

Oct. 1, 1940.

W. J. MADDEN

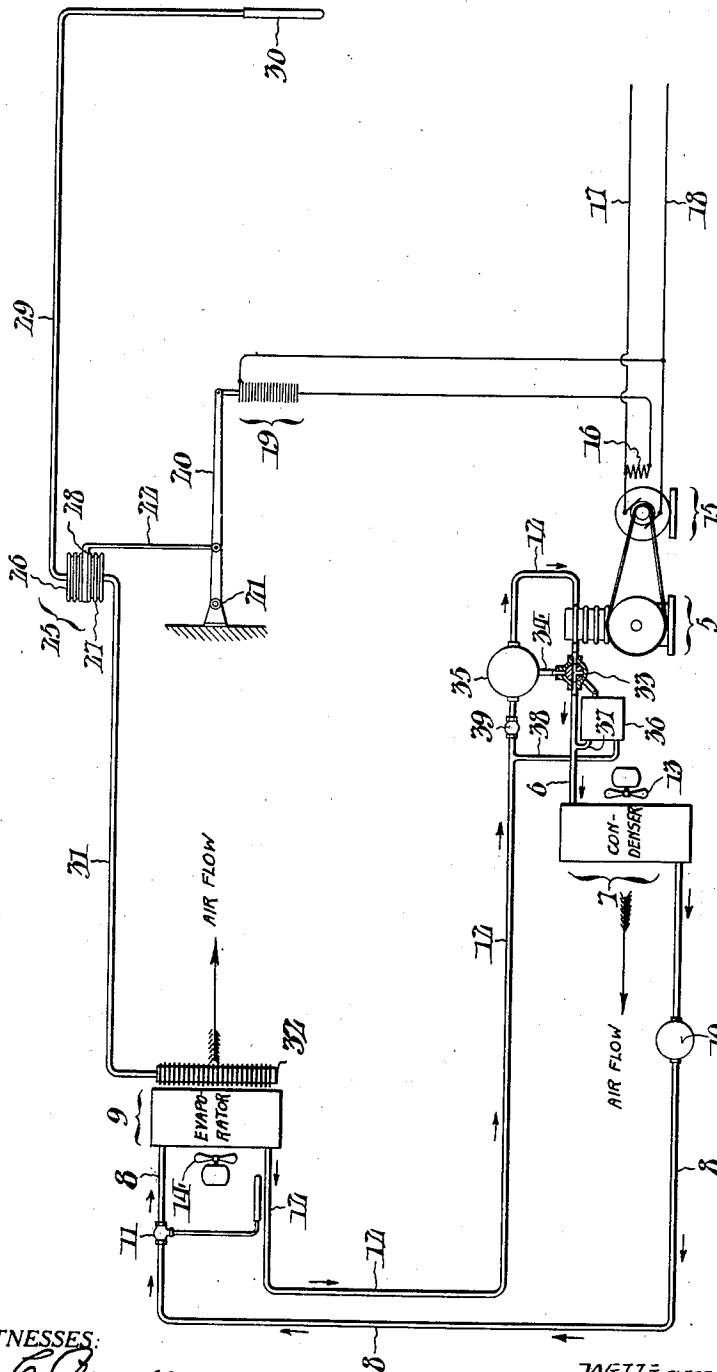
2,216,690

AIR CONDITIONING APPARATUS AND METHOD

Filed Dec. 7, 1936

4 Sheets-Sheet 1

FIG. 1.



