

sary. With *Shippers' Protective Service*, heaters are furnished and installed by shipper and are serviced by carrier as directed by shipper. With *Shippers' Specified Service*, heaters are furnished, installed and serviced by carriers as directed by shipper. Protection furnished by carrier after service has been changed in transit from refrigeration or ventilation is known as *Modified Carriers' Protective Service*, and protection supplied without request on a shipment originating outside regular Heater Territory and west of the Mississippi River is known as *Voluntary Heater Service*. Protection by the use of liquid fuel heaters furnished, installed and serviced by carrier with thermostat set as directed by shipper and with ventilators manipulated at the degree of temperature specified by shipper is known as *Special Heater Protective Service*.

Special Handling of Bananas

The handling of banana shipments by the large banana importers is unique in that trained perishable freight inspectors decide how much heat, refrigeration, or ventilation each carload requires. These inspectors open the car doors at certain stations and check the temperature and condition of the bananas every 12 to 18 hr in transit. Inspectors sometimes accompany the banana shipments in transit and obtain round trip rail transportation from the carriers at no charge. As a result of this close supervision of protective services, bananas show less railroad loss and damage claims paid per car than any other perishable commodity. (See Chapter 47.)

Other Special Services

In addition to the many protective services described above, several special services or privileges are provided by the railroad industry in connection with the movement of perishable freight. Shipments of commodities under refrigeration and shipments of dried peas may be stopped in transit and fumigated in refrigerator car on instructions from shipper. Shipper may also fumigate lading in cars, prior to departure of car from loading track. Fumigation is often accomplished by burning sulfur or similar substances in a receptacle placed within the car or by the release of certain proprietary gases into the car from pressure tanks.

Sampling or inspection of a shipment in transit may be performed by the owner, his representative, or by the prospective buyer when authorized by the shipper or owner. When so instructed, a carrier will change, in transit, the type of protective service, the destination of the shipment, or the consignee. About one-half of all refrigerator car shipments are reconsignees in transit. Stop-over privileges are permitted to complete loading or to partially unload, and transit privileges are permitted for rehandling, transferring or reconditioning.

SOURCES OF REFRIGERATION

As shown in Table 1, the source of refrigeration for most of the present fleet of refrigerator cars is water ice although the number of mechanical refrigerator cars is increasing.

Considerable work has been done by the railroads and refrigerator car lines over many years, in testing the practicability of sources of refrigeration other than water ice. Numerous experimental refrigerator cars have been built using dry ice refrigeration, absorption refrigeration or mechanical refrigeration for cooling. Satisfactory systems using dry ice were developed, but the relatively high cost of dry ice has limited its use. Early mechanical refrigeration and all absorption systems were considered unsatisfactory.

While the principal source of refrigeration for refrigerator cars has remained unchanged, the effectiveness of water ice cooling has been greatly increased by numerous improvements

in the design and construction of refrigerator cars. The use of larger ice bunkers of improved design, air circulating fans, better and thicker insulation, and special air flow channels have made possible the outstanding performance of the modern ice bunker refrigerator car.

Water Ice and Salt

The advantages of water ice refrigeration are its performance, availability, dependability, simplicity and cost. Water ice together with forced air circulation provides the cooling capacity necessary to quickly remove the so-called *field heat* from warm perishables loaded directly into refrigerator cars. The availability of water ice and salt is indicated by the existence of approximately 1100 icing stations for refrigerator cars across the United States. Some of the newer icing platforms at icing stations accommodate as many as 360 refrigerator cars and are equipped with several combination icing and salting machines which have reduced the average time required to ice and salt a car to about 1 min. Some of the western railroads and refrigerator car lines also operate large modern ice plants for manufacturing and storing ice for refrigerator car use.

The ice bunker cars which are equipped with a thermostatically controlled electric fan system provide automatic temperature control, have a 10 percent increase in inside length, and permit up to a 25 percent heavier load. Heavier loads provide incentive loading rate benefits; and with automatic temperature control, the shipper can also take full advantage of the less expensive modified icing services.

Water ice furnished for refrigerator car cooling may be added in any of several different sizes depending upon the type of refrigerator car and where the ice is placed. In end bunker cars the ice sizes which may be used include *chunk ice* (pieces not exceeding 100 lb), *coarse ice* (pieces averaging 10 to 20 lb), and *crushed ice* (pieces averaging the size of a man's fist). Crushed ice is always used with overhead bunker type cars and either crushed ice or coarse ice may be used in brine tank cars. Crushed ice or snow ice is used when ice is placed in direct contact with lading.

The addition of common salt (sodium chloride) to ice in refrigerator car ice bunkers or tanks is the most common method of reducing the temperature of the cooling media. The maximum weight of salt that is used is 30 percent of the weight of ice. This amount gives a theoretical eutectic temperature of -6 F. When salt is used with chunk ice, the percentage of salt specified is usually added after icing has been completed. When salt is added with coarse ice, the salt and ice are added to the bunkers in alternate layers.

A completely mechanized car icing process starts when a conveyor system picks up blocks of ice from storage rooms and moves them to the icing platform. Mobile icing machines controlled by an operator pick the ice up from the conveyors, chop the cakes into the desired size, and then elevate the ice to a gravity chute which sends the ice cascading directly into the bunkers at each end of the car. Ice directly from storage rooms is frequently too cold for top or package icing of vegetables and should be allowed to warm to nearly 32 F before being used.

When re-icing bunker cars, the old ice is first settled or broken down by using a wooden tamping pole or a metal ice breaker. Before re-icing brine tank cars, having valves for retaining the brine, the valves are opened to release a portion of the brine. Detailed instructions for icing and re-icing the various types of refrigerator cars for each of the several types of refrigeration service are published.⁴

In view of the advantages of water ice refrigeration, the existing facilities for icing cars, and the flexibility of the

standard ice bunker refrigerator car for heater service and ventilation service as well as for refrigeration service, it can be expected that water ice will continue to be the principal source of refrigeration for several years to come.

