structural members make it difficult to obtain a high resistance to heat flow since they constitute high conductivity heat paths and interfere with the placement of the insulation. Various service conditions (including impact and vibration of the car, ram air pressure caused by the movement of the car at high speeds, body and top icing within the car, periodic washing of the car interior, and reversal of the direction of water vapor flow with the winter and summer seasons) make it difficult to retain the initial resistance to heat flow. Wetting[8] and settling of this insulation have been the principal problems that are aggravated by these service conditions.

The A.A.R. specifications for freight refrigerator cars[6] establishes a minimum insulation thickness for *RS* type cars of 4 in. in the sidewalls and ends and 4½ in. in the floor and roof. These requirements are based on insulation materials having a thermal conductivity not to exceed 0.27 Btu per (hr) (sq ft) (F deg per in.) at a mean temperature of 70 F. With bunkerless refrigerator cars (*RB*) and (*RBL*) the minimum requirements[1] are 3 in. in the sidewalls and ends and 3½ in. in the floor and roof. Cars equipped with mechanical refrigeration usually have 6 or 7 in. of insulation in the floor, sidewalls, and ends, and 9 or 10 in. in the roof.

The usual method of insulating refrigerator cars has consisted of applying continuous blanket insulation (usually composed of fine diameter glass fibers bonded with a thermosetting resin) over the floor, the roof, and in the sides and ends from door post on one side to door post on the other side. With this method the blanket insulation is compressed by the vertical steel posts in the sides and ends, by the horizontal wooden belt rails at the sides and ends, and by the longitudinal wood stringers in the floor. A sheet of reflective insulation is frequently placed over the blanket insulation in the roof. In this location, reflective insulation is quite effective since the direction of the heat flow during refrigeration service is down and since the thickness or depth of the air space is maintained in service.

In order to avoid compressing of the insulation by the structural members, some cars have been built using insulations which fit between the structural members. These insulations have included pre-cut fibrous types, multilaminar flexible insulation in panels, and pre-cut rigid types.

The selection and location of water vapor barriers has required special consideration because of the reversible water vapor flow conditions. With *RS* type cars, for example, the direction of water vapor flow depends upon whether refrigeration or heater service is being provided. To solve this problem, water vapor barriers have usually been placed on both sides of the insulation. Structural, membrane, and surface-coating type water vapor barriers have all been used in refrigerator car construction. Structural barriers include those insulations having a closed cellular structure and the external steel sheathing, which on the newer cars is all-welded rather than riveted. Surface-coating barriers include the various mastic coatings which are sprayed on the interior of the steel sides, ends, and sub-floor after they are assembled. The underside of the roof has been similarly coated on some of the cars equipped with mechanical refrigeration. The mastic is usually an asphalt base material although rubber base materials have also been used. A $^{3}/_{16}$ in. thick mastic covering is frequently applied over the top of the floor.

Membrane-type water vapor barriers are usually used as the covering for blanket insulation. Membrane barriers having 1 or 2 reflective surfaces have been placed adjacent to the steel sides in addition to being used in the roof. Some of the mechanical cars have a layer of water vapor barrier paper above the top of the ceiling plenum and also on the back side of the inside wood lining.

The use of closed cellular plastic insulations has increased greatly the past 2 years. While these insulations were first used only in the floor where, because of body and top icing, the need for water resistant insulation was the greatest, they have recently been used quite extensively throughout the car. These insulations are practically impervious to water and water vapor and many possess sufficient compressive strength to withstand the entire floor load in a refrigerator car. Some of the high conductivity heat paths through the car structure can be avoided if these insulations are used in such a manner as to provide sufficient strength to eliminate various conventional structural members such as the horizontal belt rails and the floor stringers. One method of accomplishing this is by means of *sandwich panel* construction (see Fig. 2) with cellular insulation used as the core material.

Approximately 1000 mechanical refrigerator cars have now been built using sandwich panel construction throughout the car or in the floor alone. These panels have a 6-in. thick core of cellular insulation to both sides of which is bonded a ⅜ in. thick plywood face. The length of the panels used in the floor and sides is ½ the length of the car, whereas only one panel is required for the roof and each of the ends. All of these cars have external side posts in lieu of internal side posts. Placing of the metal side posts on the outside of the car partially eliminates compressing of the insulation when fibrous insulation is used and with sandwich panel construction permits the side panels to be placed in contact with the metal side sheathing.