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FIG. II

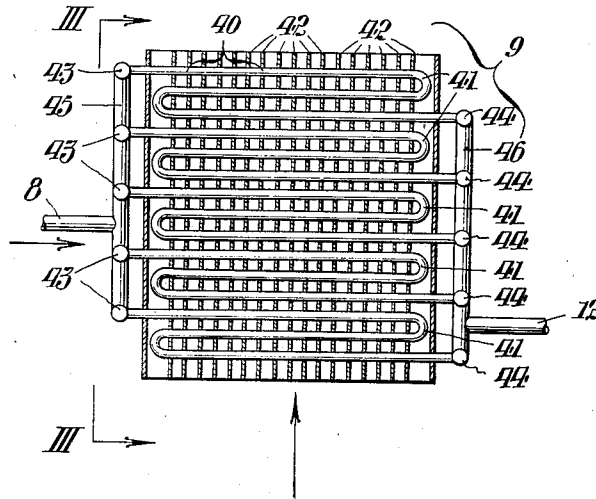
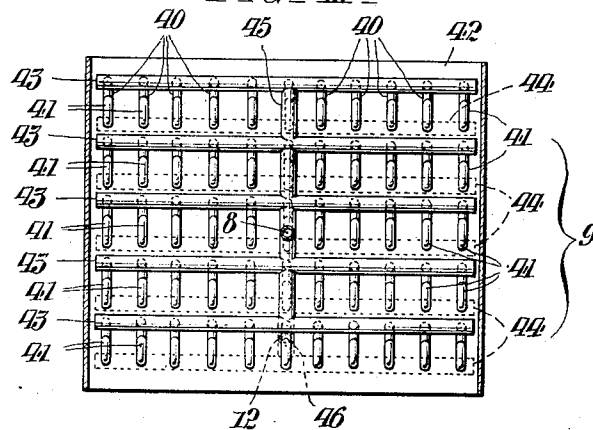


FIG. III



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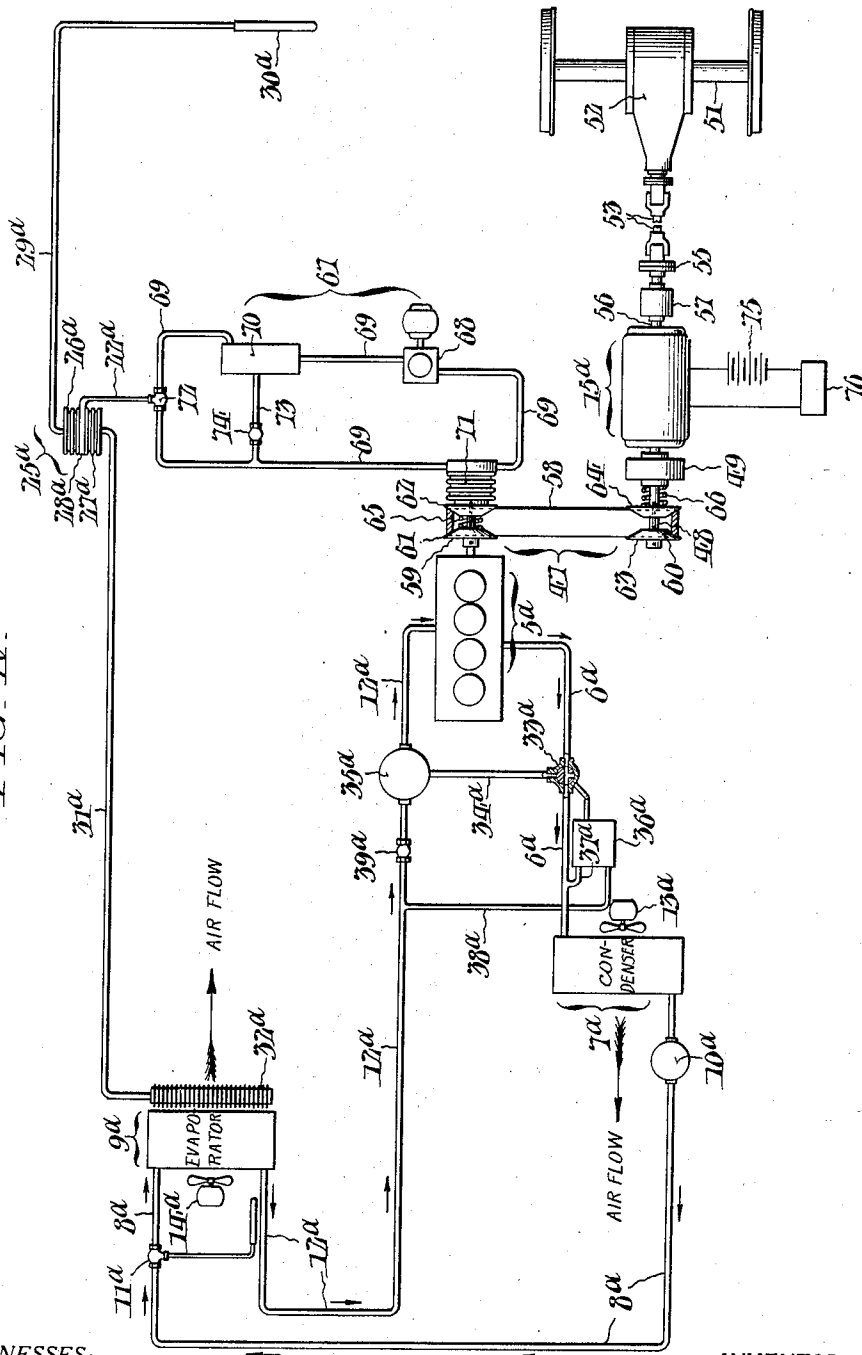
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4 Sheets-Sheet 3

