ity to resist moisture, a fact which is seldom appreciated and too often neglected. A continuous steel internal bulkhead with lap seams and welded stiffeners provides a boundary of adequate strength and tightness. Details of design may accommodate dimensioned insulators or facilitate means of fastening these materials. Doorway main bucks of steel channel provide good structure, but are usually a source of warm side sweating on low temperature rooms because of the heat gain through the metal conductor. Wooden door bucks minimize sweating but are a retreat from our efforts to eliminate concealed wooden structure.

Partitional bulkheads may be of similar detail, but airtight sealing is of less importance. Some installations are framed with angle-bar grids only, between which the insulator is installed. In passenger vessels (over 12 passengers) the Coast Guard Regulations governing fire-resistant construction are severe, and wood assembly is restricted. Under no circumstances should wood be a part of the floor assembly, because of its rapid deterioration under the prevalent conditions.

The assembled boundary of a ship's refrigerator must be able to withstand heavy floor loads and also severe wall thrusts of cargo when the vessel rolls or pitches in a heavy sea; it must be able to flex with the hull structure being stressed in any angle of the three dimensions. The assembly must resist change by forces occasioned by vibrations caused by the propelling machinery or the sea, and by the careless or accidental handling of cargo by stevedores. The moisture-vapor seal of all surfaces must be preserved under all of these conditions.

The means by which the various types and kinds of insulators are held in position are numerous. Fibrous battings are secured to steel work with welding studs or cemented fasteners. Packing type insulators are stuffed into spaces formed by two room-lining surfaces or between linings and the ship's structure. The most satisfactory means to secure

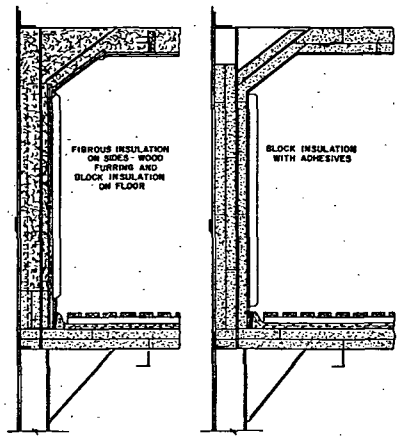


Fig. 3 .... Typical Transverse Sections at Ship's Side

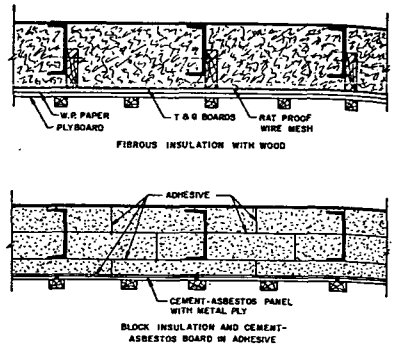


Fig. 4 .... Typical Longitudinal Sections at Ship's Side

block insulators is to apply a complete envelope of adhesives after cutting and fitting.

Adhesives, when properly applied to the total area of each piece of fitted block not only adequately secure the material but at one and the same time provide a continuous and multiple moisture-vapor seal. Steel boundary bulkheads may be of non-air tight construction with this type of installation, the cement effectively closing off all openings through which moisture-laden air could otherwise migrate. If the block is resilient and of structural strength, no furring or internal strength frame work is required. The cements should contain no materials or vehicles which will give off tainting odors that will not have been dissipated before the refrigerators are placed in service.

When polystyrene insulators are secured in this manner, the adhesive must have no solvent that will adversely affect the insulator and it should have the approval of the insulation manufacturers.

Adhesives are now available which will, by government test, provide ultimate bonds of 1500 lb per sq ft dry, and 750 lb per sq ft by submerged tests. Overhead insulation loads will seldom exceed 14 lb per sq ft which gives ample margins for imperfections in application. With adhesives, furring becomes superfluous.

Because the volatiles must be dissipated through glue lines and the joints of impervious linings (where used), a chemical setting adhesive is preferred over water emulsion adhesives.

The methods by which adhesives are applied should be prescribed by the manufacturer and his instructions strictly followed. As with all applications of insulation, the concealed steel structure of the vessel should be properly prepared to preserve the metal and to insure good adhesion of all coatings.

Only in extreme cases should there be concealed voids in the insulation assembly. It will be found more effective and of less cost to fill such volumes with insulating material than to construct internal framing. The exceptions to the rule will be in the deep volumes formed by bilge brackets, deck brackets, and open box type girders. Solid filling results in more insulation thickness than is needed for a heat barrier in the overhead in way of the beams and at the ship's side where the frames are deep, a good fault. (See Figs. 3 and 4.)

