# HISTORY AND METHODS

# OF

# AIR CONDITIONING

# ON THE

# BALTIMORE AND OHIO RAILROAD

by

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SUMMARY

After a description of "air conditioning," a historical sketch is given outlining the developments in air conditioning on the Baltimore and Ohio Railroad from the first experiment in that line in 1884 to the present day. The early developments mentioned include the ice system tried in 1906 and the air washing system tried on Coach 225 in 1925. The later developments include the chilled spray system on coach 5275, the first completely air conditioned car in the world; and the Colonial Diner, "Martha Washington," the first B. & O. car to be equipped with a mechanical refrigeration air conditioning system. A few of the first completely air conditioned trains are mentioned as well as some later developments.

There is next a discussion of the air conditioning systems tried by the B. & O., and an explanation in detail of the mechanical system. The methods used on coach 5275 and on the "Martha Washington" are described in detail due to their historic interest. A discussion of the developments since then follows, including the gasoline power plant, the discovery of Freon, the development of the high capacity storage battery and the third brush generator. A few of the more recent experiments are mentioned, including those of heating.

There follows then a discussion of the costs of operating the units, and a summary of the benefits derived in the line of increased comfort.

Finally, there is a very complete bibliography of magazine articles on the subject to date.

## - FORWARD -

It is extremely appropriate that at this time a report be made of the air conditioning of passenger cars on the Baltimore and Ohio Railroad. Appropriate because air conditioning has been the one development that has made the greatest progress during the years from 1929 to the present. It is an advancement that is having a great effect on lifting what has been called the greatest depression that the United States has ever had.

Except in a few isolated cases of theaters and special industrial processes, the growth of air conditioning began during 1929 and 1930. The railroads have perhaps more to gain from air conditioning than almost any other industry. As in practically every railroad development in this country, the Baltimore andOhio has been a pioneer in this modern evolution.

# I. AIR CONDITIONING OF PASSENGER CARS

Ever since the first passenger carriage for a horse-drawn railroad car was built, there has been the problem of proper ventilation and comfort for the passengers. With the development of the steam engine the problem became more accute, as to have the windows open meant the admittance of smoke and cinders.

For a very long time the problem of properly cooling a passenger car has been studied. The relative small capacity of the car, the crowded conditions, and the fact that a railway car is a poor insulator of heat, all contribute to making a car extremely uncomfortable in hot weather, especially if an attempt is made to keep the dirt out.

There have been many definitions of air conditioning. The definition used in this thesis is "Cooling for comfort."

# II. HISTORY

## EARLY HISTORY

The earliest records available at the Patent Office show that the first attempt of air cooling of cars occurred fifty years ago last summer, in 1884. This system was developed by a Dr. Keys and was installed in a B. & O. car at the Mt. Clare Shop. It consisted of a huge ice box in the bow of the car, equipped with air ducts which would force air over the ice from the breeze caused by the train's motion. This was only slightly successful because of poor circulation of air in the car and excessive use of the ice.

In 1906 another ice system invented and patented by J. C. Witter was installed in a B. & O. dining car. An ice box was placed in the upper deck of the car, between the dining room and the end finish. This box was in two sections with about 18 inches between the sections. An ordinary electric fan was placed in this space. The ice compartments contained several longitudinal flutes, or tubes, these being surrounded by ice. These flutes were for the purpose of giving the air a positive contact with a cooling surface as the air was drawn through these tubes by the fan. One set of flutes was on the intake side and the other on the side through which the air was discharged into the room. A trap door on the roof was the means of replenishing the ice boxes.

This car, No. 1008, was used on a trip in 1906 from Chicago to Philadelphia, and carried representatives of the railway Supply Men's Association and members of the Master Mechanics

Association and Master Car Builders Association. From a cooling standpoint it operated very satisfactorily, but the too frequent stops necessary for ice, and the consequent cost of operation, rendered it impracticle.

It should be noted that the difficulties were mainly due to the small sizes and poor insulation of the ice boxes. This system is the forerunner of ice systems used today by some railroads.

In 1925, Coach No. 225 was equipped with an air washing and conditioning system in the Mt. Clare Shop. The air was washed and cooled by being drawn through a system of chilled sprays, and then was distributed into the car through a system of air ducts. The system was satisfactory, but its use was not extended because the pumps and fans used more electrical current than could be furnished by any car generator in existence at that time.

## LATER HISTORY

Meanwhile the railroads had lost a great deal of passenger traffic due to new competition from automobiles, buses, and the beginning of airplane travel. It was decided that to regain passenger traffic it would be necessary to make train travel more inviting. The primary requesite for this was the elimination of dust, cinders, and smoke. The B. & O. mechanical experts were not slow at deciding that the only way to do this was to keep the windows and doors closed tightly while the train was moving. Of course this meant that some means must be supplied of furnishing and controlling a supply of clean and fresh air. Experiments soon showed that it would be easy to cool and dehumidify this air at the same time that it was mechanically supplied.

In 1929, experiments were made by the B. & O. which showed that cooling modern passenger cars was possible. In July, Coach 5275 was furnished for complete summer air conditioning and exhausting tests made both standing and running, and these tests showed that a mechanical air conditioning system was practical for railway cars.

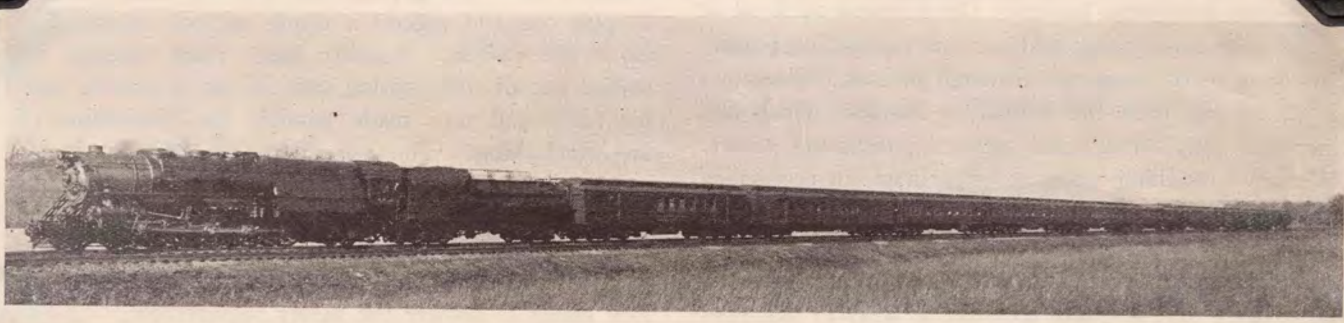
In 1930 more tests were made and equipment was installed in the Colonial Diner, Martha Washington. This car was exhibited at the 1930 A.R.A. Convention at Atlantic City in June. In 1931 this equipment was replaced by the standard equipment which is now in use, with several changes, of course. The methods used on these cars will be described in detail later.

These and other experiments in 1930 were so satisfactory that in 1931, the B. & O. installed 38 units. On May 24, 1931, the first completely air conditioned train in history, "The Columbian," was put in service between New York and Washington, one trip each way each day. These standard units were built by the York Ice Machinery Co., of York, Pennsylvania, and installed by the Railroad Company's forces in the Mt. Clare shops.

During 1932, a total of 122 cars on the B. & O. and 16 on the Alton Railroad were completed. On April 20, 1932, the "National Limited," the first long distance, fully air conditioned, sleeping car train was inaugurated. This operated daily in


Fig. 1
THE FIRST CAR IN THE WORLD EQUIPPED FOR COMPLETE AIR CONDITIONING—JULY, 1929


Figs. 4 and 5
THE MARTHA WASHINGTON, THE FIRST COMPLETELY AIR CONDITIONED CAR OPERATED IN REGULAR RAILWAY SERVICE—APRIL, 1930. SHOWING AIR INTAKE FOR COOLING TOWER AT FAR END AND OVERHEAD AIR DISTRIBUTION DUCT



The "Capitol Limited" of the Baltimore & Ohio Was the First Long-Distance Train to Be Fully Air-Conditioned both directions between New York, Cincinnati, Louisville and St. Louis. The "Capitol Limited," similarly equipped began operations between New York and Chicago on May 22.

In June of that year, theB. & O. furnished complete equipment for two trains which were to carry the Inter-Collegiate Athletes from Jersey City to Los Angeles for the Olympic Games, and there were three air conditioned cars on each of these trains, two diners and a lounge. None of these six cars showed any trouble on the trip or return.

In November, 1932, President Hoover's train in his trip to California was furnished with two B. & O. Air conditioned cars, a sleeper and a lounge. There was no trouble here either.

The Capitol Limited was put on display outside the Travel and Transport Building at the Century of Progress Exposition, both in 1933 and 1934. The locomotive was No. 5510, named "Lord Baltimore." All six cars were completely air conditioned. Following the locomotive they were: first, a standard individual seat coach; second, a reclining seat coach, used for night service, and the first coach of that kind ever air conditioned. The third car was a colonial diner, "Mary Pickersgill." The fourth car was a typical lounge car in daily service on the B. & O. The fifth car was an up-to-date sleeper, named the "Illinois." The final car was a sun-room observation car of the latest style and named the "Maryland."

In 1933, the B. & O. had 162 air conditioned cars in use, and by the end of 1934 this number will be very much higher.

## III. METHODS

### TYPES OF AIR CONDITIONING SYSTEMS

Modern air conditioning of passenger cars was not a spontaneous thought quickly developed into reality. The B. & O. gave considerable thought to it for several years and made many plans and experiments before an actual installation was made. Consideration had to be made for the various possibilities. For instance, consideration was given to having the cooling aparatus at the front of the train. This was decided unfeasible because of lack of flexibility and the fact that unequipped cars could not be used on the train. Also the apparatus would have to be so designed to take care of a very great overload to care for extra cars. For these reasons it was decided that it would be best to have an individual unit on each car.

Three methods of cooling the air was next recognized: Ice system, steam ejector system, and mechanical compression system. All these systems are now in use on different roads.

All the ice systems are basically alike. Generally there is an ice storage compartment of large size; and an air cooling unit usually in the upper deck of the car, with a suitable fan for circulating the air. In some cases closed coils of cold water cool the air, while in others a cold spray is used. Of course, pumps are also necessary for circulating the water.

The rate of ice meltage can be determined by considering the temperature and atmospheric conditions within the car. Experiments made by the B. & O. showed that the ice consumption for a standard car would vary between 385 and 500 pounds per hour, and with ice at \$.25 per hundred or \$5.00 per ton, the cost of operation was from \$.97 to \$1.25 per hour. The natural conclusion was that while it might be a suitable system for short runs, on through trains it would be rather expensive, even though the initial cost is small.