FIG. IV.



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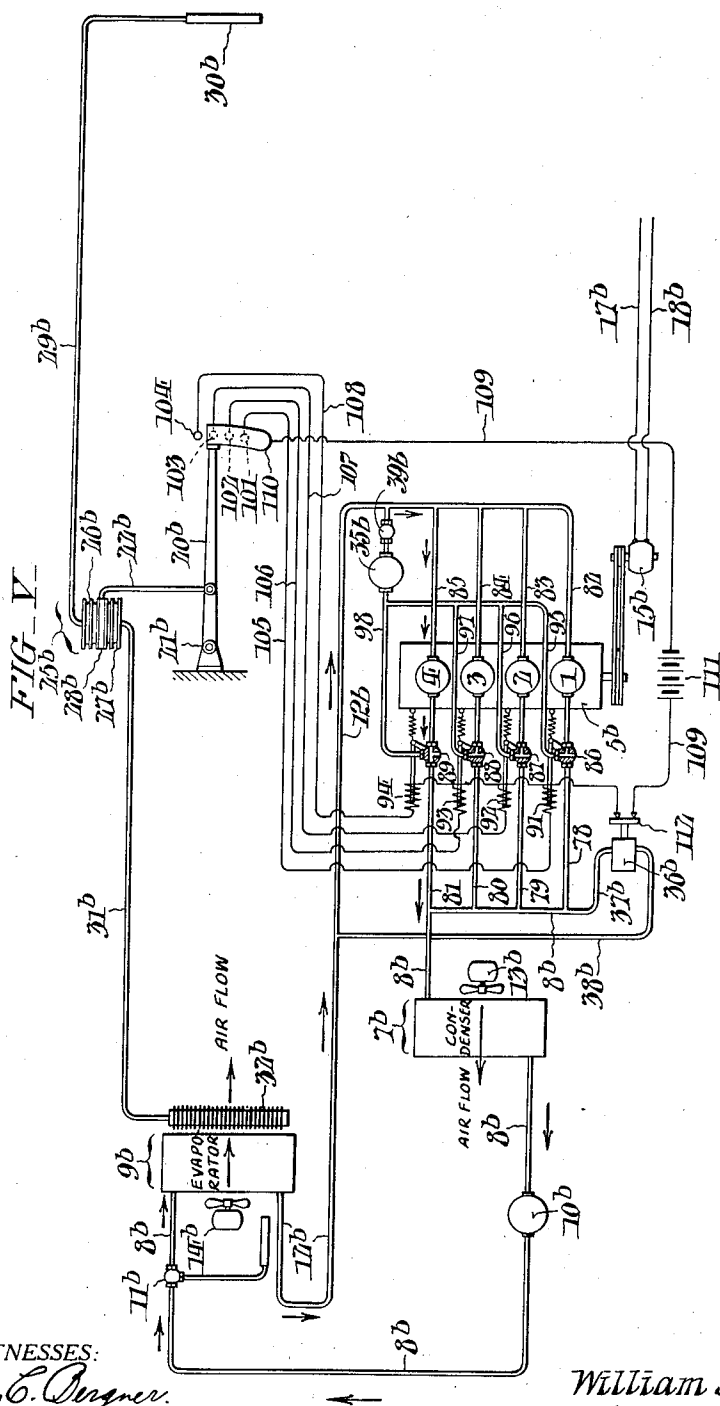
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AIR CONDITIONING APPARATUS AND METHOD

