10.24 hp from the car axle and the steam ejector system requires 230 lb steam per hour from the locomotive boiler for a 6-ton unit. The ice-activated system requires 463 lb of ice per hour and the internal combustion engine drive mechanical requires 7.3 lb propane per hour. This power, with the exception of the ice and propane, as well as the power required to move the extra weight of the equipment and the power required to overcome the axle bearing friction, must be supplied by the locomotive en route, and if a number of cars in the train are air conditioned, the effect on train performance should not be overlooked. The demand for power for cooling comes, however, at the time of the year when steam for heating is not required, and the demand for lighting is at a minimum.

The total power required by the air conditioning systems will vary with the speed of train operation because of the effect of speed upon the drive efficiency and upon the resistance due to the added weight of the equipment. Fig. 1 shows the effect of speed upon the efficiency of the direct drive used with the direct mechanical system, and upon the average efficiency of four mechanical drives and generators used for electric power generation. The total increase in weight of passenger cars because of air conditioning is approximately 9,600 lb for the electro mechanical, 8,600 lb for the direct mechanical, 8,600 lb for the internal combustion engine drive mechanical, 11,300 lb for the steam, and 8,500 lb for the ice-activated system.

The average refrigeration load has been found to be 3.3 tons, and the average capacity of air conditioning systems is about 5.92 tons. The relation of load to capacity, $3.3 \div 5.92 = 0.56$ or 56 per cent, is that percentage of the time during the cooling season that the cooling equipment will be in operation. The average drawbar horsepower demand upon a locomotive, accordingly, consists of 56 per cent of the horsepower required for continuous operation and 44 per cent of the horsepower required for non-operation. Table 2 shows the drawbar horsepower that must be supplied by the locomotive for each air conditioned car for continuous operation of the air conditioning system, for non-operation of the equipment, and for an average condition when the air conditioning equipment is operating continuously 56 per cent of the time and is not operating 44 per cent of the time. It is important not to overlook the horsepower demand on the locomotive when the air conditioning equipment is not operating, which includes the horsepower required to operate the blower fan, to haul the weight of the equipment, to overcome drive and generator friction, and to replace the losses occasioned by the removal of current from the storage battery.

Fig. 2 shows the tractive resistance of a 75-ton passenger car with six wheel trucks without an axle generator, with a 4 kw generator load, and, for the same car with an increase in weight of 5 tons and a 20 kw axle generator load. The curve with the 4 kw generator is representative of a car before air conditioning, and the curve with the 20 kw generator and 5 tons added weight is representative of a car after air conditioning. At 50 mph, the tractive resistances of these two cars are 520 lb and 745 lb respectively, or a difference of 225 lb. Then: $\dfrac{225 \times 5280 \times 50}{60 \times 33000} = 29.7$ hp is required due to a 16 kw load and 5 tons added weight. Ten cars with a

similar load would require 297 horsepower or roughly 10 per cent of the capacity of a 3,000 hp passenger locomotive.

Consideration must also be given to the power requirements for refrigeration while the car is standing or running at slow speeds. The electrical energy required for the ice-activated, steam, and internal combustion engine drive mechanical systems is easily supplied from the

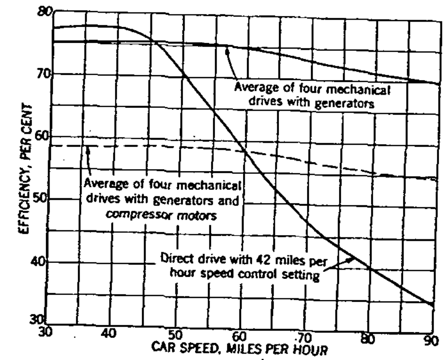

FIG. 1. EFFICIENCIES OF DRIVE MECHANISMS FOR RAILWAY AIR CONDITIONING SYSTEMS

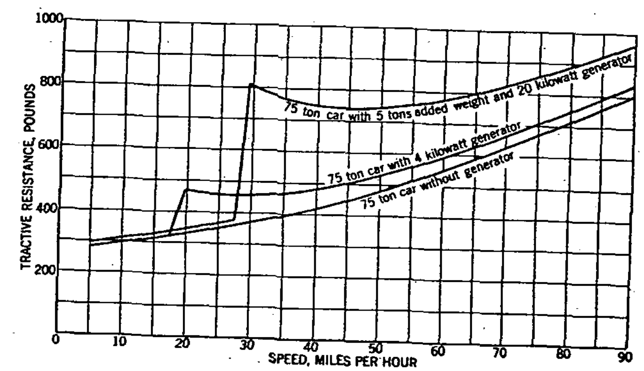

FIG. 2. TRACTIVE RESISTANCE OF 75 TON PASSENGER CAR WITH SIX WHEEL TRUCKS

storage battery. Steam for the steam system can be supplied from the locomotive or from a stationary plant. The majority of the electro mechanical systems are equipped with A. C.—D. C. motors. While standing in the yards and stations the A. C. motor is connected to a 220-volt, 3-phase circuit. The majority of these equipments are so arranged that, while operating on A. C. power, the D. C. motor may be used as a generator for battery charging. If an auxiliary circuit is not available the D. C. compressor motor may be operated from the storage battery for short periods of time. The direct drive mechanical compres-