causes corrosion of track, bridge structures, and the underside of cars) in transit is eliminated. The capacity of a set of four brine tanks is from 6000 to 7900 lb of crushed ice.

Overhead bunker cars are equipped with eight (for a 40-ft car) or 10 (for a 50-ft car) shallow brine tanks located along the ceiling of the car. The tanks are filled with crushed ice with (or without) salt through separate hatches in the roof of the car. Water or brine released from the tanks drops onto inclined drain pans located directly under the tanks and then drains down the side wall air flues into floor troughs leading to well traps and drains located at each end of the car. Warm air in the car rises and enters the bunker space through an opening extending longitudinally at the center of the car between the drain pans. Cooled air from around the brine tanks passes down the side wall flues and is discharged under the floor racks. After being heated by the load, the air rises to the top of the car where it is re-cooled and recirculates.

The advantages of overhead bunkers are increased loading space (at the ends of the car) and sufficient air circulation by natural convection to maintain uniform temperature in the load without fans. The disadvantages are increased initial and maintenance costs, increased time required for icing, and the fact that only crushed ice can be used. While only about 200 U.S. cars are equipped with overhead bunkers, the majority of Canadian cars have overhead bunkers.

Air Circulation

Floor racks, side and end wall flues, and special ceiling ducts have been provided in refrigerator car construction to facilitate the circulation of air. Floor racks provide space for air circulation, under the load. Typical wooden floor racks consist of crosswise (or *herringbone* arranged) surface slats, spaced about one in. apart, attached to longitudinal stringers spaced about 14 in. on center. The racks are usually constructed in sections averaging about 4 ft wide and 6 ft long and are hinged to the side walls. Openings in the longitudinal stringers permit side to side air circulation and are especially important in cars equipped with side wall flues. Metal floor racks designed to support loaded lift trucks are replacing the usual wooden racks. Height of floor racks varies from about $4\frac{3}{4}$–$7\frac{1}{2}$ in. Minimum clearance under floor rack slats is 4 in.

Over 40,000 refrigerator cars are equipped with vertical side wall flues which protect the load from direct contact with a very warm or cold side wall by permitting air circulation around the load. Side wall flues are formed by a continuous plywood or tongue and groove lining spaced 1 to $1\frac{1}{2}$ in. from the regular inside wall by vertical spacers and are open at the top (above the load) and at the bottom (below the floor racks). Cars equipped with mechanical refrigeration have end wall flues in addition to side wall flues. The depth of flues located at the machinery compartment end of mechanical cars varies from $3^{3}/_{16}$ in. when the evaporator is located in a recessed area above the machinery compartment to 12 in. when the evaporator is located between the end lining and the machinery compartment bulkhead partition. Flues in the opposite end of mechanical cars vary in depth from 1 to $2\frac{3}{8}$ in. The side wall flues in mechanical cars, having a ceiling duct, extend from the ceiling duct to the underside of the floor rack slats; and with the complete envelope system they extend from the ceiling plenum to the air return duct below the floor.

The principal types of air circulation systems used in mechanical refrigerator cars are as follows:

1. *Open.* The air is discharged directly over the load from the evaporator end of the car. The air passes down through the load (and the wall flues) and returns to the evaporator via the channels formed by the floor rack stringers.

2. *Plenum.* Same as the *open* system except the air is discharged into a slotted or perforated ceiling supply duct which distributes the air uniformly over the top of the load.

3. *Envelope.* The air is discharged into a ceiling duct which, together with the wall ducts and a special floor duct form a completely closed envelope around the car. The air circulated within the envelope does not enter the loading area nor does it escape from the envelope even when the side doors are opened.

4. *Semi-envelope.* Same as the *envelope* system in that the wall flues extend into the ceiling duct, but the air returns under conventional open floor racks. The ceiling duct is usually the same as for the *plenum* system.

Approximately 13 percent of the mechanical cars have the *envelope* system, about 3 percent have an *open* system, and nearly all of the remaining cars have a *plenum* or *semi-envelope* system. A few mechanical cars have a modified *open* system with reversed air circulation. In these cars the air is discharged below the floor racks, which are of the solid type with a thick plywood top, then passes up the side and end wall flues and out over the top of the load. The air is returned to the evaporator through a return air grille located at the top of the machinery compartment bulkhead.

