

as twelve doors each serving a separate compartment, many of which are operated at different temperatures. All doors must close tightly to provide an airtight seal, and must be insulated. Some door mullions and breaker strips must be treated to prevent ice seizure. Door gaskets must be used and kept in good condition. Door hinges must be adequate to withstand the road shock and vibration and the abuse of heavy service. Door latches must be capable of opening from within the vehicle to avoid accidental entrapment.

Floor racks are usually made of wood or aluminum and should provide at least 2 in. of clear passage for air with the runners in the direction of air flow. They can be removable or hinged.

Drains must be provided in all vehicles using water ice bunkers, and may be provided for other vehicles to facilitate cleaning. Non-freezing trapped drains must be provided for defrost water to leave the vehicle. Floor drains in low temperature vehicles must be plugged or trapped to prevent air infiltration. Side wall weep holes, if used, should drain into the truck interior and not communicate with trailer exterior.

Indicating Thermometers

Any vehicle used for refrigerated hauling should be equipped with some type of indicating thermometer. The instrument used most often is a remote reading dial thermometer mounted on the exterior surface of the vehicle, preferably where the operator can see it from the cab. Often, the thermometer is combined with a control instrument which cycles fans, or the unit, to provide control of the temperature of the vehicle interior. In many trucks, the instrument is mounted in the truck cab; with trailers it should be mounted where the driver can read it from the tractor cab. There is an increasing use of temperature recording instruments mounted on the trailer nose to indicate, record and sometimes control the temperature in the trailer.^{13,17} The sensing bulb for a remote reading thermometer should be installed in the return air stream in the cargo space for any vehicle with adequate forced air circulation. In a gravity circulation vehicle or with inadequate forced circulation the thermometer bulb should be in a protected location about midheight in the cargo space of the vehicle. It should be remembered that a thermometer can only indicate the temperature at its sensing element, and does not assure proper temperatures throughout the cargo space.

TYPES OF REFRIGERATING SYSTEMS

References 1 to 5, 25, and 27 to 31 at the end of the chapter deal with one or more types of refrigerating systems. In this section, 13 methods of controlling cargo space temperature are discussed.

Use of Product Subcooling

As insulated vehicles have become more effective with improved insulating materials and construction methods, it has become possible to satisfactorily ship some commodities requiring refrigeration without providing any refrigerating equipment on the truck or trailer but by utilizing the heat absorbing capacity of the product itself. One example of this technique is the shipment of milk in tank trucks and trailers, some as large as 5300 gal capacity. Orange juice is also transported in this fashion. Many hot liquids are moved this way, but this is mentioned only because the same principle is involved. It is probable that, intentional or not, many refrigerated loads are received in satisfactory condition partly because of a considerable reserve heat absorbing capacity in the

commodity itself due to subcooling before loading to a temperature below the maximum that it can tolerate. For example, 35,000 lb of frozen strawberries warming from -15 F to 0 F during a 30 hr haul will absorb 247,000 Btu, or 8233 Btu per hr through the trip. In some cases this would be sufficient total refrigerating effect. Fifty-three hundred gallons of milk will absorb 42,380 Btu per F deg temperature rise. If the average tank heat leakage were for example, 6500 Btu per hr during the trip, a temperature rise of less than 6 1/4 F deg would permit transportation of 5300 gal of milk 1600 miles (40 hr at an average speed of 40 mph) without any refrigeration other than the heat absorbing capacity of the milk. One source reports shipments of orange juice in bulk from Florida to New York, a distance of nearly 1400 miles, with temperature rises less than 9 F deg, again with no refrigeration other than the product itself. Careful consideration of all factors is necessary to determine the feasibility of this manner of refrigerated transportation.

Use of insulated containers, with the product subcooled by liquid nitrogen, is being tried experimentally.

Ventilation

Temperature control in an insulated vehicle by ventilation is the simplest but least dependable of any system. Obviously it is limited to areas or times of the year when outdoor conditions are appropriate. Generally this is used only when it is coincidental that conditions are suitable, as, for example, bringing produce into an area which happens to be at or below the desired temperature in the vehicle. Ventilation is usually accomplished by leaving small doors open at the front and rear of the vehicle to take advantage of the pressure caused by forward motion of the vehicle, and the doors are adjusted by the driver as best he can.

Water Ice, Crushed or Snow, Used as Top Icing

Icing, usually by blowing a layer of crushed or snow ice on top of a load after the vehicle is loaded, is widely used for products which need to be kept wet, or which are not harmed by water. The bottom of the load is seldom maintained at a satisfactory temperature with this method, and the vehicle must be opened at intervals for re-icing. The melted ice keeps the interior wet, necessitating drains and accelerating corrosion. For certain produce top icing is recommended in combination with ice bunker operation.¹⁴

Water Ice, in Bunker, with Forced Air Circulation

This type of refrigerating system is widely used in produce hauling where temperatures between 38 F and 55 F, approximately, are satisfactory. The bunker may be either permanent or temporary. Block ice, usually in 25 lb pieces, is dropped or placed in a bunker in the nose of the truck or trailer, with bunker capacities ranging from 1000-3000 lb. Although some ice bunker vehicles use the gravity effect of the chilled air to move air through the vehicle, they are in the minority. Air is usually circulated through the vehicle by blowers or fans which draw the air into the bottom of the bunker, up through the melting ice, and discharge it at the ceiling with sufficient force to throw it to the rear of the vehicle. The fan can be driven by auxiliary gasoline engine or electric motor. Fig. 3 is a cross section of an ice bunker showing the air movement through the bunker. Obviously the lowest temperature which can be produced by this system is 32 F, and, if the air delivery by the fan is constant, the vehicle interior temperature will change as the outdoor temperature changes, and in outdoor temperatures of 100 F, trailer temperatures may in

