The liquid (usually an antifreeze) is mechanically circulated through plain finned tubing. When steam is used directly, the tube-within-a-tube construction makes it possible to obtain uniform distribution throughout the length of the car. It is achieved by means of heat transfer between the steam within the inner tube and the condensate returning in the annular space between the tubes.

The finned tubing at the floor must have sufficient capacity to offset effects of cold walls and windows during normal operation, and to heat the entire car to a minimum temperature of 60 F during standby when the overhead system is not operating. The maximum capacity required (determined by standby requirements) varies with car construction and design temperatures, but is approximately 90,000 Btu per hour. This requires a heating capacity in finned tube of approximately 650 Btu per linear foot.

The overhead air heating coil must have sufficient capacity to heat the outside air brought into the car for ventilation, and to supply approximately 20 percent of the internal heat loss of the car so as to permit supply of floor heat at all times at an output that will not be objectionable to passengers sitting near it. The usual capacity of the overhead heating coil is approximately 100,000 Btu based on 2400 cfm of circulated air, with 600 cfm of this being outside air for ventilation. All Btu figures are approximations of actual heating requirements, and do not include heat losses in the trainline (or leakage) or losses in the undercar piping. Recent car designs have enabled the car builder to run the steam supply lines in recesses within the car body, thus greatly diminishing under-car losses.

Refrigeration

For cooling and dehumidification during summer, refrigeration may be obtained from ice bunkers, steam jet systems, or mechanical compressors (driven directly from car axle by electric motors or by gas engines). Refrigeration required varies with load conditions, but $7\frac{1}{2}$ tons per car is one capacity frequently used. Evaporative type condensers are sometimes used in combination with the usual air condenser on either steam jet or mechanical refrigeration.

When an electric motor (approx. 10 hp) is used to drive the air conditioning compressor, the electric power source is a problem. If the power source is an axle-driven generator, there is an appreciable increase in the drag on locomotive, and the power available for refrigeration, when train is stopped at a station, is limited to storage batteries. One solution to this problem is to use a d-c generator driven by a gas engine. Another is to use a Diesel-driven alternator in a special head-end car to furnish power to the entire train. Recently there have been installations in which a Diesel-driven alternator is mounted on an individual passenger car to supply the power requirements of the car. The attractiveness of this type of installation can be increased by utilizing spare alternator capacity in winter for electric heating. If this capacity is supplemented by exhaust heat from the Diesel engine, there is sufficient capacity to heat the entire car and to provide hot water for wash rooms when outside temperatures are above approximately 30 F. This feature is important on trains using Diesel locomotives, since it eliminates the need for firing the steam heating boiler in the locomotive during a portion of the year.

Air Distribution and Cleaning

Railway cars present critical problems in air distribution because air space per passenger is small (60 to 190 cu ft), and the sun load is great.

An average passenger car contains approximately 5000 cu ft of air, and may seat as many as 80 passengers. The occupants are continually liberating heat, carbon dioxide, moisture, odors, and some organic matter from their breath, skin and clothing. The heat and moisture can be removed by cooling and dehumidification, but other constituents can be successfully handled only by proper ventilation and air cleansing. In an average car, from 2000 to 2500 cfm are circulated by the air conditioning unit. Some of this air may be recirculated, but a portion of it should always be brought in from outside. The amount of outside air desirable depends upon the type of car, number of passengers, air temperature, humidity, odors, and whether or not the occupants are smoking, and will vary from 15 to 90 percent of the total air circulated.

Careful attention must be exercised in specifying the rate of outside air taken in so as to fit the type of service adequately, and yet not supply more ventilation than is necessary. Conditioning of this outside air is a major factor in determining size of both summer and winter equipment.

For normal conditions, 10 cfm of outside air per passenger are provided. When smoking is permitted, at least 15 cfm should be admitted. In some dining cars, and deluxe sleeping cars, outside air rates as high as 20 to 30 cfm per occupant are used. A ceiling duct lengthwise along the center of the car is usually used to distribute the air to the interior by fans or blowers. A perforated ceiling supplied from an overhead duct, or delivery grilles and plaques designed to give considerable entrainment and mixing, are used to deliver air to the car space.

Smoking rooms present a special problem. The cloud of smoke that usually hangs near the ceiling can be broken up by directing incoming air along the ceiling at a velocity somewhat higher than that used for the rest of car. The air is exhausted through the washroom or lavatory. For compartments, provision is made in the door or partition for removal of used air. Lower berths are provided with a low velocity air outlet.

Recirculating air grilles are usually of straight flow types. Outside air intakes are usually located in the vestibule, on the side of the car, or on the roof, depending upon location of the cooling coils. On many recently air-conditioned cars, there are no dampers or shutters at the outside air intakes; the percentage of the outside air is controlled by adjusting flow through the recirculating grille.

A considerable number of coach cars are now being equipped with return air ducts fitted in the structure of baggage racks. Part of the air circulated is returned to the blower unit through these ducts, and part through the car body. This arrangement reduces quantity and velocity of air returning through the car body, and removes smoke fumes at the source. This, and any other design features aimed at taking recirculated air at the floor and adjacent to both end doors (rather than drawing all recirculated air to one end of the car) also reduces infiltration of cold air in ankle height strata, when doors are opened during the heating season.

All air circulated by the blower is filtered before passing over the cooling and heating coils. In some cars outside air and recirculated air are filtered separately before mixing, while in others air from the two sources is mixed before passing through a common filter. Filters in use are combinations of metal, wool, cloth, spun glass, hemp, paper, hair and wire screen. Most filters have a viscous coating of oil for greater cleaning efficiency. Some types may be cleaned, re-treated, and re-used, while other types are discarded when dirty. Applications are also being made of electric precipitation for air cleaning. In this system the coarser particles are removed