The steam ejector system depends upon the fact that water will boil at low temperatures if the pressure is reduced. The refrigerant used is water and the refrigerating power comes from steam from the locomotive. Experiments showed that the system required 205 pounds of steam per hour per car at 50 pounds of pressure for operating the ejector, plus a line loss of 35 pounds per car, or a total of 240 pounds of steam per hour per car. The additional load on the locomotive is about 10½ horse-power. The pressure drop along the line would limit the number of cars that could be served by this system, and also steam would have to be provided from another source when the car is in a station or yard without the locomotive connected.

The system had many good points, but it was decided that the mechanical compression system would be better. In this system, a mechanical compressor takes the place of the steam in the steam ejector system.

The following are considerations to be met in the required system:

1. Low initial investment.
2. Long life.
3. Low operating cost.

4. Low maintenance cost.
5. Low supervision cost.
6. Low obsolescence.
7. Expensive additions to yard and terminals must not be necessary.
8. Flexibility of operation.
9. Light weight.
10. Small space.
11. Safety.
12. Simplicity.
13. Dependability.
14. Capacity must be great enough to keep the car at a comfortable temperature.

Before taking up the study of specific equipment, it would be well to consider the general theory back of mechanical refrigeration.

## AIR CONDITIONING CYCLE

Air is taken from the body of the car and mixed with filtered outside air and then passed through the air conditioner, (Fig. 13). The air is cooled in the air conditioning unit, and moisture will condense out due to the fact that air at a lower temperature will hold less water than at a higher temperature. This cooled and dehumidified air then passes into a duct along one side of the roof, or through the center top section, of the entire length of the car.

The air leaves the outlet grilles with just sufficient velocity to carry the width of the upper deck of the car. Cool air has greater density than warm air and so it decends evenly

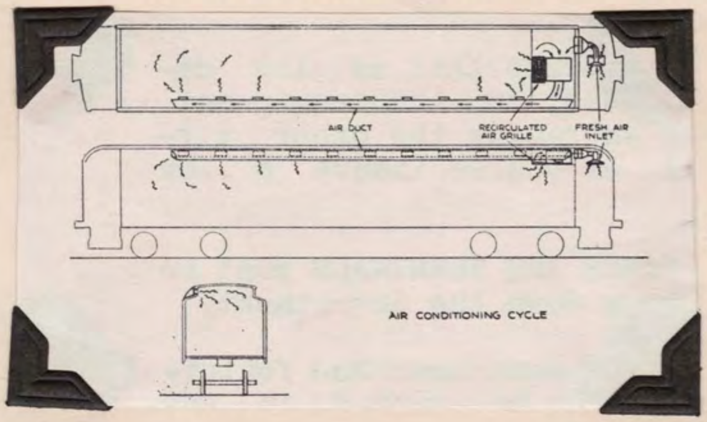



Fig. 13

over the whole passenger area, mixing with the air that is already there and providing draft-free ventilation and cooling. The ventilators along one side of the car are available in case of an emergency.

## REFRIGERATING CYCLE

This discussion of the refrigerating cycle will consider the refrigerant FREON because that is used today exclusively. The previous application ofammonia will be later discussed.

Figure 14 shows a representation of this cycle and the characteristic P-H diagram. The whole principle lies in the refrigerant picking up heat at one pressure and temperature level and giving up the heat at a higher temperature and pressure level. Every liquid has a definite temperature--pressure relation.

The refrigerating system consists primarily of a compressor, a condenser, a regulating valve, and an evaporator.

Following the diagram, Figure 14, FREON liquid at 120 pounds and 102° is allowed to pass the regulating valve. The pressure

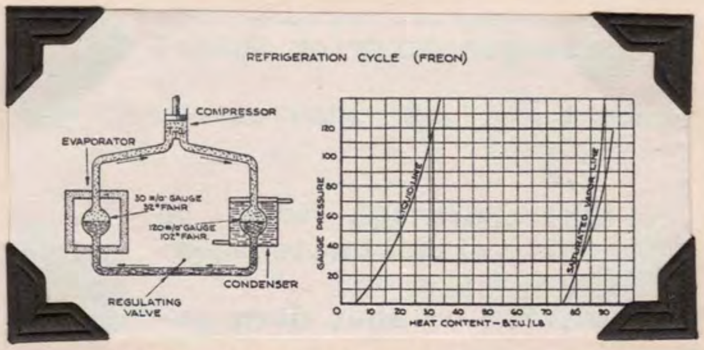



Fig. 14

will here be much reduced, to say 30 pounds, and the FREON will assume a temperature of 32°. The refrigerant will boil due to the heat from the air around the evaporator. This vapor will be taken by the compressor and recompressed to 120 pounds and then discharged into the condenser. Here water of say 80° temperature passes over the condenser and takes up heat from the compressed gas and condenses it into a liquid. Thus the heat is removed by the water and the refrigerant is only a transfer agent. It picks up heat at a low temperature level from the air and discharges it to the condensing water at a higher level.

Figure 15 shows just such a system diagrammatically, and is the type used on most modern passenger cars. All the essential components may be seen: compressor, condenser-cooling tower, float regulator and evaporator in the air conditioner unit. The condenser cooling tower had to be novelly designed because it is impossible to carry a sufficient supply of water on the car for the condensing purpose. This cooling tower takes the condensing water and sprays it to the open air over the coil, where by evaporation of a little of the water, it cools and condenses the compressed gas. The air is supplied by being continuously pulled through the tower by a fan. Thus the transfer of heat is from the air passing through the air conditioning unit

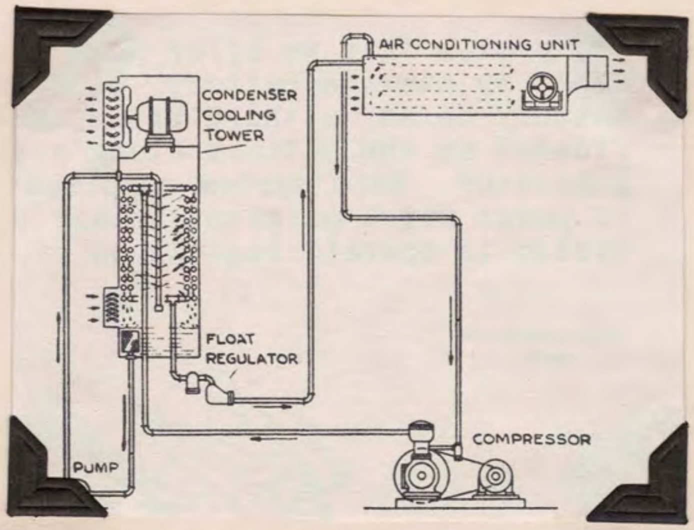



Fig. 15

to the refrigerant, from the refrigerant to the condenser water, and from the condenser water to the outside air. Some of the water lost from the cooling tower by evaporation is replenished by an ingenious method of using the water that is dehumidified from the air in the air conditioner. The level of water is automatically maintained from a reservoir through a valve. Another type of condensing medium is used in some cases, air being used without any water sprays, (Fig. 16)

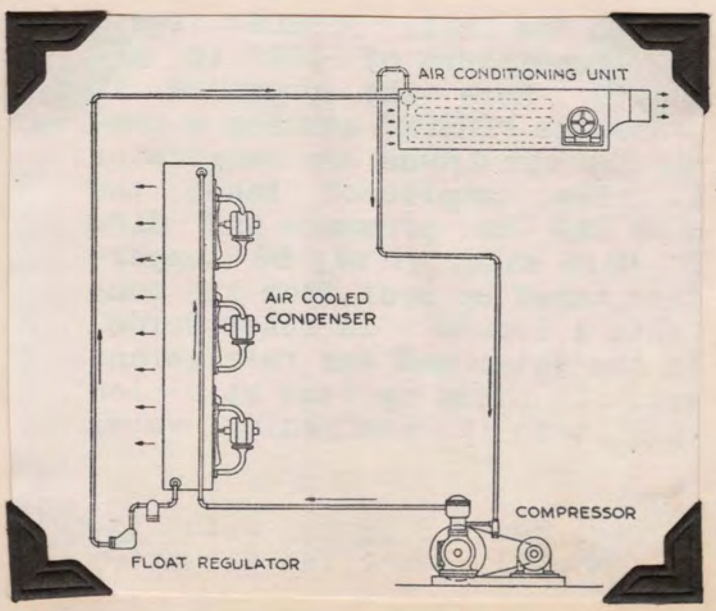



Fig. 16

A very large volume of air is drawn across the condenser coils by more than one fan, and the condensation takes place without the use of water.

The theory above explained has been the same for all mechanical air conditioning systems. The major developments have been in the design of the power supply and in the refrigerant gas used. These will be taken up in chronological order.

The first two cars ever to be completely air conditioned will be described in detail, due to the historic interest.

## THE FIRST COMPLETELY AIR CONDITIONED CAR

The B. & O. Coach No. 5275, was the first railway passenger car in the world (July, 1929) to be equipped for complete air conditioning, i.e., freeing the air from all dust, soot, cinders and other foreign material and controlling its temperature and humidify. (Fig. 1. page 7)

Except for the evaporators, commercially available equipment was used. Two water spray units were placed in the car, one at each diagonal corner, a seat being removed from each place to accomodate the unit. A belt drive motor driven compressor was installed in one of the saloons and two ammonia condensing tanks were located near the roof of another saloon. Two evaporators and two water circulating pumps were located beneath the car floor. Five single phase 60 cycle 220 volt A-C motors were used. The $7\frac{1}{2}$ ton ammonia compressor required a $7\frac{1}{2}$ horse-power motor. The two centrifugal pumps were driven by a $\frac{3}{4}$ horse-power motor and the two water spray units each by a 1 horse-power