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,216,690

AIR CONDITIONING APPARATUS AND METHOD

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Application December 7, 1936, Serial No. 114,569

11 Claims. (Cl. 62—6)

This invention relates to apparatus and meth-
ods in which a compressible circulating refriger-
ant is utilized in a closed circulatory system
to condition the air within a railway car or other
enclosure intended for human occupancy; and
it has reference more particularly to mechan-
ical air conditioning apparatus and methods for
railway passenger cars.

With the usual forms of mechanical condi-
tioning apparatus for railway cars, a certain
amount of fresh air is admitted into the car at
all times, and the compressor stopped and start-
ed automatically under control of thermostatic
means. During the "off" cycles of such appa-
ratus, considerable moisture is carried into the
car with the fresh air and to this is added the
moisture emanating from the passengers. The
excess moisture thus accumulated renders diffi-
cult the maintenance of a properly conditioned
atmosphere within the car. Moreover, with the
"off" and "on" types of control, the dry bulb
temperature "drifts" since a considerable inter-
val elapses between the time that the thermo-
stat functions and the time that the thermal
change is effective within the car, with attendant
causation of alternate warm and cool air cur-
rents. The frequent starting and stopping of
the compressor is moreover disadvantageous be-
cause of the excessive wear incurred and be-
cause of the high upkeep cost of the electric
instrumentalities which are essential to the con-
trol of the compressor.

My invention is directed toward overcoming
the above mentioned drawbacks of previous
practice, that is to say, I aim to make possible
the maintenance within a passenger car or other
enclosure intended for human occupancy at all
times, of a properly conditioned atmosphere as
regards both temperature and humidity which
is consistent with external atmospheric changes.
This objective I realize, as hereinafter more
fully set forth, through provision of a simple
and efficient method and economically operative
automatic apparatus wherein the compressor is
continuously run and its functioning controlled
to vary the rate of circulation of the refrigerant
by modulation dependent upon variations in the
differential between the temperature of fresh
air constantly admitted into the car and the
temperature of the atmosphere within the car,
which atmosphere is maintained in constant cir-
culation by suitable means embodied in the ap-
paratus.

Other objects and attendant advantages will
appear from the following detailed description

of the attached drawings, wherein Fig. I is a
diagrammatic view of a mechanical air condi-
tioning apparatus conveniently embodying my
invention in one form, and suitable to the prac-
tice of my new method.

Fig. II is a vertical sectional view through an
evaporator forming one of the elements of the
apparatus.

Fig. III is a view of the evaporator looking
as indicated by the arrows III—III in Fig. II,
with the end wall nearest the observer removed.

Fig. IV is a view corresponding to Fig. I show-
ing an alternative form of my improved air
conditioning apparatus; and

Fig. V is likewise a view similar to Fig. I show-
ing another alternative form of apparatus.

Referring first to Fig. I of these illustrations,
the air conditioning apparatus there diagram-
matically shown includes a high-speed compres-
sor 5 which delivers through a pipe 6 to a con-
denser 7. Interposed in a pipe 8 leading from
the condenser 7 to an evaporator 9, is a liquid
receiver 10 and an expansion valve 11 of a suit-
able commercial type. By means of a return
pipe line 12, the vaporized refrigerant is con-
ducted from the evaporator 9 to the compressor
5. A motor driven fan 13 is employed to circulate
outside over the condenser 7. Another mo-
tor driven fan 14 constantly circulates the air
within the enclosure or car over the evaporator
9. It is to be understood, of course, that in ac-
tual practice the elements thus far described
are all suitably allocated for cooperation in a
well-known manner.

