Sept. 19, 1939. C. R. NEESON ET AL 2,173,285

RAILROAD REFRIGERANT COMPRESSOR DRIVE

Filed Dec. 2, 1937 8 Sheets-Sheet 1

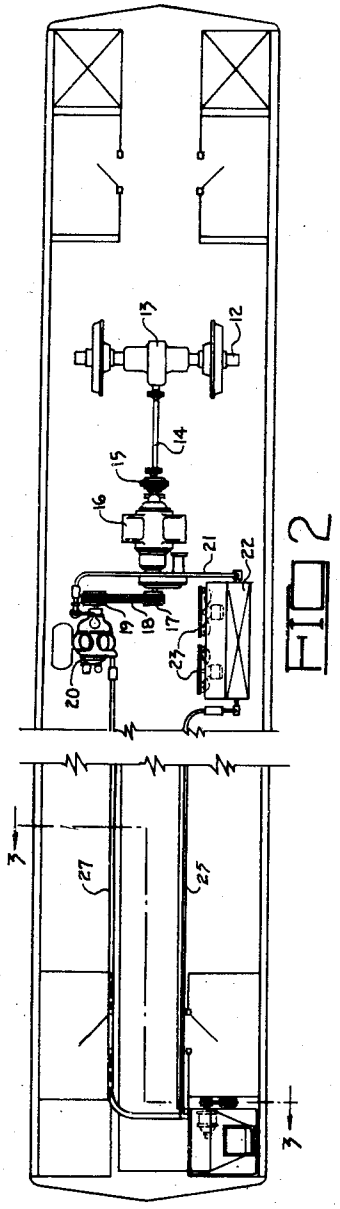


FIG 2

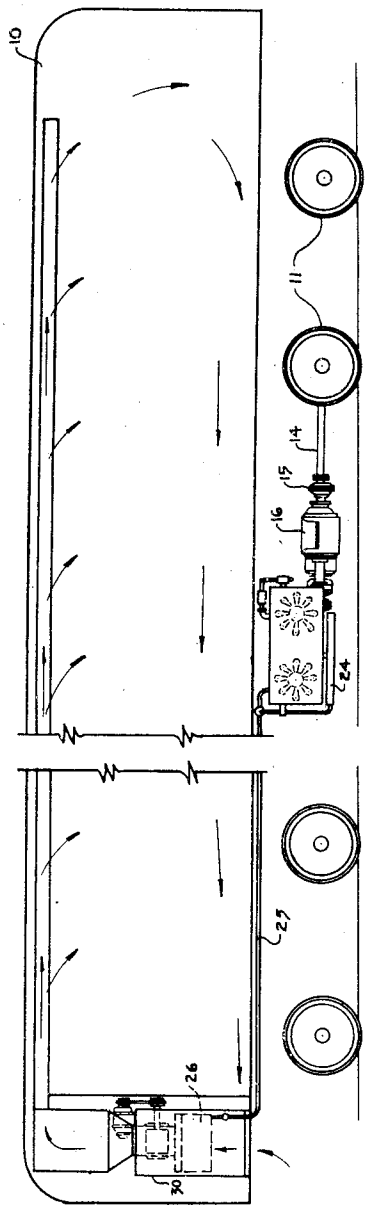


FIG 1

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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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FIG 4