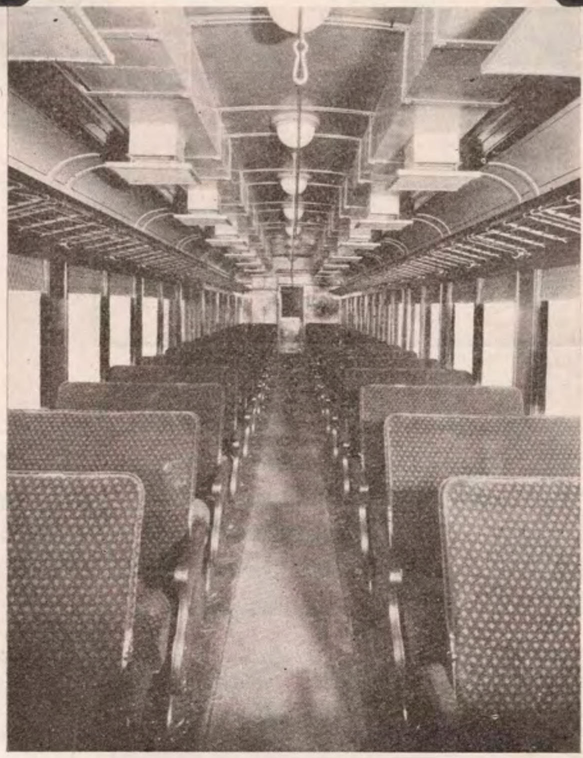


Fig. 2
COACH 5275—SHOWING AIR DISTRIBUTION DUCTS

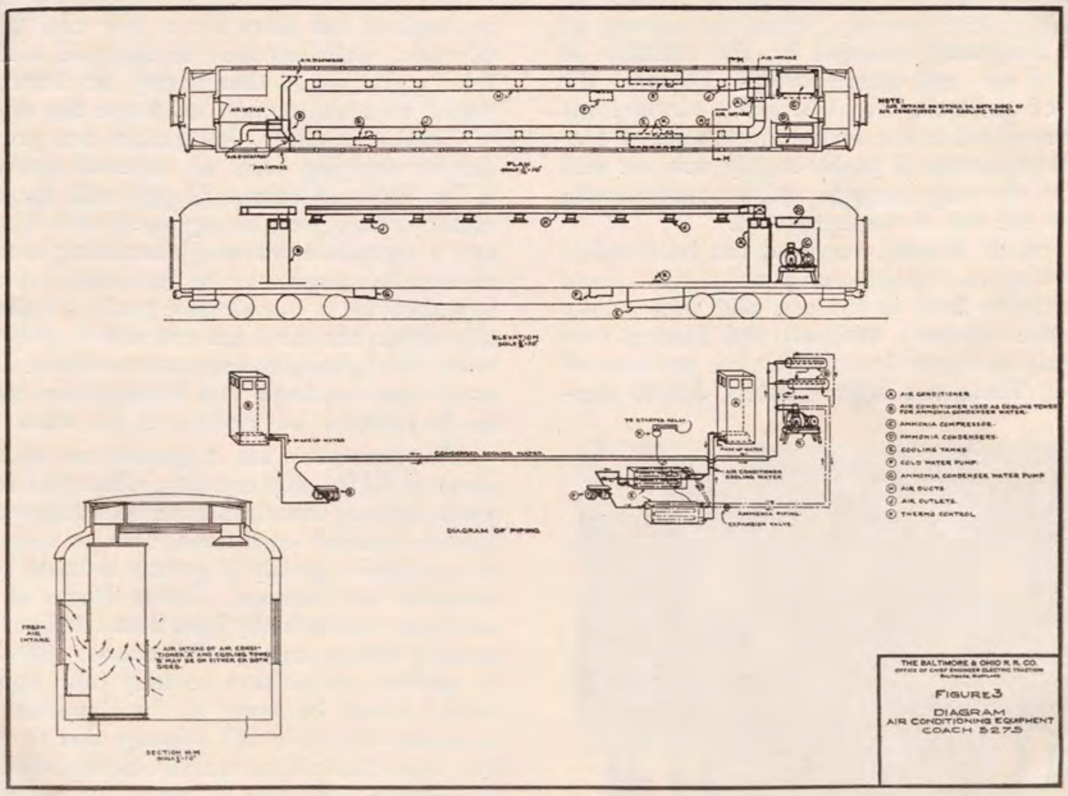



Fig. 3

motor. Each of these units handled 27 gallons of water per minute against about 40 pounds gauge pressure and delivered about 2500 cubic feet of air per minute against a pressure of about .6 inch WG.

All car windows were double sashed and the ventilators closed. Fresh air and re-circulated air was passed through the chilled water spray where dust and foreign matter was removed. Air at the desired temperature and humidity was then distributed without drafts through insulated air ducts attached to the half deck of the car.

The spray water was recooled and re-used. Ammonia was the refrigerant used in the compressor as previously described. The condenser cooling water was passed through the other air conditioning unit where outside air was drawn through the warm water spray, cooling the condenser water back to approximately the temperature of the outside air. In this way the condenser water was available for re-use. About 12 gallons of water per hour were lost under the worst conditions and was automatically replaced from the water supply system on the car. An automatic electrically operated thermal device cohrolled the motor driven compressor in accordance with predetermined setting for the desired car temperature.

After a series of standing and road tests covering about two months, the test equipment was removed and the car restored to its original condition as the air conditioning equipment was not suitable for permanent use and the power supply proved inadequate.

Figures 1 and 2 show pictures of this car, and a diagram of its equipment is shown in Figure 3.

## DEVELOPMENTS

This preliminary experiment shows that there were two obstacles still to be overcome before air conditioning could be commercially attained in railway cars. What was needed was a suitable power supply, and a compressing unit of proper capacity and design to be placed underneath the car. Ammonia was considered the only applicable refrigerant and it was recognized that no chances should be taken for allowing any ammonia gas from leaking into the car. A special $7\frac{1}{2}$ ton, smaller, lighter compressor was designed that could be mounted below the floor, ($7\frac{1}{2}$ ton means capacity equivalent to cooling by $7\frac{1}{2}$ tons of ice). For the supply problem, a gear driven 10 Kilowatt 110 volt D-C generator was developed. The gear drive was constructed with a ratio of 2.43 to 1. With 36 inch car wheels, the generator gave it full output at about 31 miles per hour, declining with declining speed to 85 volts at about 28 miles per hour.

## MARTHA WASHINGTON

The next car to be completely conditioned was the colonial dining car, the Martha Washington (No. 1036). Pictures of this car are shown in Figures 4 & 5, 9, 10, 11, and 12.

The function of the air conditioning equipment can be followed by consulting Figure 6. The mechanical air filters were sheet steel housings containing steel wool, as shown at (a) along the roof line near the pantry. The airwas cleaned of cinders, dust, and other foreign matter here. The air then passed over the cooling coils (b) which were 51 1-inch aerofin pipes each 3 feet long, and giving a cooling surface of about 600 square feet. The air was then blown by two fans (c) driven by one $\frac{1}{2}$ horse-power 110 volt motor operating at 1,000 RPM, each fan delivering about 1200 cubic feet of air per minute against a static pressure of .6 inch WG. The air was distributed through the insulated ducts (d) on the roof. It was delivered to the interior of the car through the louvered openings in the half deck. Adjustable perforated openings were provided to prevent drafts and to give equal distribution of air.

When the temperature inside the car reached a certain temperature below the outside temperature, the temperature regulator (f) controlled the air recirculating intake (e) to prevent further cooling. A mechanical interlock with the regulator (f), the louvers of intake (e) were closed and the louvers of (e') were opened to permit recirculation of air without passing over the cooling coils (b). The regulator (f) reversed the process when the temperature rose to a predetermined point. The regulation worked on a difference of about 3 to 5 degrees F.

In the refrigeration cycle, after compression, the hot ammonia gas was delivered to condenser (m). In this tank were coils of pipe containing water. The condenser liquid ammonia was then passed to the expansion valve (p) from where it went to the evaporator (i). In this evaporator were pipe coils through which water circulated to the cooling air conditioning unit. The ammonia gas was returned to the suction side of the

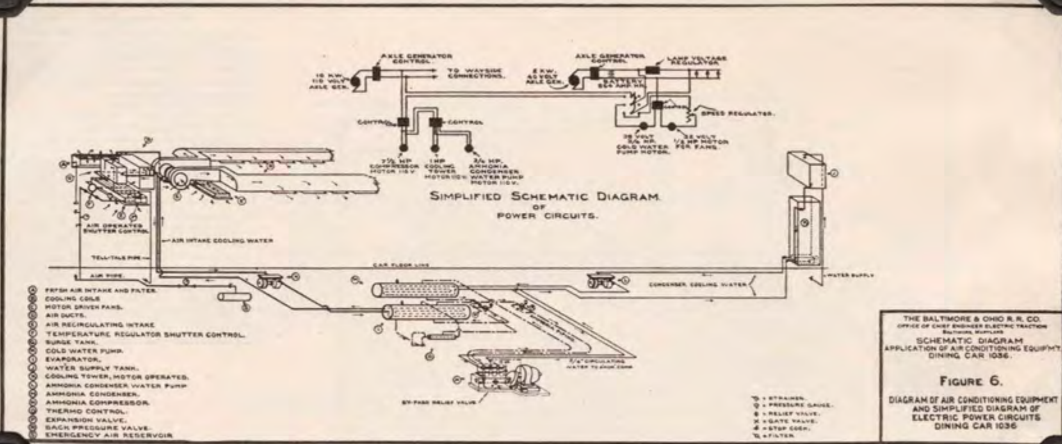



FIGURE 6.

