships' service systems. Such equipment, however, must be designed to be unaffected by vibration or ship's motion. Mercury bulb controls should not be used.

Direct-expansion controls should be located adjacent to their respective units, be installed so that they are clear of ordinary hazards of damage due to handling stores, have strongly built guards, and be fitted with locked covers to prevent tampering with the sensitive apparatus by unauthorized persons. Controls should be installed outside the refrigerators. On closely coupled systems using a central plant, they may be installed in the machinery room without benefit of guards.

On vessels outfitted with alternating current electric systems, the use of factory assembled refrigerators is possible.

Load Calculations

The calculation of refrigerant loads of a ship's service refrigerator system should follow the same procedure indicated for cargo systems in the section Marine Cargo Refrigeration. A larger margin for miscellaneous heat gain, such as frequently opened doors, should be allowed. An arbitrary figure of from 10 to 25 percent of the total load may be used.

PART III: FISHING BOATS

As fishing vessels are forced to travel longer distances to find desirable and profitable varieties of fish to satisfy the market, the need for refrigeration becomes more acute. Fish is a very perishable commodity and must be quickly lowered to and kept continuously at 32 F or below if undesirable bacterial action and spoilage are to be kept to a minimum. On long trips most of the smaller fishing vessels use crushed ice, supplemented in some cases with mechanical refrigeration. When properly used, ice (or ice and salt) will bring the temperature of the fish down to 32 F, and in favorable circumstances as low as 26 F.

AMERICAN PRACTICE

This section deals with the refrigeration required on fishing boats for the purpose of preserving the fish in a salable condition from the time they are caught until the vessel returns to port. Freezing fish at sea in the ordinary fishing vessels, except in the case of the tuna clipper, is not a common American practice though it has been successfully used in France. Plate freezers for shrimp, and freezer storage holds, aboard vessels have been tried out in the Gulf of Mexico fishery with considerable success.

One of the latest developments has been the use of recirculating refrigerated sea water, instead of ice, for holding the fish in a satisfactory condition after being caught. The sea water is continuously circulated by means of pumps, through the fish and over baffled cooling coils placed along one side of the insulated tank, or through external brine coolers. Welded reinforced aluminum tanks and aluminum cooling coils have been used successfully. Ammonia and Refrigerants 12 and 22 have been used. The smaller trollers, thus equipped, require about 1 ton refrigeration capacity for each 2 tons of fish capacity, while the larger fishing vessels require about 1 ton refrigeration capacity for each 5 to 6 tons fish capacity.

REFRIGERATION WITH ICE

The most common method for preserving fish at sea in fishing vessels is by means of ice. Bin or pen boards may be installed to divide the hold as desired (Fig. 10). Ice is usually stored in alternate bins so that it will be handy for packing around the fish as it is loaded into the adjacent bin. The

crushed ice varies in size all the way up to lumps the size of a man's fist.

As the fish are stowed with crushed ice, each pen is generally divided horizontally by the additional insertion of horizontal boards so that the bottom fish will not be crushed by the weight of ice and fish above. The compartmented sections should not be more than 30 in. high if undesirable crushing and bruising of the bottom layer of fish are to be avoided.

The approximate amount of ice required is 1 ton for each 2 tons of fish capacity in summer, and 1 ton to each 3 tons of fish capacity in winter, based on a voyage of about 8 days. Less ice is needed if the ship has mechanical refrigeration.

The method of stowing the fish in ice is very important to the keeping qualities. The depth of ice on the floor of the pen should be a minimum of two inches at the end of the voyage. Experience has shown that this is obtained by having the initial bedding of ice one inch thick for each day of the voyage. In stowing, one or two layers of fish are laid upon the bedding ice in such a way that the ice is just covered completely. In no case should the layer of fish exceed 12 in. in thickness. The top covering layer of ice is about 9 in. thick, heaped up higher in the center than along the sides. This method of stowing permits the pile to adjust itself to subsequent melting and settling, and results in good drainage of water and fish slime from the pile.

