generator and 600 volts when taking power from the third rail. Power supplied from diesel or gas (propane) generators is usually 220 volts, 3-phase, 60 cycle or 440 volts, 3-phase, 60 cycle. Where direct current is obtained from axle driven generators, large batteries must be provided to provide power at train stops. For precooling the cars in the yards and for keeping up the charge on the batteries, the usual 25 KW generators have an a.c. motor on the same shaft which operates the generator from a standby power source of 220/3/60 power.

The *operating requirements* of the cars to be air conditioned will to some extent determine the type of equipment to be used. Passenger cars that will always operate in the same train can receive their power from a head end source by train-lining down through the cars. In this case 440/3/60 power is used and this permits light weight units using hermetic compressors. However, if a train has to be made up of cars from different railroads, each car must have its own power plant and can then be of any type design. Similarly, commuter cars using 600 v d.c. power from the third rail will normally be designed to use the 600 v d.c. power for the air conditioning equipment. Railroads using steam ejector type air conditioning systems usually keep these cars in the same train. Therefore it is necessary to know in advance where and what type trains the car will operate in before deciding on a specific design.

Unlike a building which has a fixed *geographical location*, a railroad car can operate in any part of the country. This is true in the case of coaches and sleepers which are leased to other railroads at certain times of the year. In this case the maximum outside air dry bulb and wet bulb design temperatures for any part of the country should be considered. In many cases such as commuter cars and subway cars they will operate in a relatively small geographic area and only the local design temperatures must be considered.

As discussed above the question of *interchangeability* of the cars between different railroads must be considered at the time of selecting both the type power and the specific design of the air conditioning equipment.

EQUIPMENT DESIGN LIMITATIONS

Space both underneath and inside a railroad car is at a premium. A typical cross section of a passenger car is shown in Fig. 10. This lack of space for the air conditioning equipment is even more pronounced on subway cars and commuter cars where maximum carrying capacity of passengers is required during rush hours. This problem generally rules out the use of floor mounted units. The usual case is to build the components of the system to meet the configuration of the space that is available. The curvature of the roof and the clearance line beneath the car are two of the major factors that determine the shape and size of the equipment.

The *weight* of the equipment is more a problem today then formerly because the trend is toward lighter and lighter cars to reduce the power required for faster acceleration. Unlike the aircraft industry other considerations than weight alone have a greater bearing on the design. Present equipment will vary from 1100 lb for a self-contained unit of 7 tons capacity to 3000 lb for a steam-jet system not including all the piping and controls. Lighter equipment can be designed using additional aluminum and other light weight materials but the added cost does not justify it.

The major factor determining weight is the type of *power* available. With alternating current, hermetic compressors, light weight motors and controls can be used which greatly reduces the weight over that of a system using direct current power.

With the event of the light weight railroad car, noise and vibration has become a greater design consideration then pre-

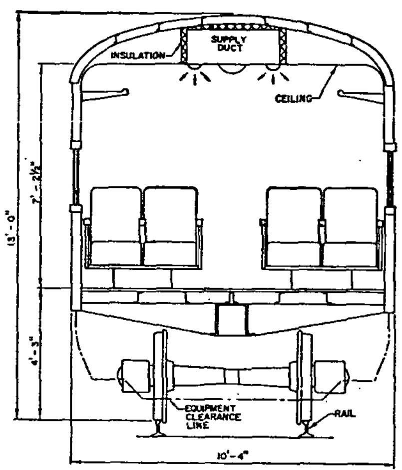

Fig. 10 .... Typical Cross-section of Railroad Passenger Car

viously. This is particularly true on sleepers, reclining chair cars and business cars. All the air conditioning equipment components are resiliently mounted on the car structure. Where a package unit is used the complete unit is generally resilient mounted as well as the internal components such as fans, motors and compressors to reduce vibration from being transmitted to the car structure. Air noises and other sounds can be reduced by the proper use of sound deadening materials of the blanket type or spray on type.

On a railroad car the problem of *dirt and corrosion* is an important design factor. This holds true especially if the equipment is beneath the car floor where it is subject to all types of weather both summer and winter as well as the most severe dirt conditions as can be found. For this reason corrosion resistant materials and coatings must be used wherever possible. Copper silicon has been more widely used than stainless steel for casings because of its easy working qualities. Aluminum has not proven durable enough when used under the severe conditions encountered. The sand blasting effect destroys any type of surface treatment on aluminum when used beneath the car.

Since the dirt problem cannot be eliminated, provisions must be designed into the equipment to quickly and easily clean the dirt out. This requires access doors where needed to get inside or behind coils for blowing out the dirt. The dirt problem enters into the design of the fin spacing on condenser and evaporator coils and limits the fin spacing to 8 to 10 fins per inch compared to 18 fins per inch on commercial and industrial type equipment. The closer the fin spacing the more rapid the dirt build up and the more costly it is to clean the coils. The dirt problem as well as the severe environmental conditions must be considered in the type of motors and controls used.