The ceiling duct in mechanical cars is usually aluminum and varies in depth from about $4\frac{3}{4}$ in. to 9 in., with a 5 to 6 in. depth most common. Perforations in the ceiling duct usually consist of numerous one or two in. diameter openings uniformly spaced. Some of the mechanical cars have a ceiling duct with 2 in. shutter openings on approximately 50 in. centers and manually operated louvers for varying the amount of air circulated within the loading area.

SUPPLEMENTAL REFRIGERATOR CAR EQUIPMENT

In addition to the standard refrigerator car construction features, various portable or built-in supplemental equipment is used with certain types of refrigerator cars. This equipment includes air circulating fans, heaters, mechanical refrigeration (covered separately in the next section of this chapter), and temperature indicating devices.

Forced air circulation in transit is provided by built-in fan systems driven mechanically from the car wheels or electrically by a generator operated from the car wheel, a special diesel engine, or the mechanical refrigeration power unit.

Heater service is provided by the use of portable heaters placed in and fastened to the bunkers of end bunker cars. About 65,000 portable, thermostatically controlled alcohol heaters have been acquired by the railroad industry for this service; replacing nearly all of the old style charcoal heaters. A limited number of cars are equipped with built-in underslung type charcoal heaters.

Temperature indicating devices, which show the temperature of the air inside the car have been installed in a number of refrigerator cars, including all of the mechanical cars.

Air Circulating Fans

Approximately 80,000 refrigerator cars, which include all of the mechanical refrigerator cars and nearly all of the end bunker cars, are equipped with air circulating fans. Forced air circulation reduces the difference in temperature between the various sections of the load and increases the rate of heat transfer. Fans thus provide better temperature control and reduce the time necessary to bring the load to the desired temperature. All forced air circulation systems in end bunker cars have been designed so that the air flows down through the load and wall flues into the bunkers from below the floor racks, up through the ice bunkers, and out the upper bulkhead openings.

All but two of the fan systems used in end bunker cars obtain driving power from the shaft of a small rubber surfaced wheel (about 8 in. in diameter) which is held in contact with the tread of one of the car wheels. Power from the drive wheel shaft is conveyed to the fan either mechanically or electrically depending upon the type of fan system. Mechanical fan systems require a drive wheel at each end of the car. Only a single drive wheel is used with electric fan systems.

The first commercially successful refrigerator car fan system was the floor type shown in Fig. 1. About 40,000 car sets of floor fans were installed during the period from 1938 to 1952. This system consists of two fan housings located under the floor racks about two feet in front of the bottom bunker openings at each end of the car and extending the width of the car. Each housing supports four rubber-mounted ball bearings that carry the shaft on which are mounted seven centrifugal blowers ($6\frac{3}{4}$ in. in diameter), each operating in a separate compartment of the housing. The blower shaft is belt driven from a pulley mounted on the shaft of the rubber drive wheel. While the direction of rotation of the blowers depends upon the direction of car movement, the air delivery always remains in one direction due to the design of the blower and housing.

A limited number of cars are equipped with mechanically driven fans located in the upper bulkhead openings. Power from the drive wheel is conveyed to the fans by means of a flexible shaft. Either one or two propeller type fans, 15 in. in diameter, are located at each end of the car. With two fans per bulkhead, each is belt driven from pulleys connected to the end of the flexible shaft. When the direction of the car is reversed, the fan rotation is also reversed; but by the use of tilting fan blades, the flow of air remains in the same direction.

The fans installed in end bunker cars since 1952 have been electrically driven, of two types. Each type consists of a permanent magnet generator mounted on the rubber drive wheel shaft, and two fan panels located in the upper bulkhead openings, each housing three electric motor driven propeller type fans. The principal differences between the two types are in the electrical systems and the fan blades. The electric fan system in the standard ice bunker refrigerator car is a three-phase, low voltage, high current system using three-bladed fans, $11\frac{3}{8}$ in. in diameter and a six-pole generator with a mechanical reversing switch, which gives the same fan rotation regardless of the direction of car movement. The other electric fan system is a two-phase, three-wire, high voltage, low current system having four-bladed fans, $13\frac{1}{2}$ in. in diameter, and a four-pole generator with built-in magnetic reversing switch.

