

BUS AIR CONDITIONING, USA



*Santa Fe Trailways Time Tables, 1946**

Text from 1939 paper in "Refrigerating Engineering," USA

*Pictures marked * from www.cw42.tripod.com*

Bus Air Conditioning*

By A. J. Mallinckrodt¹ and Lars Hanson²

A NUMBER of years ago an operator of one of the larger bus lines observed that, on the northern routes, bus passenger traffic remained fairly constant throughout the year; but, on southern routes, there was a decided drop in traffic during the warm season. It was further observed that a great portion of the loss in traffic on the southern routes was gained by railroads which were operating air conditioned equipment. Bus lines, in order to be profitable, must be in a position to compete with air conditioned equipment on railroads as well as with private passenger cars. In order to do so, buses must be air conditioned. Attracting one additional passenger per trip more than pays the cost.

Even though a great part of our bus transportation system is owned by railroads paralleling the bus lines, it is highly desirable to prevent decided seasonal shifts from one means of transportation to another. If, at one season, a greater proportion of the traffic is carried on buses than at others, it results in a duplication of equipment because it is necessary to provide sufficient equipment of both types to carry the maximum load.

History of efforts in this field during the past few years has been fairly well publicized, but it may be of interest to mention that since early in 1936, several air conditioned buses have been in successful operation in the Arabian Desert, between Damascus and Baghdad. The fact that the operator has recently bought additional equipment indicates satisfactory performance and the acceptance of air conditioned bus transportation in other parts of the world.

Special Requirements for Bus Air Conditioning Equipment

IN the study of the requirements of air conditioning equipment for buses, it is necessary to stress considerations which in other applications of such equipment are of less importance.

One of the first of these considerations is the greatest possible weight reduction commensurate with the required capacity. The average weight of a 35 to 37 passenger bus—without load—is 20,000 lb. The passenger load—with baggage—is about 6300 lb., making a gross loaded weight of approximately 26,000 lb. A number of states limit the weight of vehicles permitted on highways to 26,000 lb. In most states, this portion of the law is not rigidly enforced, but where it is, any additional weight due to the use of air conditioning equipment results in a reduction of the pay

load. It has been found necessary, in some instances, to rope off some of the seats to limit the number of passengers that may be carried. Where state regulations limit the weight to be carried per wheel or per axle, the weight distribution of the air conditioning equipment becomes very important. It may also affect the required tire size or the amount of wear that may be expected from a given size tire. If the weight is not properly distributed, the road stability of the vehicle is impaired and it becomes impossible to maintain the schedules of speed made necessary by competitive means of travel. The importance of the weight of the equipment may make it desirable to sacrifice somewhat on the peak capacity in order to hold the weight within reasonable limits.

The temperature differential to be maintained for greatest comfort is somewhat different than it would be on the usual stationary air conditioning system, due to the fact that a bus may leave Los Angeles with an outside temperature of 75° and in a few hours be in Needles, Calif., with a temperature of possibly 115° to 120°. The passenger reaction is, of course, that which one would expect at the point where he embarked.

Reduction of required cooling load by means of improved body construction is essential. With the speeds employed on western highways, the body must be made quite tight to prevent excessive air leakage. The use of permanently closed windows is desirable both for the effect on cooling load and for cleanliness. Body insulation to the extent of 1½ in. blanket insulation is usually employed. To minimize sun effect through the walls and roof, it is desirable that at least the roof be painted to reflect sunlight, even though the remainder of the paint scheme is based on other considerations.

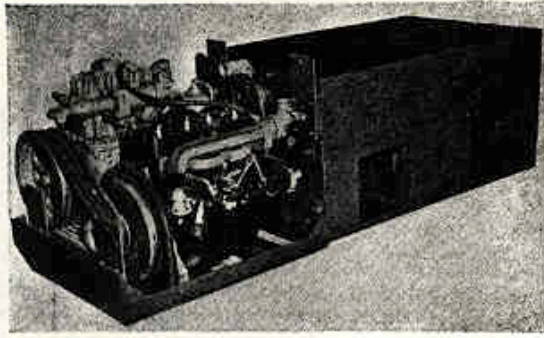
Bus travel usually affords a greater opportunity for sightseeing than does travel by rail, and many people travel on buses for this very reason. It is, therefore, essential that large windows be provided and, under the circumstances, it would not be desirable to request the passengers to keep the shades drawn. This condition must be taken into consideration in determining the solar heat load.