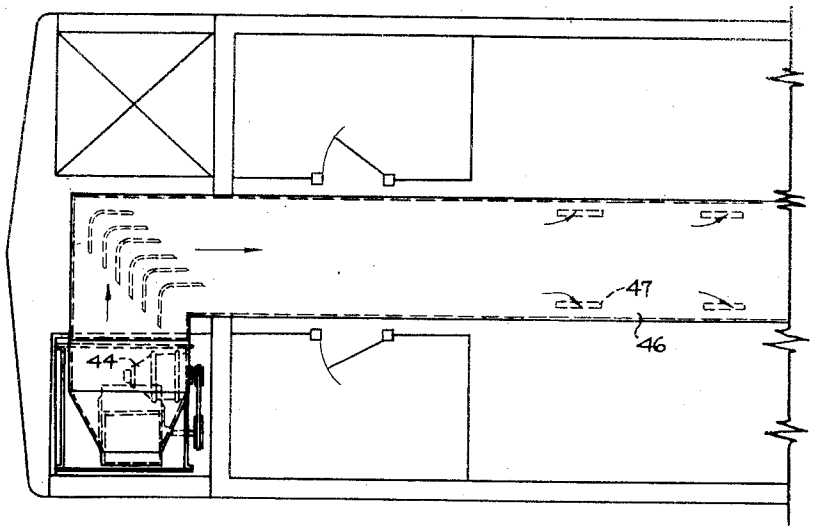
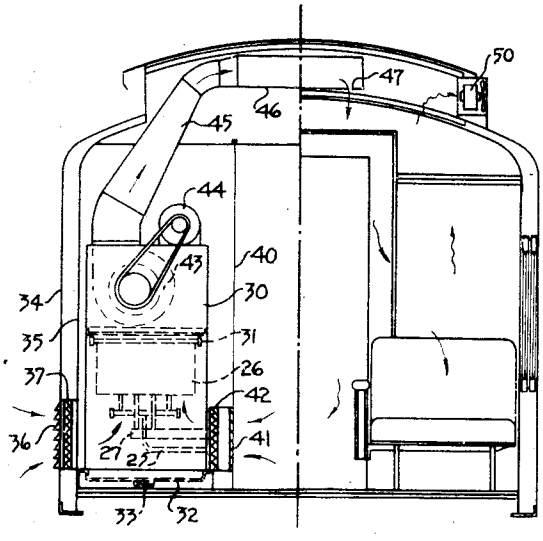


FIG 3



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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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FIG 5

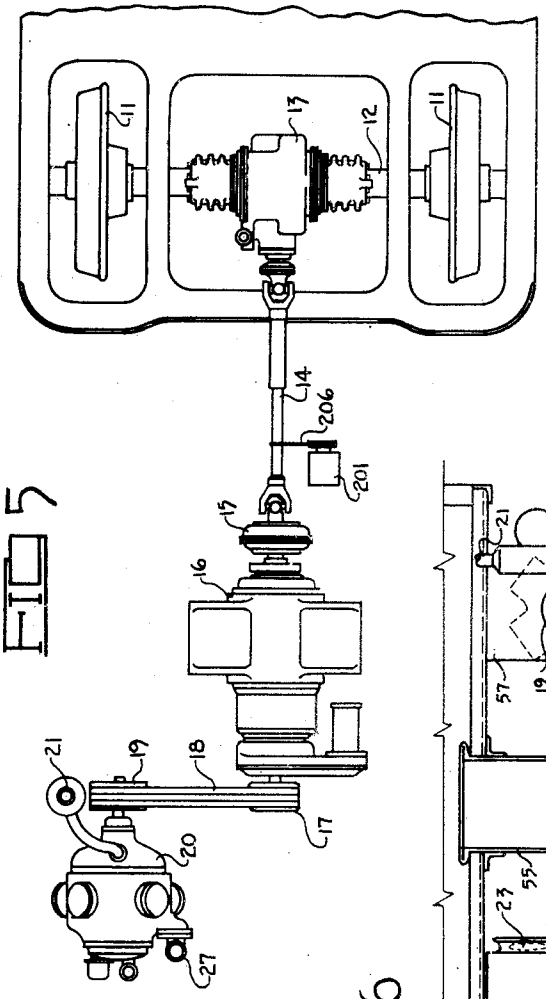
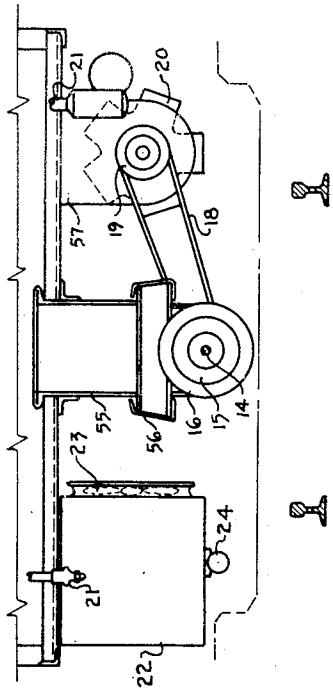