Ice Bunkers and Brine Tanks

The ice bunker space in end bunker cars is formed by an insulated bulkhead, placed about 4 ft from the car ends, having an opening at the top and bottom for air circulation. The bunkers in end bunker cars are usually of the basket type which consist of heavy wire screens or perforated metal plates, or both, placed a few inches from the walls of the bunker space. Two hatch openings at the top of the bunker space permit icing and are normally tightly sealed by insulated integral hatch covers and plugs. A few of the older cars in service are equipped with insulated hatch plugs that are separate from the hinged hatch covers. Vent irons attached to the car roof are used to hold the hatch covers in an open position for ventilation service.

The floor of the end bunker space is covered by a metal pan which is depressed below the level of the floor in the loading area. Water and brine that accumulates on the floor pan flows to well traps on each side of the pan, and then through drain tubes extending from the exterior of the car. Ice placed in basket type bunkers rests on metal ice grates which have small openings that permit water and brine drainage. Nearly all of the cars with end bunkers are equipped for half-stage icing by having a second set of hinged ice grates located half way from the top of the bunker to the lower ice grates or by having ice grates which can be removed from the bottom of the bunker and placed half way up the bunker. The purpose of *stage* icings is to permit more effective and efficient use of the ice by confining it to the upper portion of the bunker so as to maintain a high thermal head for air flow by natural convection and reduce the amount of ice remaining in the bunkers at destination. Stage icing is used quite extensively, especially in moderate weather. The chunk ice capacity of end bunkers varies from 4200 to 14,600 lb depending upon the size of the bunker; however, the majority have a capacity of 9600 to 11,500 lb. The capacity of end bunkers with coarse ice is about 6 percent greater and with crushed ice about 10 percent greater than with chunk ice. The bunker capacity with half-stage icing is usually one half

the full bunker capacity. A few cars are equipped with three stage icing devices which give bunker capacities of 11,000, 8000, or 6000 lb of crushed ice.

A number of end bunker cars used exclusively for meat and packing house products are equipped with brine tanks. Each bunker space contains four separate tanks and each hatch opening serves two tanks. The tanks retain the brine from melted ice and salt and are usually provided with valves to permit draining at icing stations and at destination. A significant advantage of brine tanks is that dripping of brine (which

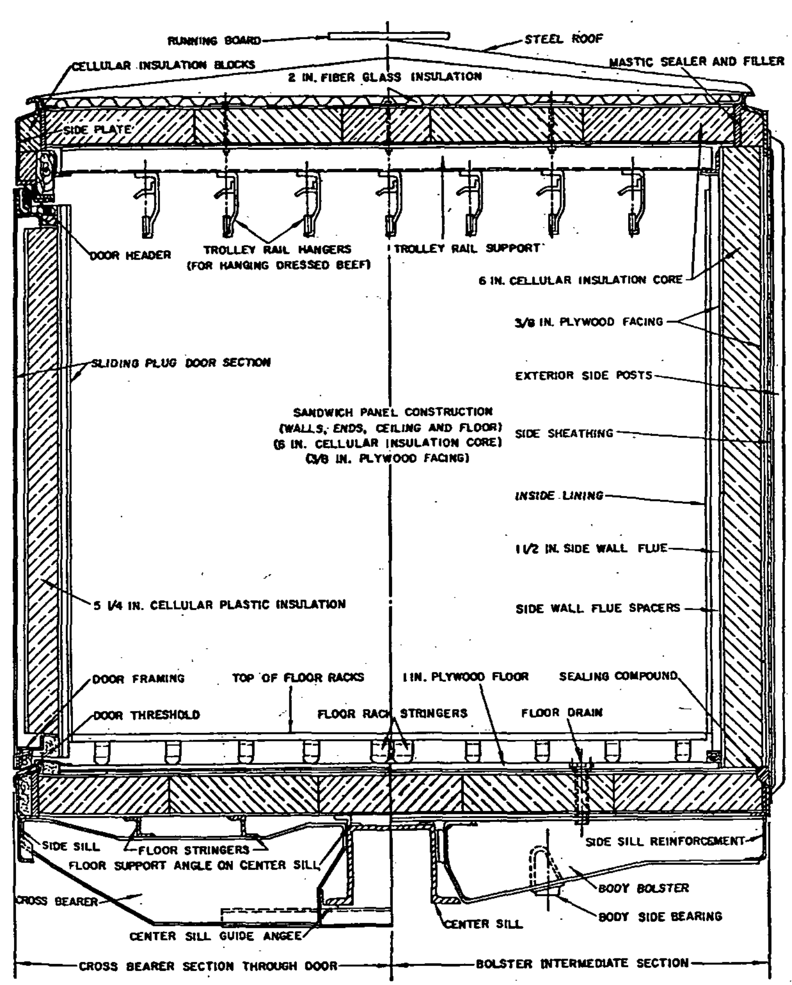

Fig. 2 .... Cross-Section of Sandwich-Panel Construction for Refrigerator Car