Mechanical Refrigeration

The rapid development of the present fleet of mechanical refrigerator cars was initiated by an Eastern refrigerator car line about 15 years ago for the primary purpose of meeting the needs of the frozen citrus concentrate industry.

As of January 1, 1962 there were over 6200 mechanical refrigerator cars in service. About 700 are so-called *Zero* cars designed only for frozen loads, and about 400 are *Fresh* cars that operate only at temperatures above 28 or 30 F and carry non-frozen perishables (usually meat). The remaining cars are *All-Purpose* cars capable of maintaining any desired temperature from 0 to 70 F.

The *zero* cars were the first to be built and provided the very low temperatures needed for frozen foods. The *all-purpose* cars followed and permitted experimental shipments of fresh fruits and vegetables. The close temperature control which was obtained during these shipments and the greater loading capacity of mechanical cars account for the interest in these cars by the fresh fruit and vegetable shippers. The *fresh* type mechanical car is the most recent type to be built in any appreciable number and represents an interest in establishing a fleet of mechanical cars for packing-house products and an interest in testing experimental cars designed to reduce transportation costs for fresh fruits and vegetables.

Another advantage of mechanical cars (and temperature controlled ice bunker cars) is that they provide maximum refrigeration immediately upon loading and starting the engine, whereas with the usual fan cars, maximum cooling is not obtained until the car is moving at high speed. Another significant advantage of mechanical cars is that switching between the heating and cooling cycles is accomplished automatically. Variations in ambient temperature in transit frequently requires alternate periods of heating and cooling which is difficult to accomplish with ice bunker cars.

Other Sources of Refrigeration

Dry ice is sometimes used as a supplemental refrigerant in conjunction with water ice for shipments of fresh or frozen meat and meat products. It is placed directly on top of the water ice in the end bunkers or placed in receptacles located in the bunkers or in the lading space. The quantity of dry ice used in this manner is small and, therefore, no temperature control equipment is needed. Dry ice is also used as a source of CO₂ gas to control ripening and decay in some shipments of fresh strawberries and cherries.

During the past two years, several experimental refrigerator car shipments of frozen food have been made with liquid nitrogen as the source of refrigeration. Liquid nitrogen is a somewhat unwanted by-product in the production of liquid oxygen from air and is currently available in fairly great quantities because of the greatly expanded government requirements for liquid oxygen in recent years.

REFRIGERATOR CAR DESIGN AND CONSTRUCTION

The basic design and construction of refrigerator cars is very similar to that used for railway box cars since refrigerator cars must meet all the structural, safety, and performance requirements demanded in railway freight service. Specifications for standard freight refrigerator cars have been estab-

lished⁴ by the Association of American Railroads and are frequently revised by the A.A.R. Committee on Freight and Passenger Car Construction in order to incorporate improved standards.

The principal construction features of refrigerator cars that are different from those found in conventional freight cars include the thermal insulation and water vapor barriers incorporated within the structure of the car; the ice bunkers, brine tanks, or mechanical refrigeration equipment; and the various features which facilitate the circulation of air.

Conventional Freight Car Features

The refrigerator car construction features common to the standard box car include the trucks (wheels, axles, bearing, springs, and supporting members); steel underframe; brakes and brake equipment; couplers and draft gears; and the superstructure consisting of structural members, exterior steel sheathing (on the sides, ends, and roof), interior wood lining and floor, side door openings, and various safety appliances.

Improvements in conventional freight car equipment have been incorporated in refrigerator cars. These improvements include high speed trucks equipped with snubbing devices to prevent harmonic oscillation of springs and utilizing increased spring travel to provide softer rides. Underframes have been improved considerably in design, and advantage has been taken of modern methods of welding. An improved type of automatic air brake is now in use on all cars, and the newer refrigerator cars have extra high capacity long travel draft gears and car axles with roller bearings.

Some of the latest refrigerator cars also have special long wearing steel wheels and cushion underframes which absorb and dissipate impact forces through a special cushioning device built into the center sill (the longitudinal steel member which is the backbone of the underframe).

In order to permit palletized loading and unloading of refrigerator cars with fork lift trucks, the width of the door openings in refrigerator cars has been increased from 4 ft (with two 2-ft hinged doors) to 6 and then 8-ft with a single sliding plug door. A few of the *RS* cars were equipped with 6-ft split type doors that have a 2-ft hinged door section which may be opened quite easily for in-transit inspection.

One of the latest freight car features which is being installed in new refrigerator cars is the movable steel load dividers which brace the load and sectionalize the loading compartment into three sections. These load dividers or compartmentizers are utilized to reduce impact damage and for segmentation of loads billed to stop for partial loading or unloading.

Refrigerator cars are approximately 42 or 52-ft long and are referred to as 40 or 50-ft cars respectively. Most of the passenger express refrigerator cars are 50-ft cars and approximately 85 percent of the *RBL* and mechanical refrigerator cars are 50-ft cars. Of the remaining types of refrigerator cars, over 98 percent are 40-ft cars. The cubic and load capacity of those refrigerator cars which provide cooling varies from approximately 2000 cu ft and 75,000 lb for a 40-ft end bunker car to approximately 3000 cu ft and 125,000 lbs for a 50-ft mechanical car. For a 50-ft bunkerless refrigerator car the capacity may be as high as 4600 cu ft and 140,000 lbs. A complete summary of railway equipment information is published quarterly.⁵

Insulation of Car Structure

The primary purpose of refrigerator car construction is to obtain (and retain) a high resistance to the flow of heat (and water vapor) through the structure of the car. The usual