DIAGRAM OF AIR CONDITIONING EQUIPMENT AND SIMPLIFIED DIAGRAM OF ELECTRIC POWER CIRCUITS DINING CAR 1036

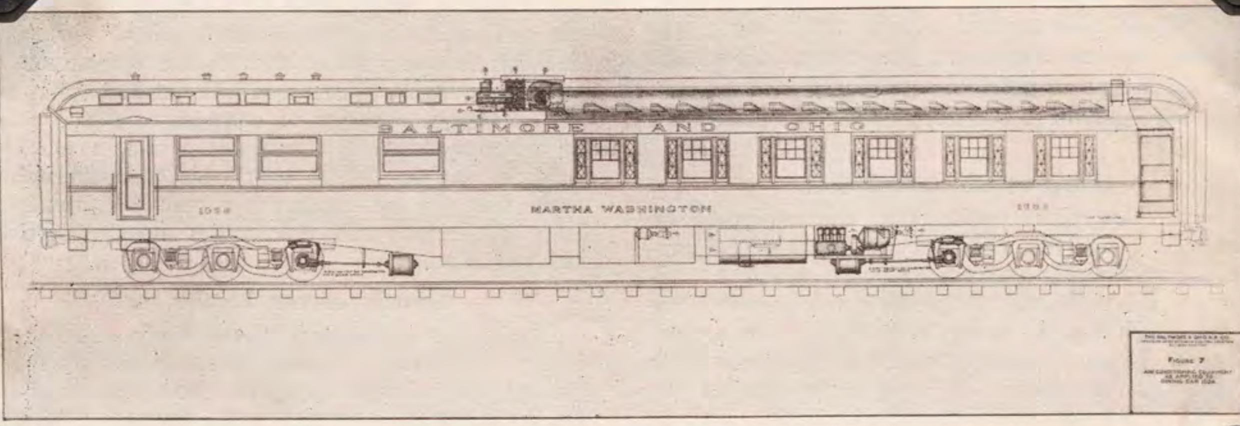


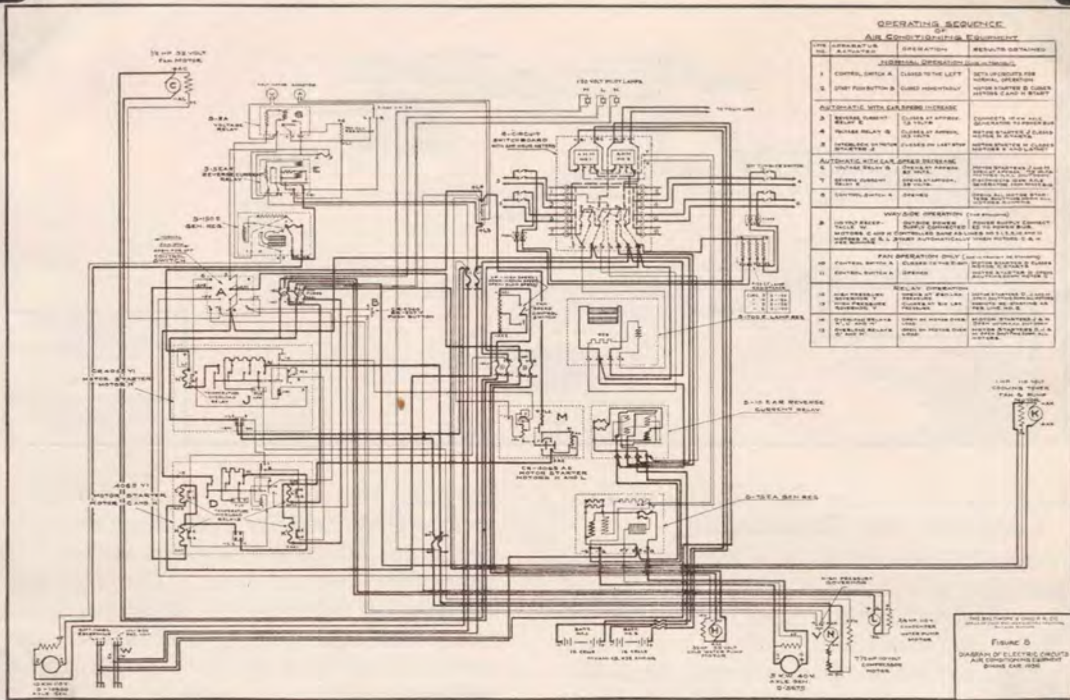

Fig. 11
LOUVERED OUTLETS IN HALF DECK FOR AIR DELIVERY
APPLE BLOSSOM FESTIVAL, WINCHESTER, VA.—BALTIMORE AND OHIO COLONIAL DINING CAR, MARTHA WASHINGTON

compressor (n) through the back pressure valve (r). The ammonia discharge pressure was 160 to 170 pounds, and the suction pressure 55 to 60 pounds. The compressor is pictured in Fig. 10.

Return to the condenser (m). Thecondensing of the ammonia imparted heat to the water. The motor driven pump (l) circulated this water to the cooling tower (k). The water was cooled here by a spray at a rate of about 27 gallons of water per minute at a pressure of 40 pounds per square inch, and outside air was drawn into the water spray by means of a fan mounted on the same shaft with the spray pump. Some condenser water was lost by evaporation and was resupplied by the water tank (j) located overhead, and through an automatic float control valve at the tower (k). Under worst conditions, a loss of 10 to 12 gallons of water per hour were experienced.

Now reconsider the evaporator (i). Due to the expansion of the ammonia through this tank the temperature of the water in the pipe coils of the tank was reduced and the pump (h) delivered the chilled water from the evaporator (i) to the cooling coils (b), and thence around again to complete the cycle.

The thermal control (o) prevented the temperature of the evaporator from going so low that the water in the cooling coils would freeze. This valve controled the back pressure valve (r). As the compressor continued to run, local circulation continued through the by-pass valve as shown on the compressor (n). If for some reason the pressure on the discharge side would rise beyond a certain point, a safety switch disconnected the motor through a relay.



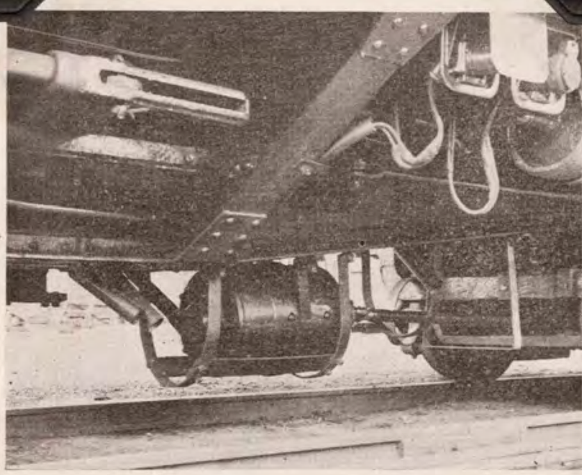



Fig. 9
10 K.W. 110 Volt Direct Current Gear Driven Axle Generator. Car 1036

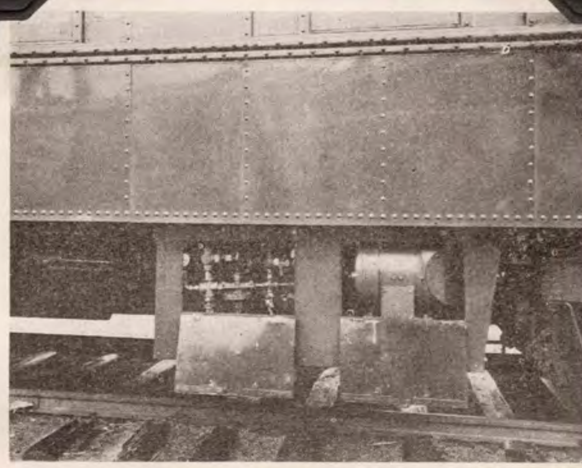


Fig. 10
Motor Driven Refrigerating Compressor, Located Beneath the Floor of Car 1036

Fig. 12
Overhead Bronze Grills Concealing the Automatically Controlled Air Recirculating Dampers. Pantry End. Car 1036

Power was supplied by a 10 K.W. 110 volt direct current gear driven generator (Fig. 9), operating above a critical speed of 28 miles per hour with a gear ratio of 2.73 to 1. Provision was made for receiving power from a wayside connection when the car was standing at stations or in yards.

The fan (c) and the cold water pump (h) were later changed to operate from the regular car lighting batteries at 32 volts, direct current, and the 4 kilowatt belt driven axle generator was replaced with a 5 kilowatt gear driven generator. This enabled the circulation of air and cold water when the car was standing still or moving slower than 28 miles per hour.

When the car speed reached 28 miles per hour, an automatic switch closed on the 110 volt generator. The various motors were automatically started through automatic controls until the car speed declined below the critical speed. A voltage regulator kept the voltage below 115 volts at higher speeds.

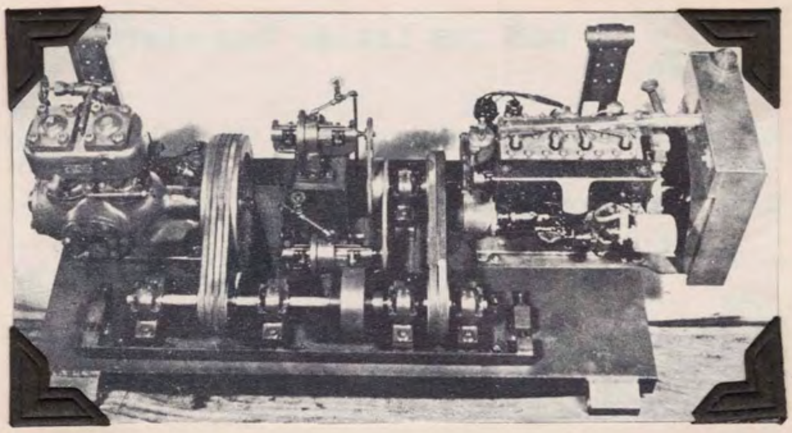
Figure 8 shows the electrical diagram of the control. The compressor motor will start first, followed by the condenser motor pump and the cooling tower fan motor. Automatic protection was provided so that if any of the auxiliary motors failed to start the compressor was discontinued, and a light signal was given the steward of the car.

The cold water pump and motor driven fans were subject to manual control. The control circuit was so interlocked that the compressor and its auxiliaries could not be operated unless the fans and cold water pump were running.