In the fall of 1936, experimental work was begun to provide an air conditioning system which would fulfill these requirements. The preliminary work was done in the laboratory where conditions surrounding the bus could be controlled. The passenger load was simulated as closely as possible by means of electric heaters and steam jets distributed evenly throughout the bus. Proper distribution and air velocities were determined under these conditions; after this the bus was taken on the road to get the effect of wind velocity on outside air inlets, leakage through bus body, and

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¹ Research Engineer, Carrier Corporation.

² Assistant Director of Development, Carrier Corporation.

FIG. 1. BUS COOLING UNIT— $3\frac{1}{2}$ TONS.

performance of condenser under various wind directions. It was considered desirable to have the outside air inlets located so that the quantity of air taken in would be independent of the speed of the bus, that is, at points of neutral pressure on the contour of the bus body. These points had been determined by pressure readings taken over a wide range of bus speeds.

On the basis of this preliminary experimental work, a unit was built and installed in a bus which was then driven to the Arizona desert. The test operation of this experimental bus covered a period of several months, during which time all major design problems were carefully analyzed.

Air conditioning equipment was built and installed in a fleet of buses put in operation during the summer of 1938. The capacity of the unit was $3\frac{1}{2}$ tons which was sufficient to maintain inside conditions of 80° dry bulb and 68° wet bulb when outside conditions were 100° dry bulb and 78° wet bulb. The equipment, generally, consisted of a 4-cylinder gasoline engine connected by V-belts to a compressor, an air-cooled condenser, and a receiver mounted as one condensing unit (Fig. 1). The condenser fans were of the centrifugal type, mounted on a shaft direct connected to the engine. The cooling system of the air conditioning engine was connected to the main engine radiator which had been increased in size to take this additional load. Evaporator coils and fans were located under the roof above the driver's seat, the housing for this equipment being built in as part of the bus body to conserve space and to blend with the decorative design of the interior. Evaporator fans having a capacity of 1100 c.f.m. were driven by a $\frac{1}{4}$ h.p. motor receiving its energy from the bus lighting system. The electrical system had been increased in capacity for this purpose. 360 c.f.m. of the air circulated was outside, filtered air. Conditioned air was admitted through a single outlet discharging horizontally under

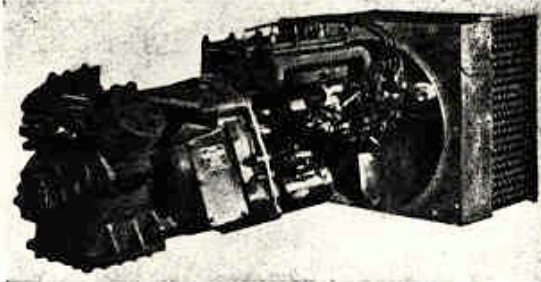


FIG. 3. REDESIGNED CONDENSING UNIT.

the ceiling toward the rear (Fig. 2). The control equipment consisted of a thermostat connected to a liquid line solenoid valve. When the temperature fell to the desired point, the thermostat would close the liquid line solenoid valve, permitting the compressor to pump down the system. When the suction pressure was reduced to a predetermined point, a pressurestat opened a bypass solenoid valve around the compressor, permitting the compressor to idle. The engine was permitted to operate at constant speed throughout the cycle. A high pressure cutout was provided to guard against excessive head pressures. The total weight of the mechanical equipment was approximately 1250 lb., not including insulation of the bus body.



FIG. 2. CONDITIONED AIR IS ADMITTED THROUGH A SINGLE OUTLET DISCHARGING HORIZONTALLY UNDER THE CEILING TOWARD THE REAR.

