

inner lining. The furring acts as heat bridges and can increase the transmitted heat gain by as much as 35 percent over that of a homogeneous insulation.

In marine service, the containers are subjected to frequent hogging stresses from fork-lift handling, sagging stresses from 4-corner hoisting at the ship, and torsional stresses in land transport. While an effort is made to seal all joints of the container shell, these stresses can quickly nullify the effort, and a permeable insulation is subject to heavy moisture gain such as is experienced by the trucks. In truck service, air infiltration through the insulation while under motion has been found to increase transmission heat loads by 10 to 27 percent. Similar conditions should be anticipated for on-deck sea service.

The ideal container would be one in which the boundaries, except the roof and floor, would be stiffened externally by metal shapes or corrugations. Internally mounted roof framing will not interfere with stacking, and the internal structure in some cases is called upon to support hanging meat rails. To clothe such internal structure additional thicknesses of insulation are required. All framing should be of such scantling that they will resist racking stresses under superimposed loads of stacking, on-deck lashing, or tilting in a seaway. The external panneling must be of materials or coatings that will resist corrosion by salt air, sea spray, or trailing stack gases. The under-floor structure should be covered with automotive undercoating.

The insulation should be of such effectiveness that it can economically provide sub-zero temperatures in 100 F ambient. The ideal assembly will call for polyurethane resin foams poured in place between shell and lining and without benefit of furring. The insulation should be applied with bonded joints between successive pours, as it will chafe under frictional movement. These foams have sufficient strength characteristics for the service and their high bond to the forms lends strength to the overall assembly. Properly applied, they will provide adequate moisture-vapor resistance.

Internal linings of walls and overhead may be of plywood, wood fiber hardboard, glass fiber sheet, or plastic laminates. The walls must be fitted with the equivalent of cargo battens to insure air circulation between the cargo and the linings. The floor may be of square metal corrugations or extruded aluminum shapes to permit circulation of air under the cargo and to support all service loads during loading or discharge.

There are fundamental differences in the bases which govern the design and operations of the marine refrigerated cargo container from those which guide the design and operations of the ship's built-in cold storage plant. While the ship's plant is not called upon to freeze cargo, it covers all other refrigeration demands including the arbitrary 72 hr (equivalent) pull-down load of unprecooled fresh produce. Furthermore, the ship's plant traditionally is designed with spare refrigerating machinery and ample margins of heat removal capacity. The possibility of failure in performance is extremely remote.

It is the generally accepted concept that the sea-going refrigerated container has inherited from the highway services the condition that the container is designed to carry only precooled or pre-frozen cargo received at carrying temperatures, and that maximum capacities of the attached refrigerating machinery may nearly match anticipated maximum heat removal loads. There are no spare machines and the only safeguards against failure and malfunctioning of an attached machine are the spare parts carried by the vessel and the alert supervision of crew members. On shore, where

the container is always accessible and spare machines are available, replacement of the entire refrigerating machine is more feasible.

With efficiently insulated containers the movement of pre-cooled or pre-frozen produce between source and ship loading may be classified as long-haul and short-haul operations. Short-haul may be defined as that in which the containers are loaded at the ship's side, at nearby terminals or cold storage plants, or at sources of moderate distance from the ship-loading berth. In such cases where the interval before resumption of applied refrigeration is not extended, the attached refrigerating machine may be idled or absent.

In long-haul operations some form of refrigeration must be provided, such as an attached refrigeration unit, dry-ice, or, with frozen foods, by residual refrigeration through sub-cooling of the product.

To meet these conditions three types of refrigerated containers have been developed or proposed. The first method utilizes the conventional arrangement of insulated container with an attached refrigerating machine, which may have two sources of power: (1) a butane internal-combustion engine for use on the highway, and (2) an alternating current motor which may be powered by the ship's electric plant. Some schemes outfit the highway chassis with an electric generator which supplies the single motor with current of the same characteristics of that of the ship. When these units are carried below deck, means must be provided to remove the rejected heat from the ship's compartment. This has been accomplished by outfitting each machine with an air-cooled condenser for highway service and a water-cooled condenser for service on the ship. While in the ship, the water-cooled condenser is connected by hoses through which fresh water is successively recirculated through condensers and heat exchangers. An alternate arrangement calls for a purging mechanical ventilation system. The refrigerating machine is similar to the standard highway unit but is especially fitted to resist the severe and corrosive conditions of sea service. The power demand of these units is high. With large shipments of cargo, the supervision and maintenance of multiple machinery becomes a matter of operational concern.

A second method of transporting frozen foods has been projected in which the product is deeply subcooled by liquid nitrogen after loading into the container. The degree of sub-cooling varies with the length of voyage and is intended to allow transmitted heat gain, delivering the product at a safe temperature level.

The third method being developed places the loaded container, without refrigerating machine, in the ship's insulated compartment in the same manner as the traditional built-in plant having remote and centrally controlled refrigerating machinery. The container is fitted with closeable low inlet openings at the door end, through which ambient air is drawn by an exhaust fan located high in the front end of the container. The fan discharges the air back into the ambient space. The method has been designated as an *ambient refrigeration system*. It is intended that, for short-haul service, no attached refrigerating machine is required. For long-haul service, the portable attached refrigerating machine is substituted at the ship's side with an insulated aperture panel upon which the exhaust fan is mounted. The fans are connected to the ship's electric system by portable cords with remote gang circuit control.