Extensive laboratory performance tests have been conducted[9] on the two types of electric fan systems. The volume of air circulated in a loaded and iced refrigerator car equipped with either type is about 100 cfm times the car speed in mph. Thus, for a car speed of 60 mph, the total air delivery would be 6000 cfm (3000 cfm for each of the two fan panels).

Both the mechanical and electric fan systems have been designed so that the fans may be driven by portable electric motors for precooling before transit and for holding at destination prior to unloading. This is accomplished by manually moving the drive wheel lever to the *off* position (which raises the fan drive wheel off the car wheel), mounting a portable electric motor in the special holding bracket provided on the underside of the car, and attaching sheaves to the shaft of the electric motor and the drive wheel so that the fan drive shaft may be belt driven by the electric motor. Two 1 or $1\frac{1}{2}$ hp motors are used when precooling a car having mechanical fans and a single 1, $1\frac{1}{2}$ or 2 hp motor is used when precooling a car having electric fans. The standard generator and precool motor sheave sizes used for precooling result in fan rotation equivalent to those obtained at car speeds of about 50 to 60 mph. One-half or three-quarter hp motors are commonly used for holding service at destination.

Two types of diesel-electric driven, thermostatically controlled, fan systems have recently been installed[10] in a total of 1000 single end bunker cars. Both types are powered by an air-cooled, single-cylinder diesel engine-alternator set located underneath the car. Conventional 40-ft end bunker cars were modified by removing one ice bunker and increasing the ice capacity of the other bunker. Four electric driven fans of conventional design are located in the upper bunker bulkhead opening. Two (or in some cars three) of the fans serve as cooling fans and the others serve as circulating fans. The circulating fans operate continuously and pull air from the loading area up through special bunker bypass ducts located in the bunker bulkhead. The cooling fans operate at a fixed high speed until the temperature of the air in contact with the thermostat (located in the bunker bypass ducts) has been lowered to the thermostat setting. In one system the cooling fans are then stopped by the controls and the solenoid operated dampers in front of each cooling fan close automatically to prevent the flow of air through the bunkers by convection. When the temperature of the return air rises to the thermostat setting, the controls open the dampers and restart the fans. In the other system when the thermostat has been satisfied, a relay directs the generator power for the cooling fans through energy absorbing resistors to decrease the speed of the fans. At the reduced speed the fans merely counterbalance the tendency for flow through the bunkers by natural convection. The thermostat control range is from 30 to 70 F, and a special switch is provided for reversing the cooling cycle operation of the fans described above for heater service. Included in these cars is a tube or pipe located on each side of the car near the roof at the bunker end for convenience in the introduction of gas for such commodities as grapes and honeydew melons.

All mechanical refrigerator cars are equipped with air circulating fans which are usually mounted above the evaporator coil in the bulkhead between the machinery compartment and the loading area. Nearly all are of the backward-curved centrifugal type and draw air from the floor through the evaporator coil and discharge it into the ceiling distribution duct. The fans consist of two or three blowers mounted directly on the electric motor shaft or on a separate belt-driven shaft. The fans usually deliver about 4000 cfm and require a 1 hp, 220 volt motor; although, larger capacity fans and motors have also been used.

The condenser fans and engine radiator cooling fans in mechanical cars are of the propeller type and are usually located on opposite sides of the machinery compartment adjacent to the side louvers. Outdoor air is usually drawn across the condenser coil and into the machinery compartment by the condenser fan. A portion of this heated air is used for combustion in the engine and the balance is exhausted by the engine radiator fan. Condenser fans are usually of 24 to 25 in. diameter, deliver about 8000 cfm, and require a 2 hp, 220 volt motor. The engine radiator fan is usually belt-driven from the engine crankshaft. Some mechanical cars have a horizontally mounted condenser and engine radiator which are incorporated in a single frame, are located at the ceiling of the machinery compartment, and use a 5 hp, 220 volt, motor-driven propeller fan which discharges the air through louvers in the roof of the car.

Heaters and Heater Fuels

The use of portable heaters to protect commodities moving in refrigerator cars during the winter months began about