Generally, field experience with these units was quite satisfactory; however, when the equipment was first placed in operation, maintenance problems were exaggerated due to the fact that the personnel in charge of service was not thoroughly familiar with air conditioning equipment, and it had been decided that it would not be practical to maintain a separate force for this part of the service work. The work was, therefore, left largely to the automotive service department. Later, the work was segregated and some of the men came to specialize on air conditioning equipment. As these men took charge and the men under them became more familiar with the apparatus, road failures of the air conditioning equipment were reduced to a point that was highly acceptable. The problem of providing proper facilities for servicing air conditioning equipment will probably remain one of the major problems in connection with this work for some time to come. Unfortunately, we have not come to the point where the principles of operation of an air conditioning system are as generally understood as are those of the operation of automotive equipment.

During the first season of operation, further development work was undertaken with a view toward weight reduction and refinement of design. In this design, a high speed compressor is direct connected to the air conditioning engine shaft, the engine and compressor frames being rigidly connected by means of an aluminum casting with pilot fits on both the engine and compressor to assure alignment. The condenser fan is of the disc type, mounted on the front end of the engine shaft. The engine and compressor unit is

BOWEN TRAILWAYS

TEXAS LINES

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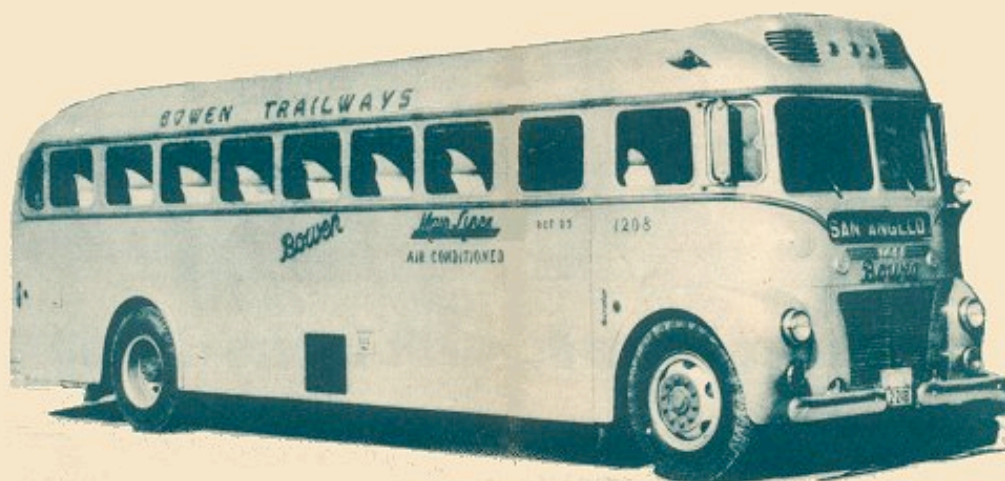
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TIME TABLES

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IMPROVED AIR-CONDITIONING

Under Your Seat Baggage Compartment

Under Floor Power - Less Noise
Less Vibration

ALL THESE
EXTRAS

EXTRA WIDE SAFETY GLASS

Windows Eliminating Rattles and Dust

SPECIALLY DESIGNED FORM FITTING
RECLINING SEATS

AT NO
EXTRA FARE

*Advertisement featuring Bowen Trailways air conditioned bus, 1942**

supported at three points by means of flexible mountings, while the condenser is mounted rigidly to the bus body (Figs. 3 and 4). The condenser is of the straight air-cooled type, liberally designed. Due consideration is given to the fact that a condenser of the evaporative type would result in lower head pressures and consequent reduction in power. The total weight of the equipment could not be reduced as it is necessary to carry a relatively large quantity of water. If an evaporative condenser were used, it would be desirable to carry a supply of water for an operating period of about four hours. In certain parts of the country, it would be detrimental to evaporate much more than half the water due to the concentration of mineral matter and the subsequent scaling of the condenser surface. Under these circumstances, it would be necessary to carry about 40 gal. of water for equipment having a capacity of $3\frac{1}{2}$ tons. For this reason, together with the greater simplicity of the air-cooled condenser, this latter type was selected.