The roll-on-roll-off method of sea transport in commercial trade is economically suited to short voyage services. Trans-

port by this method involves the use of highway trucks and trailers, complete with their running gear, and is not an efficient use of a ship's compartments. In military service this is not a prime factor. Refrigerated trucks and trailers are discussed in Chapter 55.

PART II: SHIP'S REFRIGERATED STORES

Today, most vessels are equipped to carry provisions for long voyages without provisioning en route. The refrigerating equipment must operate under extreme ambient conditions. There is increasing use of frozen foods. Modern mechanical refrigeration and food technology make possible food preserving conditions for long periods for perishable stores at sea. Hence, the trend is toward lower temperatures with increased attention given to other factors such as packaging, humidity, and air circulation, and the increase of space requirements in modern marine installations.

Perishable foods go aboard fresh, dehydrated, canned, smoked, salted and frozen. For some of these, refrigeration is an absolute necessity; for others it is advisable but may be omitted if the storage period is not too long. Space is costly aboard ship and is always limited. Therefore, many rooms at different temperatures cannot be practically provided. The benefits of modern food technology can be obtained for all practical purposes by providing conditions outlined in Table 2 and as described below.

Commodities

Meats and poultry. Substantial savings in space, labor of preparation, and better quality can now be obtained by making use of pre-cut, boned, frozen meat and poultry packed in moisture-vapor-proof cartons and wrappers. For this reason, increased 0 F storage space should be anticipated. Fresh meats are less suitable because of their relatively short storage life. The space required for fresh meats will be from two to four times that needed for prepackaged meats.

Fish. Frozen fish is now readily available. Good quality fish, properly prepared and packaged, will remain odorless and palatable for long periods of time.

Ice cream. Commercially prepared ice cream is nearly always available and used to a great extent for both passenger and freight vessels. Ice cream for immediate service should be kept at a slightly higher temperature in an ice cream cabinet in the galley or pantry. Ice cream making equipment may be desired, in which case provision must be made for hardening the machine-made ice cream, ices, and sherbets.

Bread. Excellent results can be obtained by purchasing bread freshly baked, sealed in moisture-proof wrappers, and stored at 0 F. This supply may be supplemented by bread and other bakery items made on the ship. Frozen bread may be thawed in its wrapper in a few hours.

Frozen fruits and vegetables. Packaged frozen fruits, fruit juices or concentrates, and vegetables may be stored in any freezer room. All of the packaged frozen products mentioned may be held in a common 0 F storage space. However, the increased usage, especially on large passenger vessels, may justify separate refrigerated spaces for some or all of the products.

Fresh fruits and vegetables. There are some products not suitable for freezing or in some cases the fresh grown product is desired. These items may be stored in a common room, but some compromises with their optimum storage conditions must be expected. Growing use of frozen products is reducing the demand for fresh fruits and vegetables.

Dairy products. All dairy products may be stored in a single

room, following customary shore-side practice. Strong cheeses with odors that might be adsorbed by other foods should be stored in a tightly enclosed chest or cabinet placed in the dairy refrigerator. Eggs may be processed by oil dipping or heat stabilization to make them less sensitive to unfavorable humidity conditions or odors. Large passenger vessels should be fitted with a separate egg storage room. Butter for reserve supply should come aboard frozen and be kept in a freezer. Frozen homogenized milk has been perfected to a degree that it can be carried for reasonably long periods. Aseptically canned whole milk is now available and may be stored without benefit of refrigeration, but this product has some limitations because of the faintly detectable cooked flavor.

Ice. The making of block ice on any marine installation is of questionable practice because of operating difficulties as-

Table 2 Classifications for Ships' Refrigeration Services

Service	Temp, F	For Passenger Vessels	For Freight Vessels
Freezer Rooms			
Meats—poultry	0	X	X
Frozen foods	0	X	X
Ice cream	0	X	X
Fish	0	X	X
Ice	28	X	
Bread	0	X	
Chill Rooms			
Fresh fruit—vegetables	34	X	X
Dairy products—eggs	32	X	X
Thaw rooms	40-45	X	X
Wine rooms	48	X	
Bon voyage packages	40	X	
Service Boxes			
Main galley			
Cooks' boxes	40	X	X
Butchers' boxes	40	X	
Bakers' boxes	40	X	
Salad pantry refrig.	40	X	
Coffee pantry refrig.	40	X	
Ice cream cabinet	10	X	
Ice chest		See text	
Mess Rooms or Pantries	40	X	X
Deck pantries	40	X	
Wine stewards' box	40	X	
Bars—fountains	Various	X	
Miscellaneous			
Ice cube freezers	See text	X	
Ice cream freezer	See text	X	
Biologicals	40	X	
Drinking water systems	See text	X	X
Canned foods	See text	X	X
Dehydrated foods	See text	X	X
Ventilated Stores			
Hardy root vegetables	See text	X	X
Flour cereals	See text	X	X