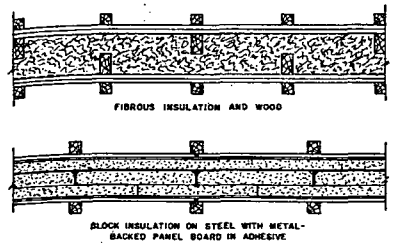


Fig. 5 .... Types of Wall Sections

The third part of the boundary assembly is the room lining. This surface must be of sturdy construction to withstand the impacts of frequent loading and handling of cargo. On passenger vessels the Coast Guard regulations require that the lining be fire-resistant. The age-old use of tongue-and-groove lumber is now considered obsolete for any type of ship and various kinds of lining are employed. On freight vessels where wood is permissible, plyboard made with water-proof glues is sometimes applied. A few installations have been made of laminated plastic sheets and of wood fiber hardboard, both satisfactory when properly supported.

Steel linings are costly and impractical, difficult to maintain and repair. The favored lining is the cement-and-asbestos hardboard panel with aluminum sandwich lamination. When the insulator is secured with adhesives having volatile solvents the aluminum laminations should be of perforated metal or mesh.

The U. S. Public Health Service requires all linings to be rat-proofed. Vulnerable linings should have an underlay of ¼ in., 16 gage galvanized wire mesh for rat-proofing.

In the application of panels with adhesives over block insulators, the butted joints should be separated sufficiently for the adhesive to extrude and provide a moisture sealed joint and to accommodate movement of the panels by the flexing of the ship's structure. The joints may be covered by cargo battens, also secured by adhesive and with brass screws. The walls of all refrigerators should be fitted with vertical cargo battens which in the case of the cement-asbestos panel, may serve dual purposes. Battens on the walls should be on 15 to 18 in. centers to hold the cargo clear of the insulated wall. This serves to permit circulation of air and to prevent the contacting package from assuming the part of a room insulator.

Container vessels of the cellular type construction move the containers along guiding columns, and the boundaries of the hold, the hatch coamings excepted, are not subject to mechanical damage. In such an installation the insulation may be of the simplest, low cost, rat-proofed form without benefit of fitted hard panels or cargo battens.

The greatest weakness in ship refrigerator construction is the floor covering. Research and practice have not brought forth a totally satisfactory covering. Unlike the warehouse, the tightly packed cargo refrigerator must have floor gratings to insure the circulation of air and to protect the bottom tier of products from the leakage heat. The bearers of the gratings carry the weight of cargo to concentrated load areas of the floor. The room may be filled with warm general cargo in alternate service and a thermo-plastic covering may be damaged through penetration by the bearers. Contrarily, the floor covering must be elastic and flexible enough to accommodate changes from the flexing of a ship, or from extreme temperature changes, as well as maintaining a moisture-proof cover over the insulation under all conditions. The most satisfactory material is a mastic composed of emulsified asphalt, sand and cement. This material is applied cold and upon setting has good load bearing qualities and is impervious to water. It has a small degree of ductility and may be used in less thickness than concrete. It should always be reinforced and there should be expansion joints to accommodate set shrinkage and adjustment to movements of the ship's structure.

All rigid or semi-rigid floor coverings should have expansion joints of rubberbase composition capable of making good bond to the edges of the floor slabs or wall and not subject to shrinking by the loss of its vehicle through evaporation or in chemical change. The pattern of the expansion joints should trace the entire periphery of the room, the line of all underdeck grider systems, bulkhead offsets to pillars and similar lines of anticipated ship stress.

The melting of ice from ice-packed vegetables and the defrosting of cooling apparatus subjects the floor covering to much water. Unless the floor covering is permanently impervious to water in the slab, as well as at the joints, the floor insulation will be wetted, and in turn will deteriorate, lose its efficiency as an insulator, or give off odors. Upon freezing, it would lift the deck covering and cause its destruction. If the water penetrates to the steel, the ship's structure will corrode unnoticed.

It is impossible to provide a floor covering that will not develop faults through cracking or damage throughout the ship's life. As a secondary security against ingress of water, a membrane should be laid between the insulator and the floor covering. A saturated asbestos felt laid in an adhesive is good design. The membrane need not be flashed to the wall if suitable sealing expansion joints are fitted at the juncture of the wall panel and the floor covering. (See Fig. 6.)

The migration of moisture into a permeable insulation can under certain circumstances cause wetting by the deposit of of condensed vapor, frosting, and general deterioration of physical properties and efficiency of the insulator. When an attempt is made to provide a seal with water-proof paper, it should be applied in double thickness and the laps and per-

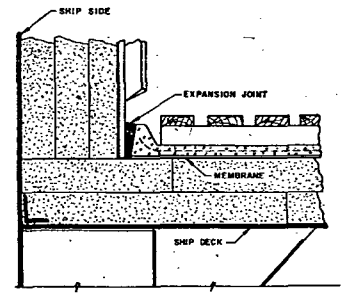


Fig. 6 .... Detail of Floor Sections