## SUBSEQUENT DEVELOPMENTS

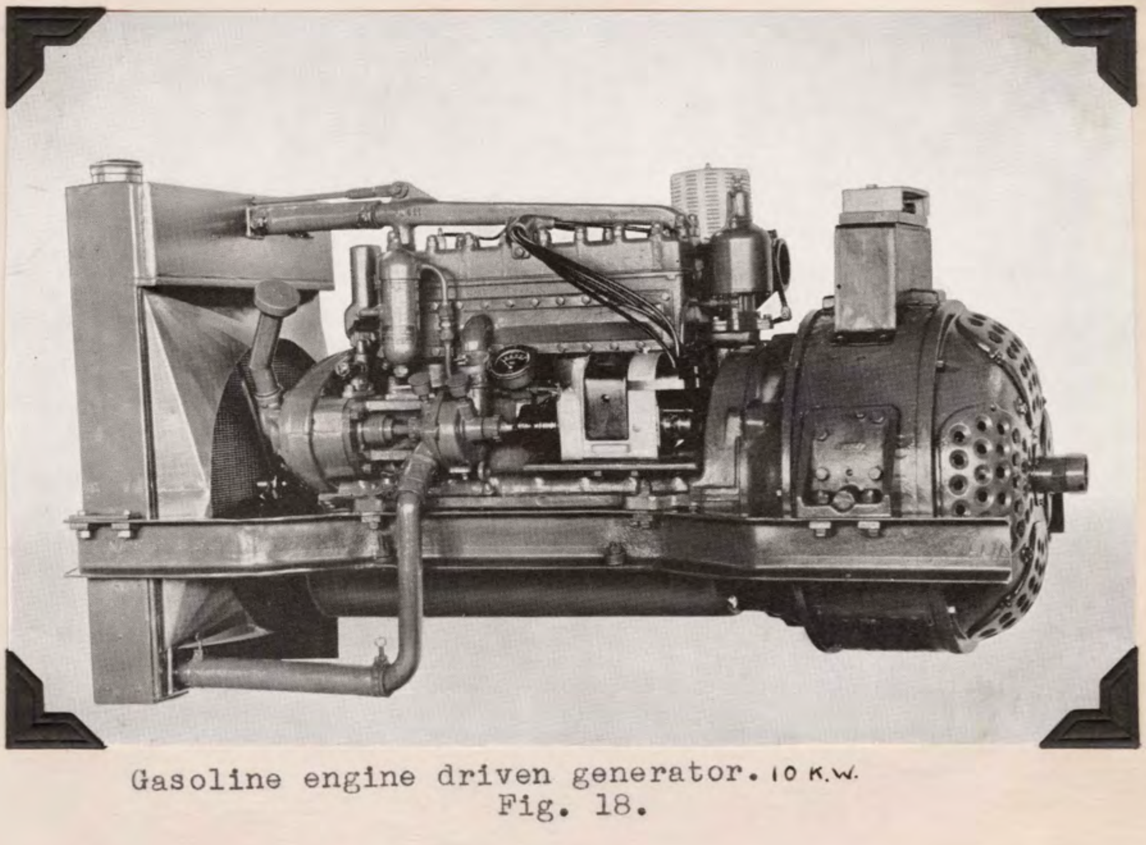
This equipment was removed the next season (1931) due to the fact that it was too dependent upon the speed of the train. Experiments were made with bulky electric storage batteries. Another scheme considered was a "central system" with the mechanical equipment installed in a forward coach. These developments showed a need for an independent reliable source of power. Several means were considered: a small steam engine in each car, Diesel engine and finally gasoline engine drive. In the subsequent season two types of gasoline installations were made. In one, the gasoline engine drove a generator, and in the other it drove the compressor and the pumps directly from a counter-shaft. (See Figs. 17, 18 page 25) Also, brine was substituted for water in the cooling unit. These systems operated successfully the whole season.

During the summer of 1931, the Kinetic Chemical Co., Inc., a subsidiary of E. I. Dupont de Nemours announced the developement of a new gas which was very superior to ammonia as a refrigerant. This gas is dichloro-difluro-methane, known as Freon or F-12. This gas is colorless, odorless, non-corrosive, non-combustible, and non-inflamable, as well as non-toxic in relation to health. This meant that it was now possible to expand the refrigerant directly into the cooling unit usually located in the upper deck of the cars, and to eliminate the necessity of the brine-cooling tank under the car, and the pump for circulating the brine. It was now able to increase the cooling capacity fifty per cent and at the same time reduce the power

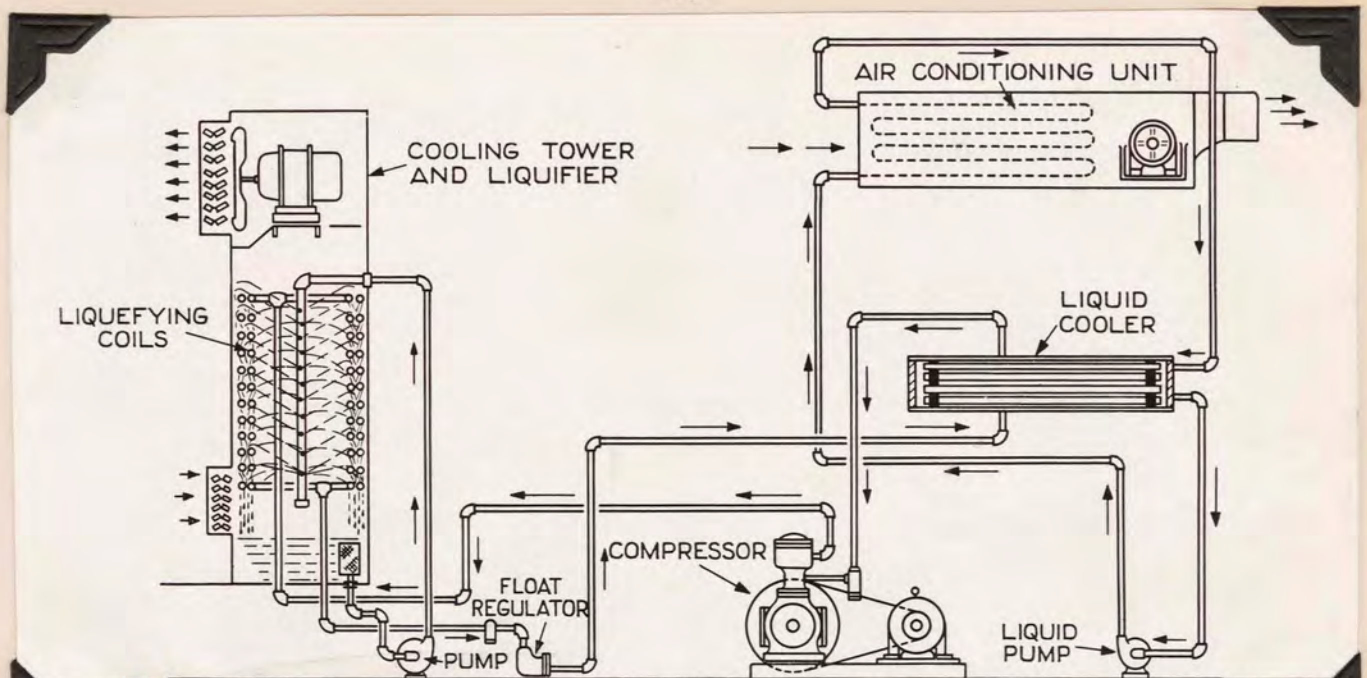


Gasoline engine driving compressor and
pumps through counter-shaft.

Fig. 17

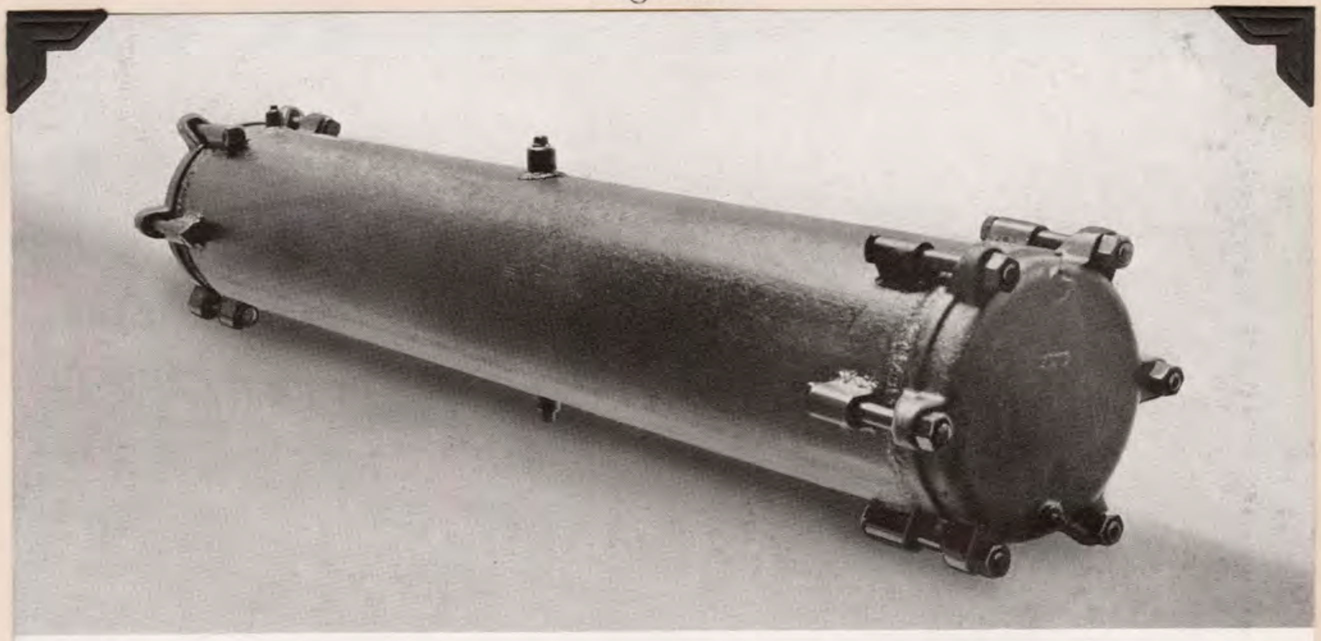


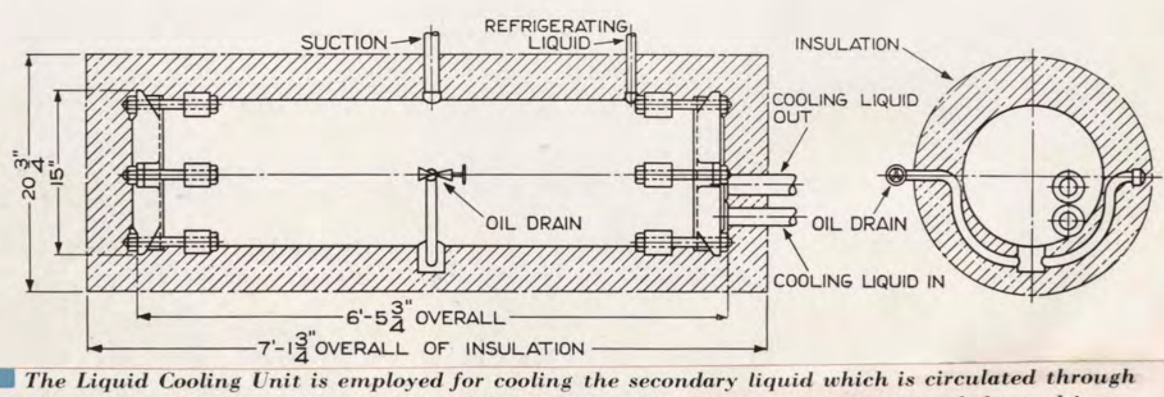
Gasoline engine driven generator. 10 K.W.
Fig. 18.