For the purpose of automatically controlling
the refrigerating system of the apparatus to
maintain a properly conditioned atmosphere
within the enclosure or car, I have made pro-
visions which, in this instance, include a con-
tinuously operating electric driving motor 15 for
the compressor 5, said motor having a shunt
field winding 16 and receiving current through
conductors 17 and 18 from a suitable source of
supply, not illustrated. Connected in series with
the shunt field winding 16 of the motor 15 is a
carbon pile 19 which is subject to the pressure
of a lever 20 fulcrumed at 21, and actuated,
through a rod 22 by a differential thermostat
comprehensively designated 25. As conven-
tionally shown, the thermostat 25 comprises a
pair of syphon bellows 26 and 27 which react
oppositely upon a member 28 to which the rod
22 is connected, the bellows 26 being in com-
munication, by way of a tube 29, with a bulb 30
in the path of fresh air admitted into the en-

closure or car from the outside through a suitable opening (not shown) and containing a thermally sensitive volatile fluid. The bellows 27, on the other hand, is in communication, by way of a tube 31, with a bulb 32 positioned in the path of the air emanating from the evaporator within the enclosure or car and containing a similar thermally-sensitive volatile fluid. By virtue of this arrangement, it will be apparent that with modulation between the temperature of the incoming fresh air and the temperature of the air circulated within the car, the thermostat 25 will cause the lever 20 to be moved downwardly or upwardly to increase or decrease the pressure on the carbon pile 19. As a consequence, the resistance in the field circuit of the motor 15 will be correspondingly increased or decreased to vary the speed of the motor 15 and in turn that of the compressor 5, with attendant variation in the amount of the refrigerant circulated through the refrigerating system. In this way, it will be seen that I am able to maintain a conditioned atmosphere within the car, the temperature and moisture characteristics of which are predeterminable by proper proportioning of the parts embodied in the thermostatically-actuated means whereby the modulated control is effected.

In the event of excessive discharge pressures or low suction pressures, the apparatus is protected against injury through automatic actuation of a three way valve 33 in the pressure line 6 which leads from the compressor 5 to the condenser 7, so that the refrigerant is shunted through a cross pipe 34 connecting into an equalizing chamber 35 interposed in the suction line 12. The operating lever of the valve 33, it will be noted, is coordinated with a suitable high-low pressure device conventionally represented at 36 which is in communication with the pressure and suction lines 6 and 12 by way of pipes 37 and 38. A check valve 39 automatically shuts off the suction line 12 when the valve 33 is operated by the device 36 so that the flow of the refrigerant from the compressor is diverted directly into the equalizing chamber 35.

In order that the maximum efficiency may be attained in a mechanical refrigerating system controlled under the above principle, I employ an evaporator 9 of the construction diagrammatically illustrated in Figs. II and III. In the evaporator 9, the coils 40 are composed of units 41 arranged one above the other with continuous parallel fins or moisture collecting plates 42 mounted on these tubes. As shown, the opposite ends of the coil units 41 are connected to horizontal headers or manifolds 43, 44 which are in turn intercommunicative by way of vertical manifolds 45, 46, the pressure and suction line 8 and 12 being respectively connected to said vertical manifolds at the levels indicated. During operation of the apparatus with the compressor 5 running at slow speed the correspondingly small amount of refrigerating medium being circulated will pass, say through the lowermost section 41 of the coils 40 only instead of through the whole of said coils as would be the case with evaporators as ordinarily constructed. By thus segregating the flow of the refrigerating medium, an effective thermal exchange is assured between said medium and the air passing through the evaporator notwithstanding the reduced flow. With increased circulation of the refrigerating medium as the compressor is speeded up, the additional flow will be accommodated successively

by the horizontal coil units at the higher levels of the evaporator until the maximum load is reached when all the coils will be traversed.