When the compressor operates bypassed, the refrigerant vapor passes through a small coil in the condenser casing to prevent excessive superheat.

The evaporator coils and fans are reduced in height to minimize the head room required. This equipment is mounted in a manner similar to that used on the first fleet; however, air is distributed through a perforated false ceiling throughout the length of the bus (Fig. 5). The air is then permitted to return through the passenger space to the return grille located at the extreme front end.

In order to realize the greatest possible capacity of the equipment installed, it was considered desirable to provide a heat exchanger to take advantage of the air exhausted from the conditioned space. In this particular bus, the engine supplying motive power for the vehicle takes its carburetor air from the conditioned space. This is done as a special safeguard, in addition to the usual air cleaner to provide air free from dust. The air required by the main engine is taken over a liquid sub-cooler coil. The quantity of air required by the engine may vary from 0 to 360 c.f.m. In order not to lose the benefit of the liquid

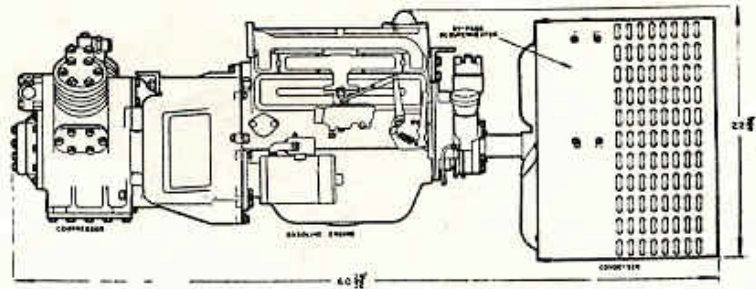


FIG. 4. CROSS SECTION SHOWING HOW CONDENSER IS MOUNTED RIGIDLY TO THE BUS BODY.

sub-cooling when the engine is working at a low speed or at a partially open throttle, an auxiliary fan is provided to exhaust air to the atmosphere after it has passed over the subcooler coil. The fan characteristics were selected so that when the engine is taking its maximum amount of air, the pressure drop through the sub-cooler coils is approximately equal to the shutoff head on the fan which, therefore, operates at zero capacity. As the air requirement of the engine decreases, the pressure drop through the sub-cooler coil is lowered and the fan begins to exhaust air to atmosphere. By means of this arrangement, a fairly uniform flow over the sub-cooler is obtained, and at the same time, the quantity of air exhausted from

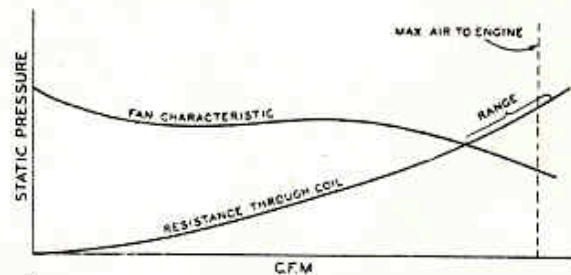


FIG. 6. FAN IS OPERATED TO PROVIDE FAIRLY UNIFORM AIR FLOW OVER THE SUBCOOLER.

the bus is not increased materially above the requirement of the engine. Thus, it is still possible to carry the bus at a pressure slightly above atmospheric. Fig. 6 shows the operating characteristics of this apparatus. This is an exclusive feature covered by patent rights of the manufacturer.

In addition to the control equipment described for the first unit, a 2-step thermostat is supplied; one step of which controls the liquid refrigerant solenoid valve; the other step controls a solenoid valve in an air supply line to a pneumatic cylinder which governs the speed of the air conditioning engine. A control system has been devised which provides modulated speed control by a similar means.

The revised design, as already described, results in a reduction in weight of the entire mechanical equipment from 1250 lb. to less than 900 lb. The accessibility of the equipment has been greatly improved due to the fact that all accessories are available either from a service pit or from the outside of the bus.

