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 the locomotive. The power available for refrigeration, when train is stopped at a station, it limited to storage batteries. One solution to this problem is to use a direct-current 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 washrooms when outdoor temperatures are above approximately 30 F. This feature is important on trains using Diesel locomotives, since it eliminates the need for operating 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 the 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 outdoors. The amount of outdoor air desirable depends upon the type of car, number of passengers, air temperature, humidity, odors, and whether or not the occupants are smoking. It will vary from 15 to 90 percent of the total air circulated.

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

For normal conditions, 10 cfm of outdoor air per passenger are provided. When smoking is permitted, at least 15 cfm should be admitted. In some dining cars, and deluxe sleeping cars, outdoor 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. Outdoor 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 air-conditioned cars, there are no dampers or shutters at the outdoor air intakes; the percentage of the outdoor air is controlled by adjusting flow through the recirculating grille.

Many 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 outdoor 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 from the air by mechanical separation; finer materials, by electrostatic action.

Activated carbon units sometimes are used in addition to the regular filters for adsorbing odors and other impurities, thus reducing the amount of outdoor air necessary for ventilation.

Temperature and Humidity Control

Controls in a passenger car should be as automatic as possible. The regular train crew cannot be relied on to make adjustments for the comfort of passengers. For this reason the latest systems of temperature control have only an off-on switch to be operated by the train crew. When the system is in operation, heating or cooling is provided automatically as required.

When heating, it is important that floor-heat finned tubing be controlled at stable temperatures. Wide fluctuation in its temperature is highly objectionable because of location close to the passengers. Stable operation may be secured by cycling the floor heat on the basis of indoor conditions in conjunction with an overhead air-circulating system to maintain final car temperatures.

Because of window condensation and other problems, no attempt is usually made to raise relative humidity in a railroad car in winter time.

When cooling, the steam-jet refrigeration system is controlled in an on-off manner. Some means are ordinarily provided for operating mechanical compressor systems at partial capacity. In this case split evaporators are used, so that evaporator surface and compressor capacity can be reduced together under light load conditions.

Attempts have been made in the past, largely on an experimental basis, to control the relative humidity in railway cars. This was done by operating the air-conditioning equipment according to outdoor temperatures and then re-heating the air to an acceptable temperature. This was found to be an expensive method of operating and the results did not justify the cost. A common method of controlling heating and cooling is to provide a thermostat to control heating only and a separate thermostat set at a slightly higher temperature to control the cooling equipment. This obtains heating control, ventilation, and cooling control and the reverse, as the case may be. A car in service can go from heating into cooling in a very short time. An example of this is found on the full-dome cars in service on several railroads in the country. In the early morning hours before sunrise, the car may be requiring a considerable amount of heat. Shortly after sunrise, the car may go into the ventilating cycle and as the sun load increases, cooling may be required. On the majority of car heating systems, frequent cycling of the compressor is prevented by the one degree difference between the heating and cooling control points and by lag imposed on the system by applying artificial heat to the heating thermostat when cooling is required. On some car heating systems, a degree of modulation is obtained by the use of split evaporation. This requires two cooling thermostats with one of them set at a somewhat higher temperature than the other. The lower temperature cooling thermostat controls a portion of the cooling capacity and, if unable to maintain the car temperature, the higher thermostat adds the remaining capacity.

PASSENGER BUS AIR CONDITIONING

The passenger bus designed for urban transportation operation presents a greater problem to the designer of heating systems than does the inter-urban bus. More frequent stops, and rapidly changing passenger load create this problem on urban vehicles. Provision of heat for the driver independent of the passenger heating system, is a further problem. The inter-urban bus, however, is usually a deluxe vehicle and may require a comfort cooling system. Space and weight limitations and vibration must be considered.

Heating

Recent designs of bus heating systems obtain improved air distribution. Heat in the engine coolant liquid is used to warm air by means of suitable finned coils and this heated air is distributed throughout the passenger space by ducts and outlets directed toward the floor. Some designs include finned surface near the floor in an application similar to that in railway passenger cars. Forced air circulation over this finned floor-heating surface has been provided to increase its effectiveness. Oil-burning booster heaters have been applied to many Diesel-powered buses to raise the temperature of the engine coolant for maximum engine operating efficiency, and to provide sufficient heat for the passenger space.

Ventilation

Air for ventilation is usually brought into a bus at the front, and distributed throughout the length of the passenger space by a duct or ducts near the ceiling. Except for a few designs employing 100 percent outdoor air for heating, no heating of the ventilating air has been provided. One type of distribution system for an inter-urban bus provides for a fixed minimum of outdoor air, and is arranged to increase the percentage of outdoor air to 100 percent when the heating or cooling load diminishes. The distribution ducts and diversion-damper arrangement of this system make available two supply ducts and one return duct for heating and for cooling, with a change-over to all three ducts to supply air during the intermediate ventilating cycle. This system permits utilization of atmospheric cooling and ventilation to the greatest degree when it can be most economically employed in the interval between the heating and cooling demand.

Conventional throw-away type filters or renewable filters are used in intake air ducts for many vehicles. Electrostatic filters have been successfully used in some installations. The need for elimination of dirt is great, but the problem is complicated by space limitations and limited power.

Refrigeration

Summer conditioning systems for inter-urban vehicles range in cooling capacity from 36,000 to 48,000 Btu per hour. Mechanical compression systems using refrigerants are used, and are powered by water-cooled gasoline engines of approximately 14 hp.

Complete systems add from 800 to 1300 lb to the weight of the coach. Sometimes an auxiliary generator driven by the refrigeration system engine is used and serves to help charge the bus battery, thereby offsetting power drain imposed by the ventilating blower. Belted reciprocating compressors and direct-driven V-type and rotary compressors are used, with engine speeds up to about 1800 rpm. Air-cooled condensers for this service require about 5000 cfm of outdoor air, and this is provided by either centrifugal or propeller type fans belted or direct-driven by the air-conditioning engine. Preventing noise and vibration from affecting passengers is of vital importance. Installations must be made for quick daily engine servicing. In all cases fuel is obtained from the main bus tanks, and in some, the main engine cooling system cools the air-conditioning engine.

Control

The simplest control system for heating of buses consists of a single thermostat, located in the passenger section to start and stop the blower of the heating unit. This method of control is not generally satisfactory because, without continuous air circulation, temperature gradients from floor to ceiling and from front to rear are quite pronounced. A more satisfactory method of control provides for continuous fan operation whenever heating is required. In this method a thermostat, usually in the return air to the heater, operates a modulating valve in the supply line to the heater to throttle the flow of engine coolant to the heater coil in accordance with bus interior temperature. On some systems a means of remotely adjusting the control point of the thermostat is provided at the operator's location. Automatic means are available for starting and stopping booster heaters in the engine coolant system, under control of the thermostat. Also, some systems provide for automatically stopping the blower of the heater unit and the booster coolant pumps when no heat is required in the bus. Outdoor air for ventilation, drawn into the bus by the heating unit blower, is usually not automatically controlled but is preset, either by means of a manual damper or by sizing the outdoor-air intake to provide the desired amount of outdoor air.

On buses equipped with mechanical refrigeration for air