*Schematic diagram of the York Air Conditioning System for passenger cars. This diagram illustrates not only the closed refrigerating cycle but also the secondary liquid circuit and the cooling water circuit.*

Fig. 19






*The Liquid Cooling Unit is employed for cooling the secondary liquid which is circulated through the air conditioning unit. The unit is York heavy duty shell and tube construction, of the multi-pass type. Dimensional drawing of Liquid Cooling Unit is also included.*

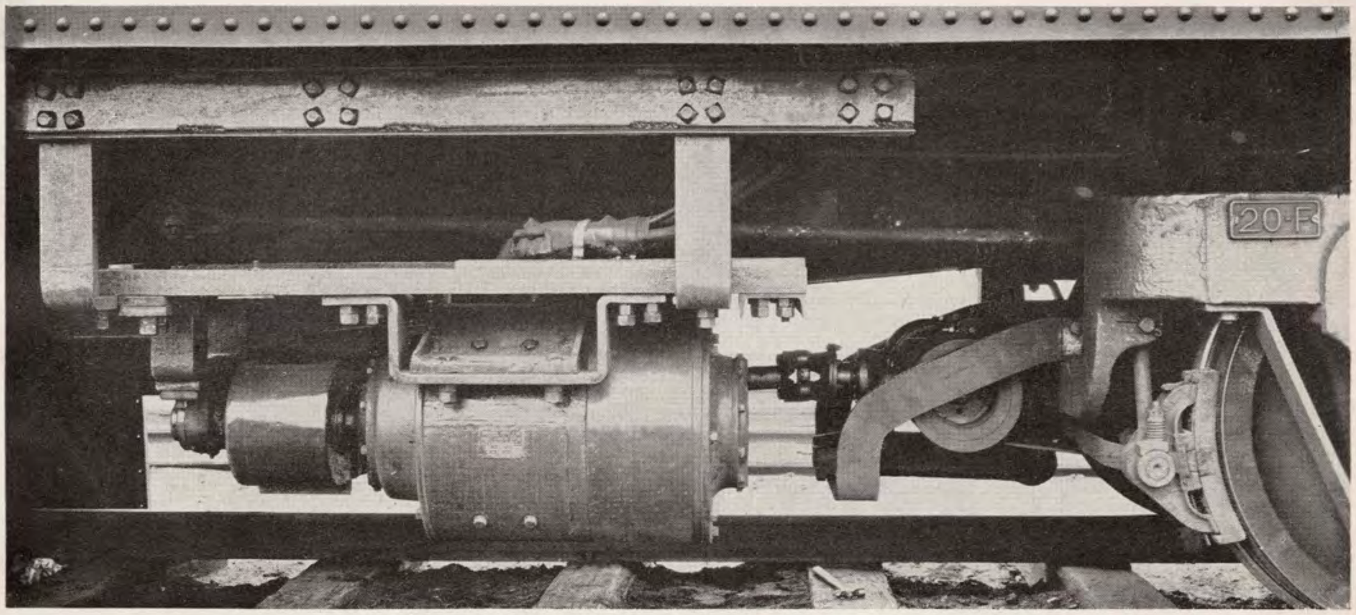
Fig. 20

needed. It also made it possible to reduce the time necessary for pre-cooling the car previous to dispatchment of the train. It had previously been necessary to turn off the compressor when in tunnels due to the possibility of the ammonia fumes getting in the car. This was no longer necessary. This discovery has helped greatly in solving the problems confronting the air conditioning of passenger cars.

About the same time, the Exide Storage Battery Co. announced the development of a high capacity storage battery which would take no more room than the old car lighting battery. This suggested that a generator might be developed that could be used with these batteries to supply all the needed power. The gas engine-driven power plant was a source of more or less unnecessary maintainance cost. This operated at 2200 RPM with full throttle for an average of 18 hours a day. The service obtained was remarkable, but the attention required to keep the unit going was troublesome.

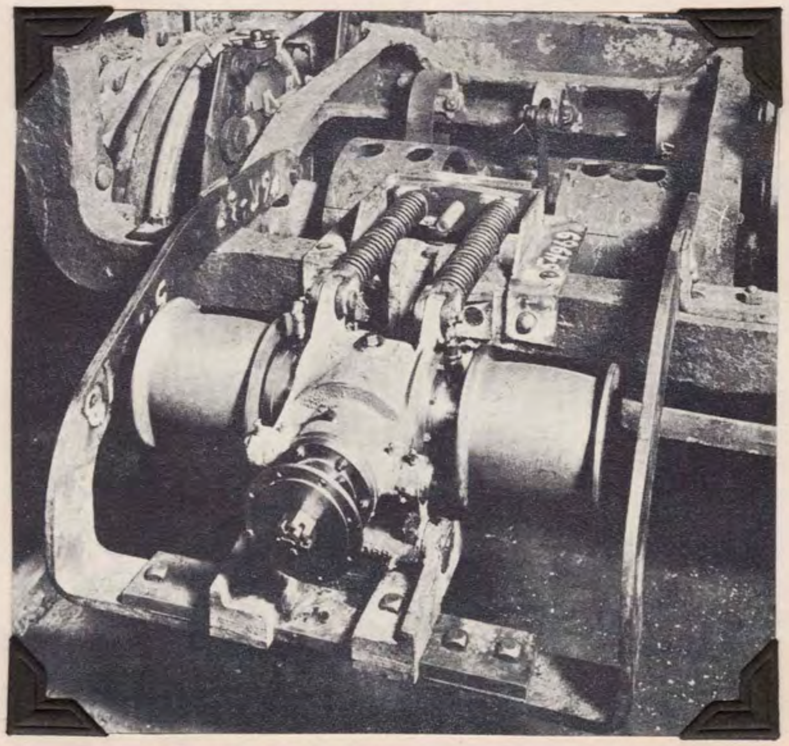
The elimination of the gas engine and the development of a generator to be used with the new batteries was solved by the development of a 7½ KW third brush type generator, driven by a special sturdy combination belt and gear drive from the car axle. (Fig. 21, 22) The maximum power requirement is from 150 to 160 amperes at 34 volts at condensing pressures from 120 to 135 pounds.

The third brush generator provides 235 amperes at 35 volts for a speed of 35 miles per hour, and 175 amperes at 35 volts at 75 miles per hour. At all times above about 20 miles




Axle Generator Which Supplies the Power for the Operation of the Air Conditioning Equipment

Fig. 21

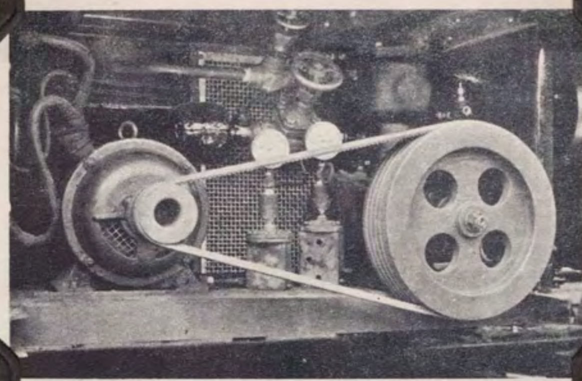


Belt pullies and gear box.
Fig. 22

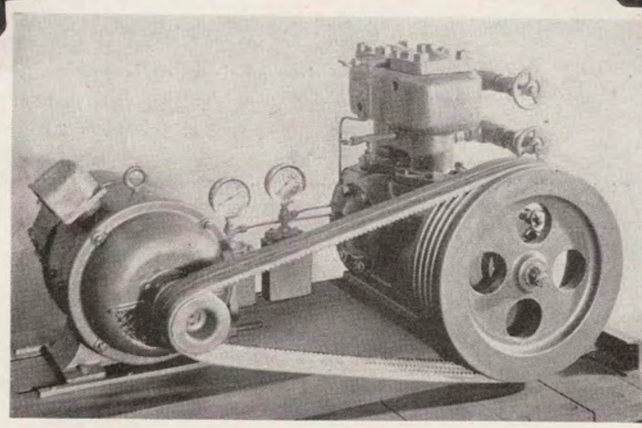
per hour the generator furnishes sufficient current for operating the cooling system and for keeping the batteries charged. The output is good at as low speeds as 20 MPH, and is regulated solely by the position of the third brushes, no other regulator being necessary.

The design of the compressor was changed slightly for use with the Freon, and a description is herewith given of the compressor which has been used since that time. It is a two cylinder 4" diam. by 3" stroke, single acting type, driven by a belt from a 5 H.P. direct current 36 volt motor, and operates at 400 to 425 RPM. This unit is mounted under the car in a small cabinet with removable sides, (Fig. 23). The tappet type valves of the earlier compressors were replaced by diaphragm type, located in the pistons. Splash lubrication is used with the oil reservoir in the crank case. These compressors have given good service for three seasons.

It is necessary to drain water from the cooling towers at the beginning of freezing weather. Since 1933, the condensers installed have been of the air cooled type, eliminating the water feature and permitting the system to operate in any season. Another feature of the air cooled condenser is that it may be mounted under the car, whereas the old water cooled condensers were mounted vertically in some space in the car. In most cases it was mounted on one side of the vestibule in what otherwise would be an entrance doorway. This was no disadvantage in diners or combination coaches, but in regular cars it eliminated one door in each car.