The general acceptance of bus air condi-
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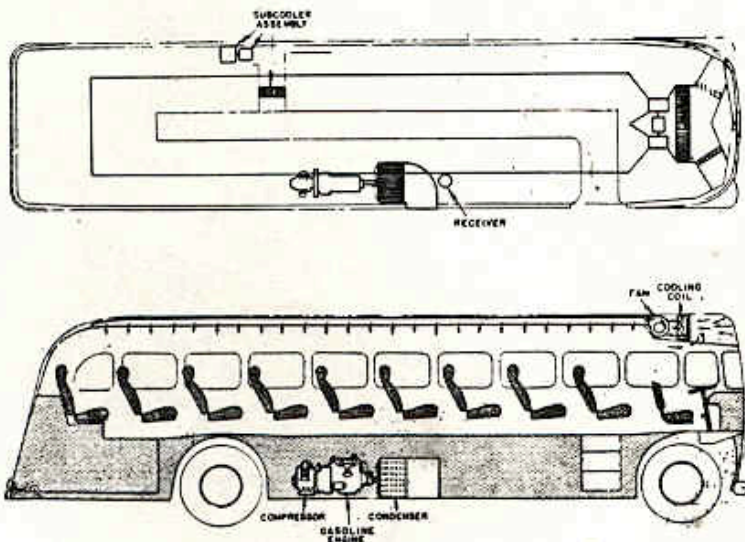
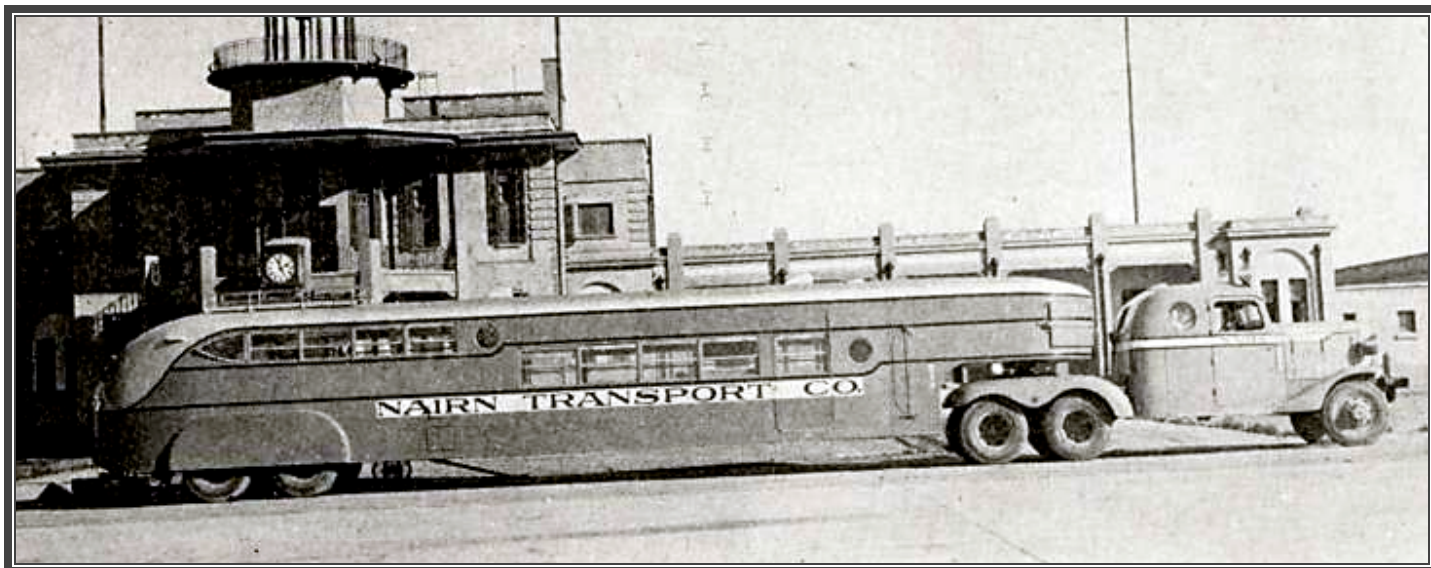


FIG. 5. AIR IS DISTRIBUTED THROUGH A PERFORATED FALSE CEILING THROUGHOUT THE LENGTH OF THE BUS.