In the alternative embodiment of my invention illustrated diagrammatically in Fig. IV, the compressor 5a is constantly operated, through a variable speed drive 47, from the shaft 48 of a speed reducing unit 49 which is coordinated with a motor (generator) 15a in turn driven by a "Spicer" or similar drive from one of the wheel axles 51 of the car. As shown, this drive includes a speed multiplying unit 52 on the car axle 51, and a propeller shaft 53 which is coordinated, through an automatic clutch 55 with the shaft 56 of the motor (generator) 15a. At 57 is conventionally indicated the exciter for the motor (generator) 15a. The variable speed drive 47 is shown as being of the type wherein a bevel edged belt 58 connects a pair of laterally adjustable pulleys 59, 60 one of which is in this instance mounted on the compressor shaft, and the other on the shaft 48 of the speed reducer 49, said pulleys comprising opposing cone components 61, 62 and 63, 64 respectively. The cone component 61 of the pulley 59 is fixed on the compressor shaft, while the opposing component 62 is slidable axially on said shaft and yieldingly urged away from the component 61 by an interposed coiled compression spring 65 surrounding the shaft. Similarly, the cone component 63 of the pulley 60 is fixed to the speed reducer shaft 48 and the opposing component 64 is axially shiftable on said shaft but yieldingly urged toward the component 63 by a spring 66. Here, as in the first described embodiment of my invention, the capacity of the compressor 5a is automatically varied for maintenance of a properly conditioned atmosphere within the car under the control of a differential thermostat 25a, which, through a fluid pressure system comprehensively designated 67, governs the variable speed drive 47. In the system 67, the pressure fluid is continuously circulated by a motor driven pump 68 through a closed circuit defined by piping 69 in which is interposed a reservoir 70, a syphon bellows 71 whereof the movable end bears against the shiftable component 62 of the pulleys 59, and a by-pass valve 72 which is directly actuated by the differential thermostat 25a. The building up of abnormally excessive pressures within the system 67 is prevented by diversion of a portion of the fluid flow through a cross pipe 73 in which a relief valve 74 is connected. At all train speeds above the cut-in speed of the automatic clutch, the compressor 5a will be driven directly from the wheel axle 51 while at station stops or slow train speeds, it will be driven by the compressor motor which at these times will receive current from a battery indicated at 75, under control of an automatic switch 76. Thus the motor (generator) operates as a motor to drive the compressor 5 during station stops and as a generator to charge the battery 75 while the car is in motion. In order to preclude the necessity for repetitive description, those elements not specifically referred to in Fig. IV but having their counterparts in the first described embodiment, are identified with the same reference numerals previously employed, with addition however in each instance, of the letter "a" for the purposes of distinction.

Obviously with the alternative arrangement of Fig. IV, the actuation of the by-pass valve 72 by the differential thermostat 25a will result in

