

ferred to shipboard for movement to another port city, or to other countries. The trailer body is lifted from the trailer chassis and placed either on deck or in the hold of the ship in one operation by the deck-mounted gantry crane. Special fittings permit these bodies to be stacked four high and locked together to prevent shifting.

One railroad has developed a means by which it claims one man can transfer a loaded trailer body from a set of bogie wheels to a special 80-ft long railroad flat car in 4 min. The trailer is backed up to the side of the car, the bogie wheel assembly is unlocked and the trailer is shoved onto the car. The driver then swings the trailer body into position. A hydraulic hoist-turntable built into the rail car raises the body to make this possible. The bodies are unloaded by the reverse of this same process.

A rail-mounted gantry crane is used in some railroad yards to transfer trailer bodies from the trailer chassis to gondola or flat cars in a manner similar to that described for the trailer-to-ship operation.¹⁷

Standard piggy-back technique is being employed by many truck and rail interests. In this operation the trailer is driven or lifted with its wheels onto a railroad flat car and attached to the car for haul by rail. USDA tests compared piggy-back trailers and rail cars.^{18,19}

Many types of insulated containers are being considered which can be attached to a truck, trailer, or rail flat car, or carried in a ship or cargo aircraft. Green discusses several of these combination services.⁸

In general, trucks are used in operations which require more door openings per day than trailers used primarily for long hauls. Body styles have been developed to suit the character and distribution requirements for perishable products. Many trucks and trailers contain more than one compartment maintained at different temperatures.

A relatively new feature, movable or hinged compartment dividers, including one inflatable type actuated by air from the vehicle air brake system, is receiving considerable attention. The dividers are used to provide compartments at different temperatures, or to reduce the size of the refrigerated compartment as the vehicle is unloaded.

Various devices such as power lift gates, conveyors, etc., which facilitate loading and unloading, are built into the body. Trucks for retail delivery may be furnished for either walk-in or reach-in service. Wheeled racks, which can be rolled into place in the truck, are used to expedite loading.

TEMPERATURE CONTROL METHODS

Refrigeration

Insulated truck and trailer bodies must be refrigerated whenever the commodity being hauled will lose value if it should warm excessively during transportation. The degree of refrigeration required and the permissible variation in temperature of the product will determine the type of refrigerating process to be used. The various types of refrigerating systems are described in a later section.

Ventilation

Whenever ambient conditions are suitable, certain products can be kept at acceptable temperatures by ventilation of the truck or trailer interior either with fans or blowers or by ventilator openings in the front and rear of the vehicle which allow movement of air through the vehicle as a result of the air pressure developed on the front during forward motion. Ventilation needed for safety in handling flammable, explosive or toxic products can also be provided.

Heating

While this chapter deals primarily with provisions for providing refrigerated protection, there are occasions when many perishable products have to be protected against ambient temperatures which are lower than the safe level for the commodity. Heating equipment of several types can be provided for this purpose and is described later.

BODY DESIGN AND CONSTRUCTION

Conventional Features

The primary function of an insulated body is to permit economical control of the environment around the commodity being transported or stored. The necessary features are determined by the type of service intended. Krotzer presented a check list of features influencing the design or purchase of a refrigerated truck.² Doors must be provided to permit loading and unloading. Many trucks used in retail delivery have small doors opening into separate compartments often at different temperatures for a variety of products. These vehicles are referred to as reach-in bodies as opposed to walk-in vehicles.

Trucks may have doors on the two sides rather than at the rear, but most trailers are equipped with full-opening rear doors large enough to permit fork-lift trucks to be driven into the vehicle. Many trailers are also equipped with a curbside door. Refrigerating equipment must be provided and, in many cases, heating and ventilating equipment is necessary. Meat trailers must be provided if vehicle is to be used for hanging meat. Temporary or permanent discharge ducts from the refrigerating unit can be used to assure air movement through the meat.^{7,10,11}

The trend in insulated body construction is toward all-metal, metal-plastic, or all-plastic construction for purposes of strength and longer life. The goal of body builders is to construct a light weight body of sufficient strength in which the insulation will stay dry and maintain its original insulating value. Increased use of plastic roof supports, meat rail bows, floor and wall supports is noted.

Bodies for low temperature use (about 0 F) are typically insulated with 6 in. of an insulating material with a k factor of lower than 0.3 Btu per hour (sq ft) (F deg per in. thickness). Chapter 22 of the 1961 ASHRAE GUIDE AND DATA BOOK discusses use of insulation and water vapor barriers for mobile use. Several types of insulation are used: glass fiber, expanded polystyrene, expanded rubber, hard-board, foamed plastics, etc. Foamed-in-place plastics such as polyurethane are receiving increasing attention. With high molecular weight gas in the cells of the insulation, such insulations may have k factors of 0.18 or lower.^{7,20,21} Loose fill material that settles during use is not recommended. Batts or sheets of semi-rigid materials are usually compressed slightly as a precaution against settling. Densities as low as $\frac{1}{4}$ lb per cu ft are common. Chapter 23 of the 1961 ASHRAE GUIDE AND DATA BOOK lists characteristics of most of the available insulating materials.

Medium temperature bodies commonly use from 2 to 4 in. of similar insulating material.