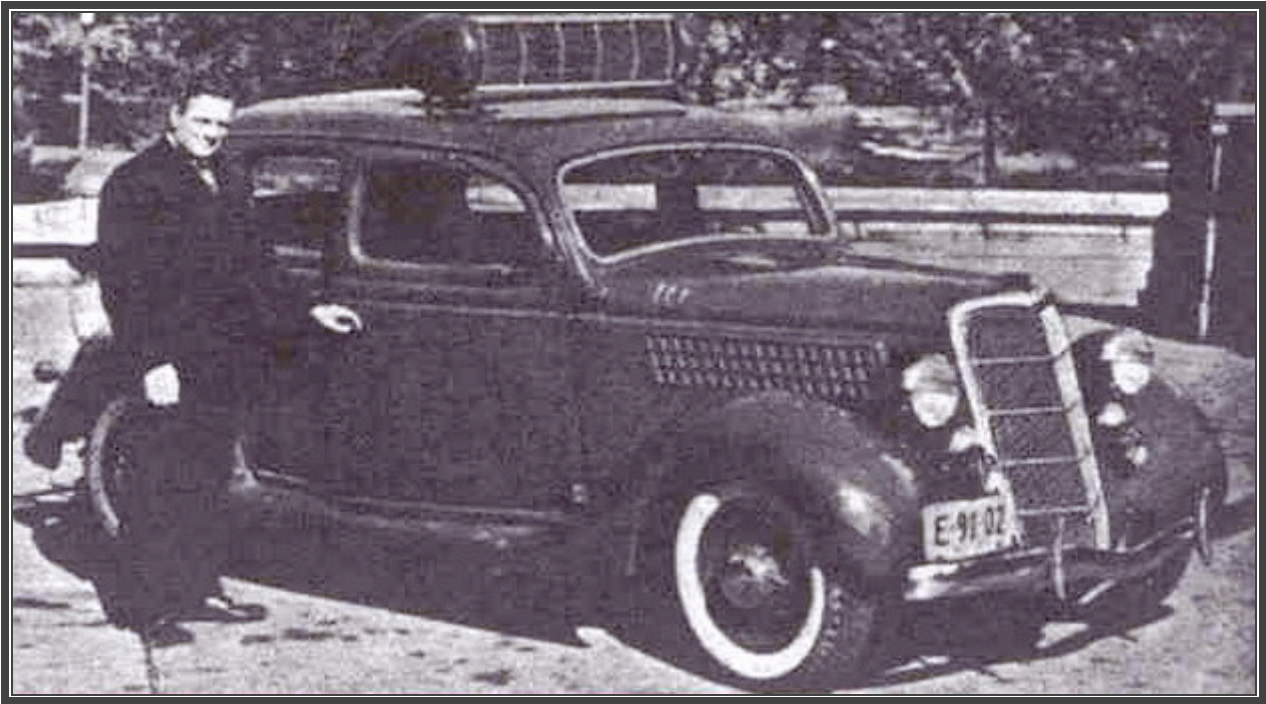
tioning by passengers as well as operators should be highly gratifying to the industry. Operators report that it is becoming more and more difficult to get the passengers to ride on non-air conditioned equipment. The future in this field will probably see a great deal of additional effort spent in reducing weight and cost of equipment. Toward this end, a number of suggestions have been made involving radical departures from present practice, but it appears that the most fruitful field of development lies along the line of refinement of design and methods now generally accepted.