Considerably more attention must be given to the problem of *maintenance and servicing* on railroad equipment then on stationary units. With a modern railroad car having sealed

Table 1 .... Approximate Capacity Required for Railroad Cars

Car Type	Length, Ft	No. of Passengers	Approximate Capacity, Tons of Refrigeration
Passenger	85	65–85	8
Commuter	85	130	8–9
Gallery Commuter	85	165	12–16
Subway	51–61	125–200	9–12
Pullman Type Sleeping	85	26–38	6–8
Dining	85	40–60	6–8
Partial Dome Type	85	40–60	12–16
Full Dome Type	85	60–80	16–20
Business	85	2–12	4–8
Military	51–85	12	4–8

windows and a well insulated structure an air conditioning failure makes the car practically unusable in hot weather. Many additional items are designed into the equipment to permit quick determination of the trouble and similarly allow a fast correction of the item causing the failure. All items such as motors, compressors, valves, etc. must be easily accessible for inspection or repair. For quick checking of the amount of refrigerant in the system, sight glasses on the liquid receiver should be provided. Likewise, a readily accessible liquid charging valve should be used. Pressure gages and test switches are used for quickly checking the operation of the system while the train is stopped at intermediate stations enroute.

Safety precautions must be given consideration on a railroad car, especially where equipment is located underneath the car.

In designing supports they should be made to fail safe, should a mounting bolt shear off or a nut become loose. Should a piece of equipment hang down or drop off, a train wreck could occur. All belt drives or other revolving items must be protected with a safety guard. High voltage controls and equipment must be so designated by approved danger signs. All pressure vessels and coils must meet ASME test specifications for protection of the passengers and maintenance people.

EQUIPMENT DESIGN

The *cooling load* on a standard 85 ft passenger car can be calculated approximately. In the early days of air conditioning railroad cars, each new type car to be built was considered separately and a cooling load estimate was made. The total cooling load usually was 6-8 tons and the capacity was usually selected for the calculated load. In recent years the practice has been to standardize on an eight ton system for an 85 ft coach operating in United States, Canada or Mexico.

Table 1 shows in a general way, the capacity in tons of refrigeration, normally used for several types of cars operating in North America.

A cooling load calculation for a typical 85 ft standard passenger car would show a load distribution as in Table 2.

Item 1—Transmission Load. This load is based on the use of three inches of glass fiber insulation on all interior walls, ceilings and floor of the car; double glass sealed windows and an outside temperature of 100 F dry bulb and 78 F wet bulb; inside 78 F dry bulb and 50 percent relative humidity.

Item 2—Sun Load. A railroad car while in motion will be exposed to the sun first on one side and then on the other. However, the above figure considers the roof and one side.

Item 3—People. Although the number of people will vary, an average figure of eighty people was used in this example.

Item 4—Electrical (Lights and Motors). The sensible heat

Table 2 .... Typical Cooling Load for a Standard 85 Ft Passenger Car

Item No.	Source of Heat Gain	Total Heat (Sensible, or Sensible and Latent), Btuh
1	Transmission	18,960 (Sensible)
2	Solar Radiation	6,460 (Sensible)
3	People (80)	32,000 (Sensible and Latent)
4	Electrical (Lights and Motors)	12,690 (Sensible)
5	Outdoor Air (Ventilation)	21,600 (Sensible and Latent)
	Total Load = 91,710	

from the lights is used here; however in bright sunshine the lights may not be on and if used, will be a safety factor.

Item 5—Outdoor Air (Ventilation). It is standard practice to take in not less than 25 percent of the total supply air for ventilation. The usual eight ton system uses 2400 cfm total supply air and 25 percent of this is 600 cfm.

There are many other factors that could be considered but experience has shown that by allowing in advance some extra capacity in the equipment, comfortable conditions can be attained with present day equipment. To prevent infiltration into the car, the usual practice is to pressurize the car at 0.02 in. water pressure. This is controlled by using exhaust fans in each of the toilets, exhausting less air than that taken in for ventilation.

HEATING LOAD

Most cars are equipped with what are called *overhead heat* and *floor heat*. The *overhead heat* is usually the primary heat source, with the *floor heat* used to maintain comfortable conditions on the floor. The indoor winter design temperature is usually set at 69 F. All three types heating media are used in both the overhead heating coil and floor heat; steam, electric and hot water. The latter is not used to any great extent because of the freezing problem, requiring the use of an anti-freeze.

The outside design temperatures will vary from 0 F in the East to −40 F in the North Central States and Canada. The overhead heat steam coils are usually designed for 100,000 Btuh while some electric heater coils will vary from 17 kw to 24 kw.

AIR DISTRIBUTION

The most common type air distribution system is a center line supply duct running the length of the car and located in the space between the ceiling and roof. The air outlets are either of the longitudinal type, individual circular type, or perforated ceiling type. Fig. 11 shows a typical air distribution system. As can be seen, no return air duct system is used. The main supply duct must be insulated on three sides because of the high temperatures in the space above the ceiling. The ventilation air should be taken in from both sides of the roof line to overcome the wind effect. Adequate snow and rain louvers must be used on the outdoor air intakes. Separate fresh air filters are usually used in conjunction with a return air filter. The air filters are of the wire mesh cleanable type and must be cleaned often.

PIPING DESIGN REQUIREMENTS

Where the component system is used, standard *refrigerant piping* practice is followed. The average length of suction line