increase or decrease of the fluid pressure within the system 67, so that through cooperation of the bellows 71 and the spring, the component 62 of the pulley will be moved toward and away from the companion component 61 with attendant compensative movement of the component 64 of the pulley 60 to correspondingly alter the speed of the compressor. The described arrangement is moreover capable of compensating for the different speeds at which the motor (generator) is driven from the car axle. In the alternative form of my invention illustrated in Fig. V, the compressor 5b is driven at substantially constant speed by an electric motor 15b, and the refrigerating capacity varied to suit the demands for cooling by progressively unloading the cylinders of said compressor and vice versa. For convenience, I have shown a compressor 5b with four cylinders designated 1-4, having their discharge outlets connected to the pressure line 8b by branch pipes 78-81 respectively, and their inlets connected with the suction line 12b by branch pipes 82-85. Interposed in the branch pipes 78-81 are three way valves 86-89 which are adapted to be operated against spring action by solenoids 91-94, and which are connected by branch pipes 95-98, with the suction line 12b. As shown, the corresponding terminals of the solenoids 91-94 are individually connected to contacts 101-104 by conductors 105-108, while their other terminals are connected in common by a conductor 109 with a switch plate 110 at the end of the thermostatically actuated arm 20b, adapted to overtravel said contacts. The current for energizing the solenoids 91-94 is supplied by a battery 111 interposed in the conductor 109 together with a switch 112, which latter is arranged to be opened automatically by the high low pressure device 36b for unloading all the compressor cylinders for protection of the apparatus in case of excessive discharge pressures or low suction pressures. Here again, those elements in Fig. V which have not been separately referred to but which have their counterparts in the first described embodiment, are identified by the same reference numeral previously employed, but distinguished in each instance by addition of the letter "b." With the arm 20b in the position shown, only the cylinder 4 of the compressor 5b is effective in maintaining circulation of the refrigerant through the cooling system, the valves 86-88 being set so that the other cylinders 1-3 are unloaded and discharging into the by-pass pipes 95-97. As the requirements for cooling increase, the arm 20b is moved downwardly under the action of the differential thermostat 25b, and the other compressor cylinders progressively loaded in the order 2-3-1 by successive actuation of the valves 88, 87, 86. On the other hand, as the desired atmospheric condition is approached in the car, the cylinders of the compressor 5b will be progressively unloaded in the order 1-3-2-4 through reverse actuation of arm 20b by the differential thermostat.

The different cooperating elements particularly shown and described for convenience of illustration in connection with the organizations of Figs. I, IV and V are of course to be regarded as typical of others which may be substituted to perform analogous functions in my new method of air conditioning, without departing from the scope of my invention as defined in the appended claims.

Having thus described my invention, I claim:

1. The method of conditioning air in a railway car or other enclosure intended for human occupancy, with apparatus utilizing a multi-cylinder compressor to circulate a compressible refrigerant in a closed circulatory system, which comprises continuously operating the compressor, constantly admitting fresh air into the car, constantly circulating the atmosphere within the car, and governing the compressor by progressively loading and unloading its cylinders to vary the rate of circulation of the refrigerant in the system by modulation dependent upon variations in the differential between the temperature of the incoming fresh air and the temperature internally of the car.

2. In air conditioning apparatus utilizing a compressible refrigerant, a closed circulatory system with an interposed continuously-operating compressor; a condenser and an evaporator having vertically-manifolded horizontal sections in superposed relation; and means including a differential thermostat responsive to temperature changes externally and internally of an enclosure being conditioned, for automatically controlling the capacity of the compressor and, in turn, the rate of circulation of the refrigerant in the system.

3. In air conditioning apparatus for a railway car or other enclosure intended for human occupancy, utilizing a compressible refrigerant, a closed circulatory system with an interposed continuously-operating compressor; means for constantly admitting fresh air into the car; means for constantly circulating the atmosphere within the car; an electric driving motor for the compressor; a variable resistance means in circuit with the field winding of the motor; and means including a differential thermostat responsive to temperature changes in the incoming fresh air and the air internally of the car, for actuating the variable resistance to correspondingly vary the speed of the compressor motor and thereby control the rate of circulation of the refrigerant in the system.

4. In air conditioning apparatus for passenger cars utilizing a compressible refrigerant, a closed circulatory system with a continuously-running compressor interposed therein; a motor (generator) normally operated, through an automatic clutch, from one of the wheel axles of the car while the car is in motion; a battery charged at train speeds above the cut-in speed of the automatic clutch and adapted to furnish energy for the operation of the compressor at low train speeds and during station stops; a variable means coordinating the motor (generator) and the compressor; and means including a differential thermostat responsive to temperature changes externally and internally of the car for actuating the variable speed means to govern the speed of the compressor, and in turn, the rate of circulation of the refrigerant in the system.