Cooling hit the road in 1930 with a system aboard the Martha Washington diner on the Baltimore and Ohio's crack New York to Washington train. The Nairn Transportation Company of Syria made the Middle-Eastern desert a far more pleasing place to travel through with the first air conditioned bus line in 1936. Two years later, Santa Fe Trailways put the first climate-controlled buses on the highways between U.S. cities.

Extract from Carrier publicity



Nairn Transport Company, picture thought to be end of 1930's



1934 Ford V-8 used as a test vehicle for bus air conditioning Carrier & Houde Engineering)



**1938 ACF Brill H-9-P
Santa Fe Trailways**

*Bus of Santa Fe Trailways, USA 1938**



Lord Kelvin, air conditioned bus 1937



*Air conditioned bus, USA 1938 (Bowen Motor Coaches)**

52. BUSES

AIR conditioning first applied to the intercity bus in 1938, is now considered a necessary part of its equipment. On the other hand, the application of air conditioning to the city bus is still in the pioneering stage, although the problem is one more of economics than of engineering. However, two important applications of air conditioning in the field of urban passenger transportation have been made, one in San Antonio, Texas and the other in Atlanta, Georgia.

When considering the application of air conditioning to buses, we must remember that buses are commonly divided into two general classifications; intercity and city. Although these two types of buses, serving different fields of passenger transportation, use the same basic air conditioning equipment, nevertheless, the problems involved are different.

Intercity Bus

The intercity bus serves the field of long distance over the highway passenger transportation. The growth of air conditioning of this type of vehicle was rapid following its introduction in 1938, until today air conditioning is standard equipment.

Because the dimensions of buses are limited by law, the cooling load does not vary greatly between different intercity bus designs, if we except recent radical innovations with observation roofs which are in the experimental and developmental stage. The capacity of the average cooling

system is in the neighborhood of four tons, which is sufficient to maintain, with a full seated load, an inside condition of 78 F dry bulb, 67 F wet bulb when the outside condition is 95 F dry bulb, 78 F wet bulb. In the West 110 F dry bulb and 80 F wet bulb will doubtless be encountered and may have to be designed for. Although extreme temperature conditions may be encountered by a bus which travels anywhere there is a highway, this capacity is adequate to maintain comfort conditions except for the infrequent extreme weather condition. Although, more capacity would be advantageous, the space and weight limitations on the equipment discourage the objective. Fig. 1 illustrates commonly attained design conditions in the average 40 passenger intercity bus.

City Bus

The city bus serving the mass transportation of people in metropolitan areas presents a more difficult problem to the air conditioning engineer. Doors are being opened at every street corner and peak passenger loads are extremely high. Figs. 2 and 3 illustrate actual data on this phase of city bus operation recorded in San Antonio, Texas.

On the other hand, the average ride is of short duration, seldom allowing time for the passenger to become completely acclimated to the inside conditions. Therefore large temperature differences need not be maintained and are not desirable. The present meager information available indicates that capacities of from five tons on a 35 passenger bus to six and one-half tons on a 48 to 50 passenger bus should do a fair job of cooling the city bus. This is not to say that comfort chart conditions will be maintained during rush hours when the bus is carrying up to 100 percent standees. Rather this capacity will maintain comfort conditions in all but the rush hours and conditions that are an appreciable improvement over outside conditions during periods of standee loading. Fig. 4 il-

ANDREW T. BROWNE, Author Chapter 52. Born 1905, in Belfast, Ireland. Educated at City of Belfast College of Technology, ME, 1923. Formerly rail car designing, Pullman Car and Mfg. Corp., Chicago; bus air conditioning design, automotive research, ACF-Brill Motors Company, Philadelphia, 1929 to date.

Co-author, "Problems Involved in the Adequate Heating and Ventilating of Buses," Assn. of Transit Equip. Men, 1938. Author, "Air Conditioning is No Mystery," Bus Transportation, 1938; "Air Conditioning of Automotive Vehicles," SAE, 1950.

Member, ASME, SAE, registered professional engineer, Pennsylvania.

At present, Project Engineer, ACF-Brill Motors Co., Philadelphia, Pa.