Trucks and Trailers

many cases be up to 60 F. Ice meltage rates for a 35 ft produce trailer with two inches of insulation in the walls and roof but no insulation in the floor can exceed 200 lb per hr with a 50 F deg difference in temperature between the inside and outside of the trailer. Block ice installed at truck terminals costs from \$6 to \$12 per ton. The refrigerating effect produced by melting water ice is 144 Btu per lb or 288,000 Btu per ton. The power required to operate some bunker fans is more than 3/4 hp. The heat equivalent of this power input is nearly 2000 Btu per hr and must be removed by melting about 14 lb of ice per hr.

Water Ice and Salt

Water ice and salt brine refrigerating systems are seldom used for truck or trailer refrigeration any more. In this system, the water ice and salt are mixed in a brine tank, usually in the nose of the vehicle, and a separate gasoline engine or electric motor is used to pump the chilled brine through either plain or finned pipe coils in the cargo space, and to drive a fan to move air across the coils and through the vehicle.

Certain sea foods are shipped in vats of salt water and ice brine but this method is not widely used because of the weight of the vats of brine and because of the corrosion caused by the slopover of brine.

Dry Ice in Vehicle Interior or on Load

Many small retail trucks used for frozen food delivery, ice cream delivery and sale, and other retail low temperature use rely completely on dry ice in the refrigerated enclosure to provide the necessary temperature. There are various systems, using dampers, blowers, and positioning of the blocks, almost always controlled by the driver, to attempt some control of the temperature. For long-haul vehicles other than those intended expressly for the transportation of dry ice, the use of dry ice in block form in or on the load is almost always a

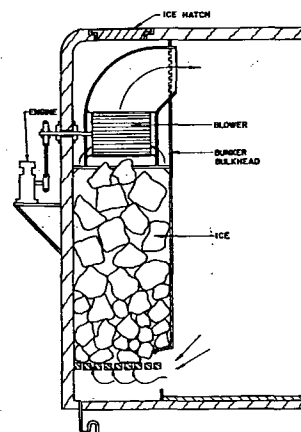


Fig. 3 Section of Ice Bunker for Trailer

temporary expedient, necessary either because the other refrigerating equipment is inadequate or inoperative, or because a vehicle without a refrigerating system is pressed into low temperature service. Garver² and Redit¹ et al¹ have reported on the results of tests with dry ice on the load. Many special items are shipped in containers with dry ice where the occasion of such shipment does not warrant acquisition of a vehicle equipped with low temperature refrigerating capacity. Dry ice can be used to bring a warm load down to temperature more rapidly than the regular equipment would be able to by itself and may be used for precooling a hot vehicle. Dry ice must not be used in or near materials which are harmed by carbon dioxide or carbonic acid, or by the low temperature of the dry ice of -109 F. Care must be exercised in the handling of dry ice to avoid burns due to the low temperature, and precaution must be exercised against suffocation due to lack of oxygen in a closed body containing dry ice. For small delivery trucks a removable gravity air dry ice bunker which can hold two or three blocks is available.

Dry Ice in Bunker with Forced Air Circulation

Two variations of this system are in limited use.^{1,13,17} In one, the blocks of dry ice are placed in a bunker in the same fashion as water ice, and the air to cool the vehicle is drawn up through the ice and forced into the cargo space. The fan is usually operated by an auxiliary gasoline engine or electric motor. Carbon dioxide gas is released into the cargo space, and the refrigerating effect falls off sharply as the size of the blocks is diminished. In the other variation, the blocks of dry ice are placed in a metal bunker which is sealed from the cargo space. The air from the vehicle interior is drawn past extended heat transfer surfaces on the exterior of the bunker and forced into the cargo space by one or more motor driven fans, which can be controlled or cycled by thermostat to hold a desired temperature in the vehicle. Power for the fan motors is taken from the truck or tractor electrical system. The fans will operate from 110 volt alternating current when on stand-by. Bunker capacities up to 28 blocks (55 lb each) are provided, and constant refrigerating effect is claimed as the blocks diminish in size because the heat transfer is effected by contact between the blocks and the several metal sheets on which they rest. Ice consumption of from 30-40 lb per hr for long hauls of frozen food in 34 ft trailers with 6 in. of insulation and outside temperatures from 60 to 87 F is reported. Redit¹ and Johnson^{13,14} have reported on tests with dry ice bunkers. Dry ice installed at truck terminals costs about \$2.20 per 55 lb block or \$80 per ton. The refrigerating effect produced by the sublimation of dry ice is about 260 Btu per lb and the sublimation temperature at atmospheric pressure is -109 F.

A system sometimes used for small trucks consists of an overhead bunker, with a metal plate for its bottom surface, which is the ceiling of the truck interior. The dry ice is placed in the bunker and the truck interior is cooled by gravity air circulation caused by the cold ceiling.

A removable bunker and fan assembly with a two or three block capacity is available for small trucks. Power for the fan motor is taken from the truck generator.

Dry Ice with Secondary Brine Circuit

Some small trucks use a form of this system in which an antifreeze solution or brine chilled by dry ice in a container is pumped through coils on the sides of the body. The pump is usually electrically driven and thermostatic control is achieved by cyclic operation of the pump.