5. In air conditioning apparatus for a railway car or other enclosure intended for human occupancy, utilizing a compressible refrigerant, a closed circulatory system with a continuously running multiple-cylinder compressor interposed therein; by-passes around the cylinders of the compressor; individual flow control valves in said by-passes; means for driving the compressor; means for constantly admitting fresh air into the car; means for constantly circulating the atmosphere within the car; and means including a differential thermostat responsive to temperature changes in the incoming fresh air and in the air

internally of the car, for automatically actuating the by-pass valves to progressively load and unload the compressor cylinders, thereby to control the rate of circulation of the refrigerant in the system.

5 6. In air conditioning apparatus for a railway car or other enclosure intended for human occupancy, utilizing a compressible refrigerant, a closed circulatory system with a continuously
10 running multiple-cylinder compressor interposed therein; by-passes around the cylinders of the compressor; individual magnetically-operated flow control valves in said by-passes; means for driving the compressor; an electric circuit including
15 individual switch contacts for the valve magnets and a switch plate movable over the contacts; means for constantly admitting fresh air into the car; means for constantly circulating the atmosphere within the car; and means including
20 a differential thermostat responsive to temperature changes in the incoming fresh air and in the air internally of the car, for moving the switch plate to effect successive actuation of the by-pass valves and progressive loading and
25 unloading of the compressor cylinders to control the rate of circulation of the refrigerant in the system.

7. The method of conditioning air in a railway car with apparatus utilizing a compressor
30 to circulate a compressible refrigerant in a closed circulatory system, main power means operated from one of the wheel axles of the car while the car is in motion, auxiliary power means operative during station stops, and variable speed means
35 connecting the main and the auxiliary power means with the compressor, which method comprises constantly admitting fresh air into the car; constantly circulating the atmosphere within the car; and controlling the variable speed means
40 through modulation dependent upon variations in the differential between the temperature of the incoming air and the temperature within the car.

8. The method of conditioning air in a railway car with apparatus utilizing a compressor to
45 circulate a compressible refrigerant in a closed circulatory system, a motor (generator), an automatic clutch through which the motor generator is operated from one of the wheel axles
50 of the car while the car is in motion, a battery charged at train speeds above the cut-in speed of the automatic clutch and adapted to furnish energy for operation of the compressor at slow train speeds and during station stops, and variable
55 speed means interposed between the motor

generator and the compressor, which method comprises constantly admitting fresh air into the car; constantly circulating the atmosphere within the car; and controlling the variable speed means by modulation dependent upon variations
5 in the differential between the temperature of the incoming air and the temperature within the car.

9. In air conditioning apparatus for passenger cars utilizing a compressible refrigerant, a closed
10 circulating system with a continuously running compressor interposed therein; main power means operated from one of the wheel axles of the car while the car is in motion; auxiliary power means operative during station stops; variable
15 speed means connecting the main and the auxiliary power means with the compressor; and means responsive to temperature changes within the car for controlling the variable speed means to govern the speed of the compressor, and in
20 turn, the rate of circulation of the refrigerant in the system.

10. In air conditioning apparatus for passenger cars utilizing a compressible refrigerant, a closed circulating system with a continuously
25 running compressor interposed therein; main power means operated from one of the wheel axles of the car while the car is in motion; auxiliary power means operative during station stops; variable speed means connecting the main
30 and auxiliary power means with the compressor; and differential thermostat means responsive to temperature changes exteriorly and interiorly of the car for controlling the variable speed means to govern the speed of the compressor, and, in
35 turn, the rate of circulation of the refrigerant in the system.

11. In air conditioning apparatus for passenger cars utilizing a compressible refrigerant, a closed circulatory system with a continuously-
40 running compressor interposed therein; a motor (generator) normally operated, through an automatic clutch, from one of the wheel axles of the car while the car is in motion; a battery charged at train speeds above the cut-in speed of the automatic clutch and adapted to furnish energy for
45 the operation of the compressor at low train speeds and during station stops; variable speed means coordinating the motor (generator) and the compressor; and means responsive to temperature changes within the car for controlling the
50 variable speed means to govern the speed of the compressor, and in turn, the rate of circulation of the refrigerant in the system.

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