Frame construction must not include through members of significant heat conducting capacity. Floor loads are frequently supported on rigid type insulating material to eliminate floor beams. Some medium or high temperature trailers are built without any insulation in the floor, but this practice is not recommended because tests have shown that engine waste heat and radiation from hot road surfaces can raise the temperature of the exposed under surface as much as 20 F

deg above the ambient air temperature. Floor surfaces may be of wood or metal. If wood floors are furnished they should be tongue-and-groove treated lumber well sealed against water penetration. Metal floors should be water tight, and if separate floor racks are not furnished the floor surface should provide for adequate air movement under the load. Several floor surfaces of formed or extruded character are available, but not all of these permit enough air circulation under the load.¹⁴ Galvanized or treated steel and aluminum are used widely for ice cream body floors in trucks, while aluminum is most often used for trailer floors. Corkboard, expanded polystyrene, expanded rubber well sealed with hydrofene or emulsified asphalt are frequently used for floor insulation. A metal skirt reaching at least 6 in. up the walls should be bonded to the floor so that water running down the wall or collecting on the floor will not enter the insulation. Plywood, aluminum, other metals and certain plastics are used for interior wall surfaces.

All exterior surfaces of an insulated body must be made as nearly air and water vapor tight as possible. Unfortunately, it appears to be impossible to fabricate walls, ceiling and floor so as to be completely moisture proof. Water vapor will pass through any opening or non-vapor proof barrier in the outer shell and will condense in the insulation space. Some ice cream truck bodies have been known to increase more than 500 lb in weight over a period of use, and large semi-trailers in frozen food service have gained up to 1500 lb, according to USDA reports. This excessive dead weight increase is of great importance to the trucking industry because of the maximum allowable weight limits prescribed by some states that tend to cut down the pay load that may be carried with such commodities as frozen citrus concentrate. Further, as the k factor of wet insulation may be much higher than its original value, either the required low temperature may not be obtained, or a much greater load is placed on the refrigerating equipment with resultant increased operating and maintenance costs. Weighing a truck when new and regularly during service will indicate whether significant amounts of water are accumulating in the insulated space.

Eby and Collister have pointed out the serious heat gain penalty imposed by air entering the insulation space through cracks in the front of the vehicle because of the ram or static pressure caused by the motion of the vehicle.²² They show that this driving force is 1.21 in. of water at 50 mph, and that a 6-ft length of unsealed seam can permit the entry of 1440 cu ft of air per hour. At conditions of 100 F ambient temperature at 50 percent rh, and a trailer temperature of 0 F, the heat gain caused by this amount of infiltration air could be 4600 Btu per hr, assuming that this leakage air left the vehicle saturated at 0 F. Phillips, Achenbach, and Lents also have discussed air leakage.^{23,24,25}

Care must be taken not to create highly conductive heat paths through the roof insulation in providing the supports for meat rails. Even where height is critical metal roof bows must not be permitted to contact the roof exterior surface. Side wall supports should not extend through from interior to exterior surfaces. Besides causing increased heat gain, such heat paths can cause condensation on the exterior surface with resultant corrosion problems.

Features to Reduce Heat Transmission and Moisture Penetration

Recent tests at the National Bureau of Standards have shown that refrigerated vehicles leak air even when stationary, probably because of the stack effect of the temperature dif-

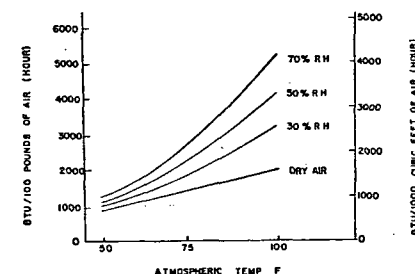
ference between inside and outside.^{26,27} This driving force for air infiltration, for a body 8 ft high and a temperature difference of 100 F, deg is about 0.030 in. of water. If it is assumed that the openings in the exterior skin function as thin plate orifices, the air leakage due to an aggregate opening equivalent to one square inch each at the top and bottom of a vehicle would permit the passage of about 120 cu ft per hr. Observed leakage rates for a nominal 35 ft trailer of more than 700 cu ft per hr, and weight gain rates due to accumulation of ice of nearly one pound per hour, at laboratory conditions of 100 F ambient temperature at 50 percent relative humidity, and 0 F trailer temperature, illustrate the benefit to be derived from improving the vapor tightness of the exterior shell. The need for better vapor sealing is even more significant at road speeds. For example, if a one square inch opening were located where it was subjected to the 1.21 in. of water ram air pressure at 50 mph, approximately 1150 cu ft of air per hr could be driven into the insulation space of the vehicle. At ambient temperature and humidity conditions of 100 F and 50 percent, the heat gain due to this leakage would be about 3800 Btu per hr, assuming that the air was cooled to the trailer temperature of 0 F.

Road tests of nominal 35 ft commercial trailers have shown minimum air leakage rates as high as 1590 cu ft per hr at 50 mph.^{28,29} Fig. 1 is a graph of the heat gain due to air leakage into a vehicle with an interior temperature of 0 F, at various ambient temperatures and relative humidities.

When moist air is permitted to move through the insulated space, some of the water vapor is left behind to cause trouble in several ways:

1. Increased heat gain due to latent heat of vaporization and fusion.
2. Loss of payload because of weight gain.
3. Corrosion.
4. Increased heat gain through insulation.
5. Coating of coils with frost with loss of refrigerating effect.
6. More frequent defrosting.
7. Physical damage to insulation.
8. Rotting of wood members.
9. Odor.

Some moisture can enter the insulation space by diffusion through cracks or permeable surfaces. The amount brought in by diffusion is, however, negligible compared to that carried in as a result of air infiltration, whether the vehicle is stationary or moving. It is, therefore, of paramount im-



* For a refrigerated vehicle with interior temperature 0 F.

Fig. 1 Heat Load Due to Air Leakage*