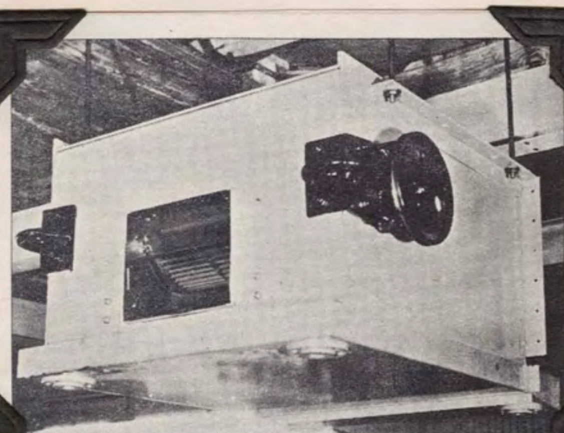


VIEW OF COMPRESSOR AND MOTOR



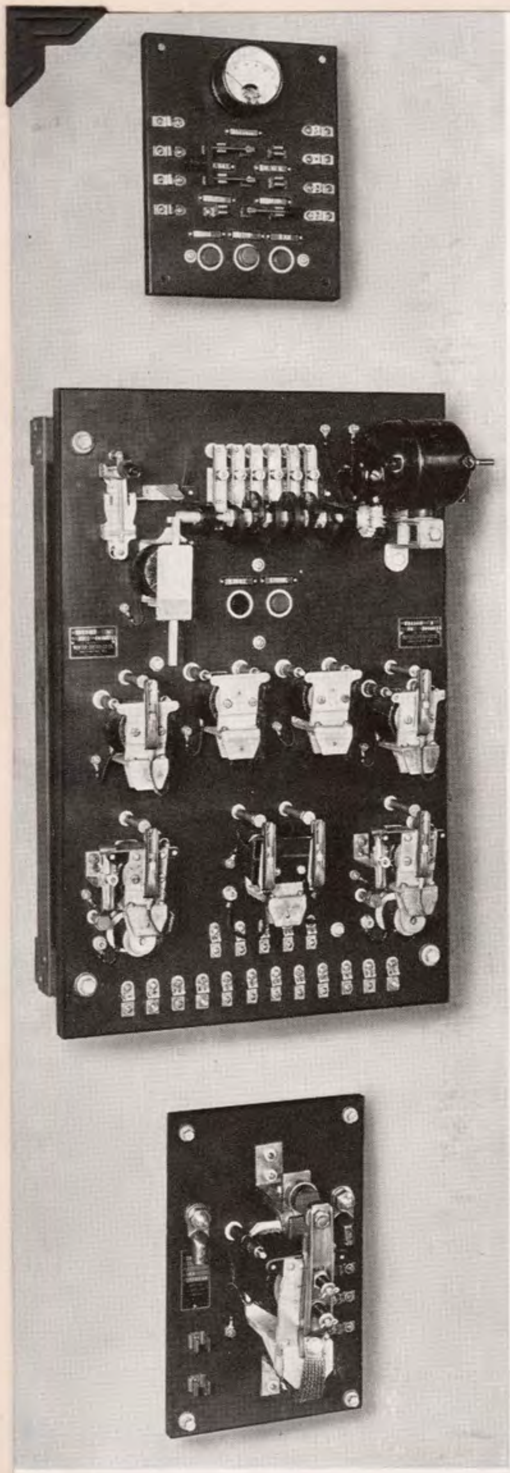
Motor-Driven Compressor Designed For the Freon (F-12) Refrigerant—The High- and Low-Pressure Cutouts For Starting and Stopping the Motor Are Shown Between the Motor and Compressor

Fig. 23



AIR CONDITIONING UNIT

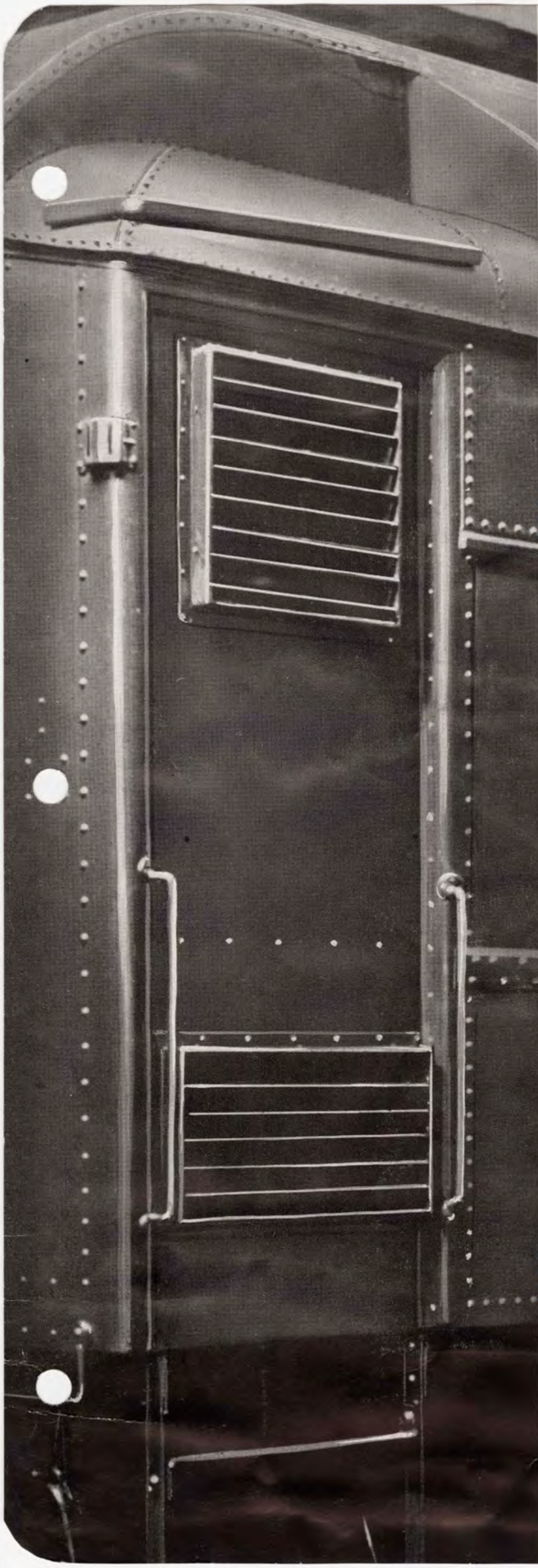
Fig. 24



# THE ELECTRICAL CONTROL PANELS

The Electrical Control Panels permit the operation of the entire equipment from button control. The "stop," "start" and "run" push buttons, easily accessible in the control cabinet, make the starting and control of the equipment as easy as turning on and off the lights in the car. A selector switch is also provided in order that air conditioning and fan equipment may be operated without refrigeration for Spring and Fall weather conditions.

Here, again, York has simplified the control mechanism as much as possible and all portions of the system are so interlocked as to incorporate every possible safety feature.



At left, the York Condensing Cooling Tower unit consists of a water spray chamber designed to fit the space available on the platform or within the body of the car.

Below, dimensional drawing of the York Condensing Cooling Tower unit.

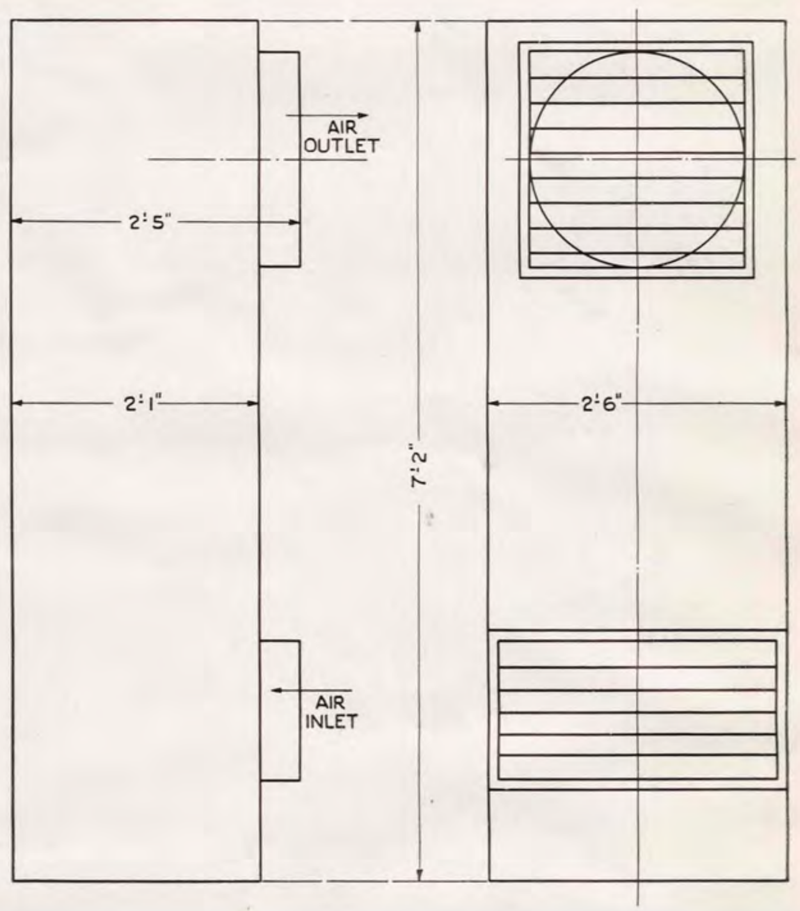
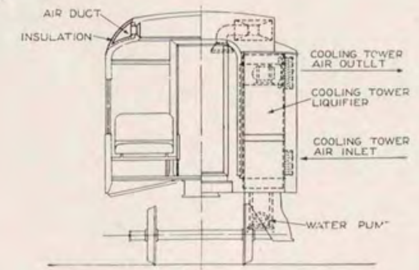
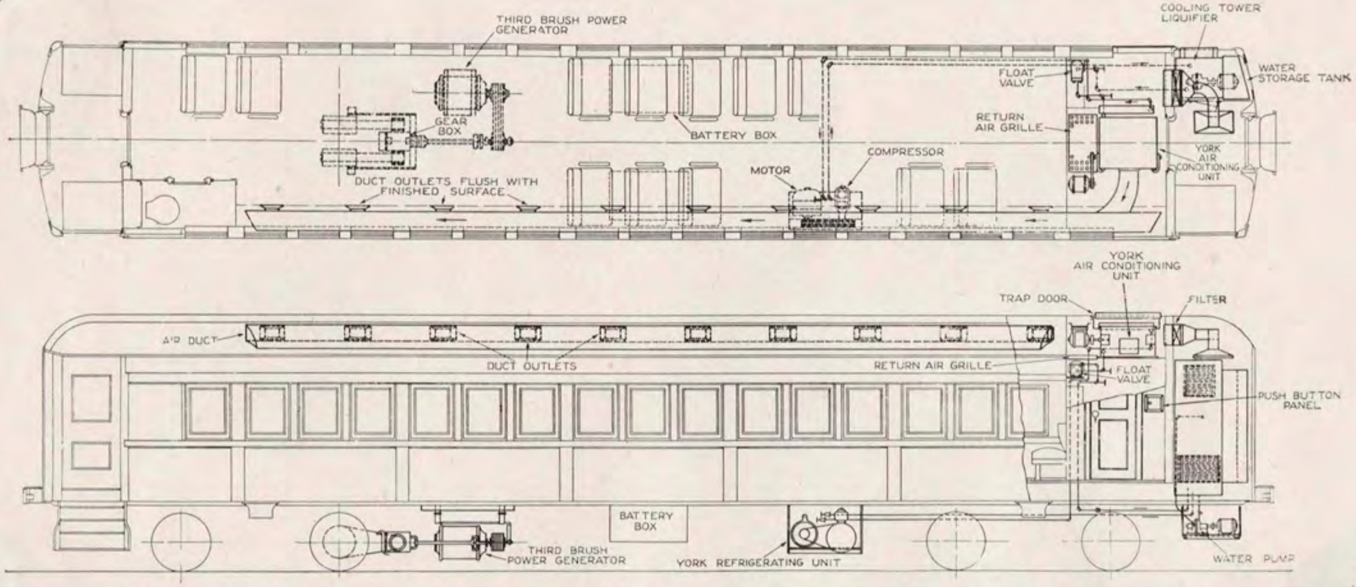