Most small fishing vessels are constructed of wood and the holds are not insulated. A few of the newer vessels are of steel construction with insulated holds. Mechanical refrigeration is used on some of the vessels to keep the ice from melting so fast, and to maintain lower temperatures. The most common type of mechanical system employs direct-expansion cooling coils under the deckhead of the hold and sometimes around the entire shell. Another system uses a double wall construction with cold air being circulated around the entire hold between the insulated hull and deck, and an inner metal lining.

In the Atlantic offshore fisheries the ice system is extensively used for cod, haddock, rosefish, flounders and other varieties of bottom fish. On both Atlantic and Pacific Coasts, many tuna trollers use ice for the preservation of their catch. On the Pacific Coast refrigerated sea water seems to be gradually displacing the ice in many areas. Ice is used extensively for the stowage of headed shrimp aboard trawlers operating in the Gulf of Mexico.

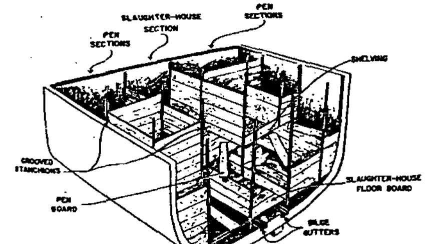

Fig. 10 .... Typical Layout of Pens in Hold of New England Trawler

MECHANICAL REFRIGERATION

Tuna Seiners

Most of the refrigerated California tuna seiners are dual purpose ships used for both sardines and tuna. Sardines are caught on short hauls and refrigeration is not used. In order not to interfere with sardining, the floor coils of the hold are flanged and made removable so that they can be taken out and stored ashore during the sardine season. Sardines are brought in at a temperature of approximately 70 F. Upon unloading and weighing, they are flumed into storage tanks and cooled in 30 F brine at the cannery for a period of eight hours before processing and canning.

When fishing for tuna, the cooling system is used to keep the crushed ice from melting on the outgoing trip. On the return trip when the hold is loaded with tuna packed in ice, the refrigeration is operated continuously to bring the hold temperature down to 25 F or to 20 F and partially freeze the fish. To prepare for unloading just before reaching port, clean sea water is pumped into the hold to loosen the fish from the ice so that they can be removed from the hold.

On the larger seiners, the refrigeration equipment is usually powered by electric motors. On the smaller vessels small diesel engines are used, or the refrigeration compressor may be V-belted from the main propulsion engine. When a separate engine is used for powering the refrigeration, the condenser pump is normally driven by the same engine.

The usual marine practice of having duplicate equipment to prevent cargo loss in case of breakdown is not as a rule carried out on seiners. There are several reasons for this, one of which is the cost. Another reason is that the ordinary seiner does not hold as much fish as the larger clipper and consequently does not go as far or stay out as long. The ice carried on a seiner will prevent loss of the fish on a run back to port in case of serious breakdown of the refrigeration machinery.

The addition of steel cargo wells on seiners, the same as are used on tuna clippers, came as a natural development as larger seiners were built for longer trips in search of tuna. One reason for this is the large fuel oil bunkerage space required for the longer trips. The steel cargo wells serve a dual purpose, as auxiliary fuel oil tanks on the outgoing trip, and as fish holds after being thoroughly scrubbed down for the return trip. In order not to reduce the holding capacity for the sardine operation, large manholes are provided through the deck for loading each tank, and several large removable bolted steel plate patches are provided in the sides of each tank. The patches are removed during the sardine season. Most large long range seiners today have at least two tanks in the hold space, and some have the entire hold space devoted to tanks like the all brine tuna clipper. In the larger brine seiners, multiple refrigeration compressors are provided as in the case of the tuna clippers.

As the main purpose of the refrigeration on the small tuna seiner is to keep the ice from melting, best results are obtained by blanketing all surfaces of the hold with cooling coils. Standard practice is to use 1¼ in. steel pipe coils hot dipped galvanized on the outside only and refrigerated by direct expansion ammonia. Refrigerant 12 systems generally use one inch pipe to obtain higher refrigerant velocities and better oil return. The greatest source of heat gain is the deck surface exposed to the heat from the sun. Therefore, the 1¼ in. overhead coils are closely spaced from 5 to 8 in. on centers (4 to 6½ in. for 1 in. pipe). Less heat comes through the skin of the ship so the 1¼ in. coil spacing on the free-board is from