Fig. 25




Plan and Elevation Showing the Location of the Air Conditioning Equipment in a Typical Railroad Coach

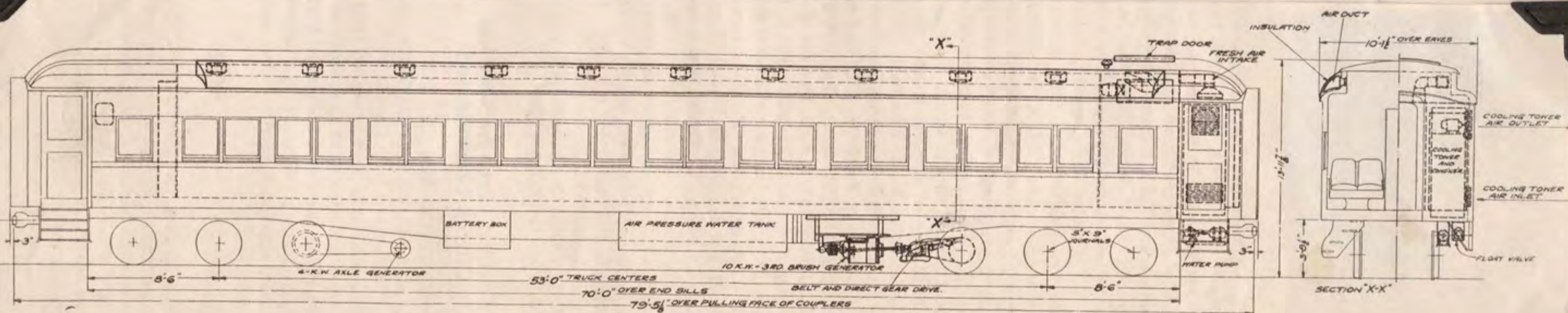



DIAGRAM SHOWING LOCATION OF ALL THE AIR-CONDITIONING EQUIPMENT ON ONE OF OUR STANDARD COACHES

In 1933, there was developed a $7\frac{1}{2}$ K.W. capacity voltage control generator similar to the standard car lighting generator. It uses the same drive as before and furnishes sufficient current to operate the air conditioning equipment. However it requires a voltage regulator which is not needed with the third brush generator. Both types are now being used.

At the beginning of the 1934 season, the B. & O. had accumulated over 21,000,000 car miles with their 149 air conditioned cars, and the Alton over 1,070,000 miles with their 16 cars. There was a total of 38 failures in which case it became necessary to raise windows and open ventilators. This makes 247,322 miles per failure on the B. & O. The Alton didn't have a single failure.

During 1934 only minor changes are being made in the installation. They are mainly a center duct installation with the air conditioning unit at the end of the car in the clerestory, and the return air grille tubing units are in the false ceiling under the unit. The fresh air is obtained from the vestibule of the car.

The electric control panel and the cooling tower are pictured on pages 31 and 32 . The complete plan of the air conditioning equipment is shown in Figure 25 page 33.

## HEATING

Experiments have been made in an attempt to heat through the same air conditioning system, using steam heating coils in the air conditioner. To date very little actual service has been gotten from these units, and no definite conclusions can be drawn regarding their practicability. Tests on the B. & O. show that it is difficult to make the thermostats operate properly in these units, and difficulty was also experienced in that heat tends to rise anyway, and so heat added to the top of the car tended to remain there and cause the floor to be cold.

During the last year, the B. & O. engineers developed a heating thermostatically controlled steam heater unit, and a humidistat which automatically controls the humidity to be added to the controlled admisture of inside and fresh outside air. This system has proven that a car can be so heated to provide maximum comfort for passengers during the winter just as the cooling system provides maximum comfort during the summer. The car provided with an air conditioning system in conjunction with the new heating system should provide satisfactory service the year around, especially on trunk lines that are subject to extreme temperature changes during a single trip. The apparatus should be so arranged that in the spring and fall, both systems would operate automatically and not depend upon a car attendant to control the car temperatures. More experimenting will be done along this line, and this will probably be the next development in railroad transportation after speedier service has been provided.

## IV. COST

Contrary to the general belief the cost of air conditioning a passenger car is not excessive. The table below shows how small an increase in passengers per car will completely pay all fixed and operating costs for the equipment. The value to the railroads may be realized by considering that every railroad in the country that has put in air conditioning has reported an increase in passenger traffic since doing so.

NUMBER OF PASSENGERS PER CAR PER RUN REQUIRED TO PAY ALL CHARGES

| Length of Run Miles | *Total Fixed and Operating Costs Daily | Fare Per Run | Increase in No. of Passengers Per Car Required to Equal Fixed and Operating Costs |
|---|---|---|---|
| 100 | $6.60 | $3.60 | 1.83 |
| 200 | 6.85 | 7.20 | .95 |
| 300 | 7.13 | 10.80 | .66 |
| 400 | 7.42 | 14.40 | .51 |
| 500 | 7.70 | 18.00 | .43 |

*Including interest and depreciation on investment.

These figures have been figured on an average cost per car for the air conditioning equipment installed of $7,000.00. Most installations will be less than this, but on some special cars such as diners and business cars the cost will be higher. The life of the equipment was conservatively chosen as 10 years, although it should last longer. $50.00 per year has been included for replacements, oil, additional refrigerant, etc. It has been assumed that the operating period will be for 150 days. The slight cost of the equipment can be seen from the above table, and it is obvious how slight an increase in traffic will make the installation worth while. It can also be seen how the length of run decreases the cost. It is reasonable to expect at least two additional passengers a day on a hundred mile run, or one additional passenger every two days on a five hundred mile run. All additional traffic obtained above these will be clear profit to the railroad company.

It might be interesting to note at this time that most of the first cars equipped with air conditioning were diners. The effect on the railroad's revenue was opposite to what was desired. It was found that people had a tendency to linger over their food for a longer time, and usually congestion occured and fewer people could be served. One or two air cooled cars on a train did not materially increase traffic. However, when whole trains were so equipped, it was extremely apparent how business increased. On one railroad (The Chesapeak and Ohio), passenger traffic has increased 600 per cent since installing air conditioning in their trains.

## V. COMFORT

The purpose of the air conditioning system is, of course, to provide comfort for the passengers. There have been set up a definite standard for comfort conditions. These standards take the form of so-called "Effective Temperatures." This is an index of the degree of warmth or cold felt in response to temperature, humidity, and air motion. These all have a definite relation to the ability of the body to rid itself of heat by radiation, convection, and perspiration. All combinations of temperature, humidity, and air motion which produce the same bodily sensations are of the same effective temperature.

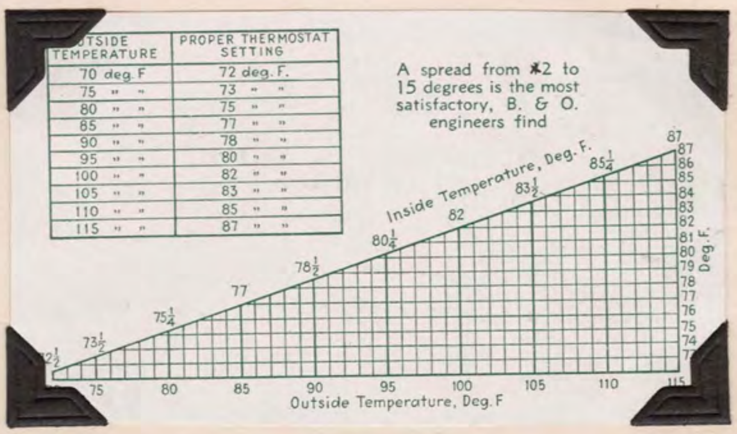
Besides the above relations, there is also a change in optimum effective temperature, which takes place with changes in outside air conditions. During summer operation of the air conditioning system, there are different desirable inside conditions corresponding to various outside conditions. The maintenance of a definite inside temperature throughout the summer would be equally absurd.

The following table shows outside temperature, inside temperature recommended by A.S.H.V.E. and the inside temperature actually found satisfactory in cars.

| Dry Bulb | Inside Dry Bulb Recommendations | Conditions Observed |
|---|---|---|
| 100° | - | 83° |
| 95° | 80.0° | 83° |
| 90° | 78.0° | 81° |
| 85° | 76.5° | 79° |
| 80° | 75.0° | 77° |
| 75° | 73.5° | 74.5° |
| 70° | 72.0° | 73° |

The above inside temperatures are higher due to the fact that the car ran lower humidities. A.S.H.V.E. standards are based on humidities of 50-60%.

The chart below shows what temperatures are maintained within the cars, and shows the 2 to 15 degree spread that has been found most satisfactory. A relative humidity between 40% and 60% will give comfort, but on the B. & O. it is held within a few percent of the 50% mark.




It is well known how fine dust tends to creep into even a tightly closed room. This is even lacking in the air conditioned railroad car, due to the fact that the air in the car is under a slight pressure as compared with outside air. Hence, rather than dust coming in, it tends to be kept out.

It should also be noticed that due to the windows being kept closed, noise has been reduced 50% to 75%.

The advantages of air conditioning may be summed up as follows: The passengers are given a comfortable atmosphere that is free from dust, cinders, and smoke. The temperature and humidity are nicely balanced and controlled. Here you have a pleasant and healthful climate and a great reduction of noise as an added attraction. All this has been accomplished without a single increase in fares.

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Some time was spent in Baltimore in an attempt to get some information from the B. & O. Railroad. The writer went to several offices and to the Mt. Clare Shops, but was unable to get any first-hand information at all. He was told everywhere that the information was not known in that office, or that it could not be given out. He was also refused permission to take any photographs. Finally a reproduction of a magazine article was obtained, but it contained no pictures.

The writer wishes to state his appreciation to the secretary of the Engineers Club of Baltimore for information and copies of the "Baltimore Engineer." Almost all of the earlier pictures were obtained from this source.

The writer also wishes to state his indebtedness to Mr. J. S. McCollam of the York Ice Machinery Corporation of York, Pa., for his very helpful letter and the excellent phamphlets he sent.

Finally, recognition is made to Mr. Edmund Freeman, Librarian of the Bureau of Railway Economics in the Transportation Building in Washington. This library is the most complete in America on railroad matters and the magazine articles above listed were read from the stock of this library.