FIG 6



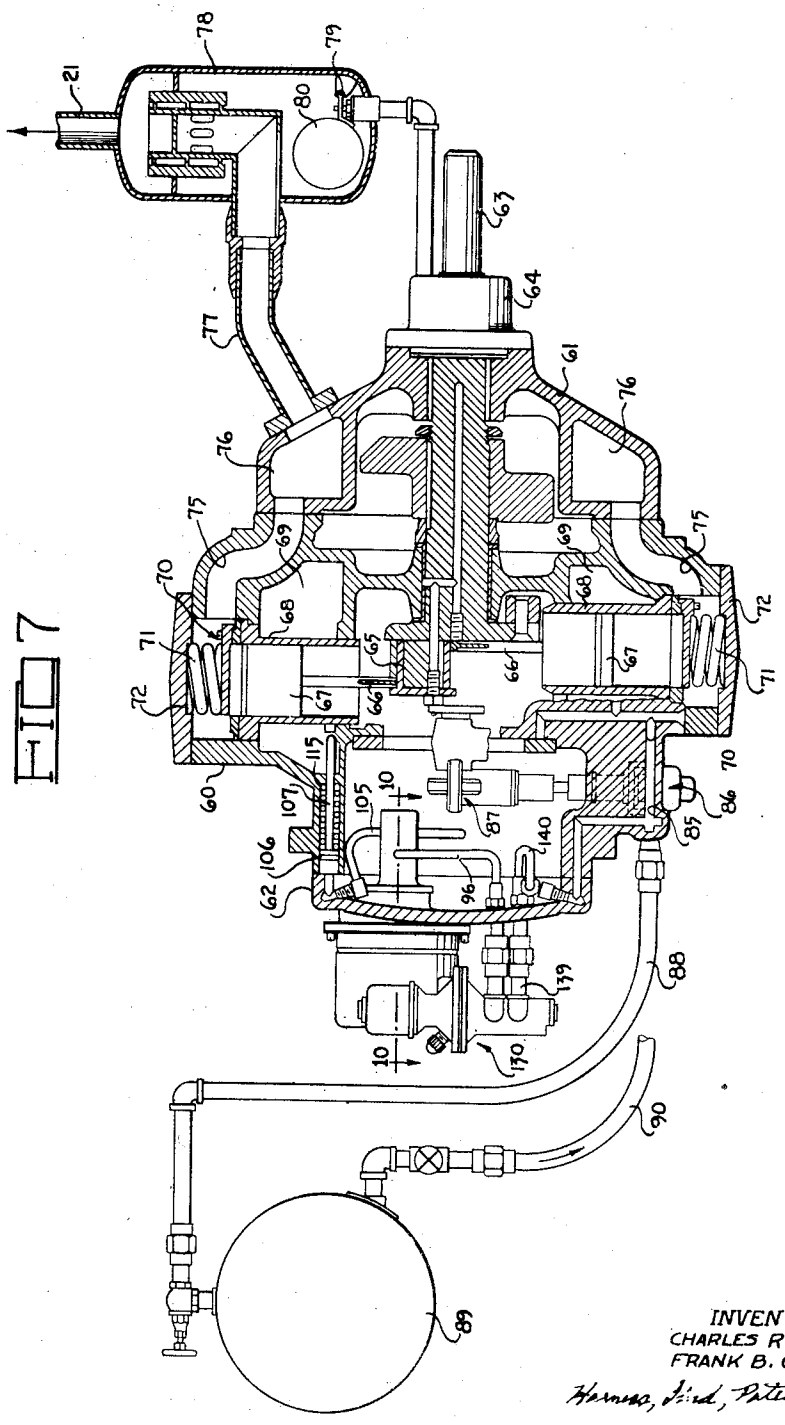
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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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FIG 7



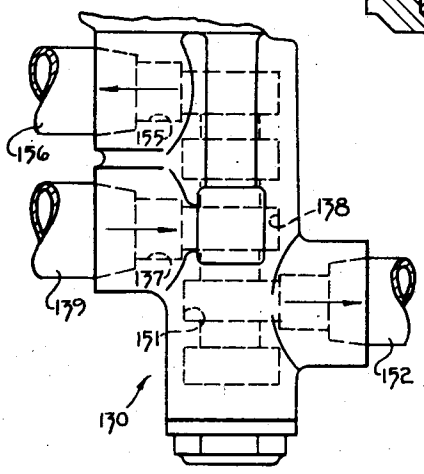
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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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FIG 9



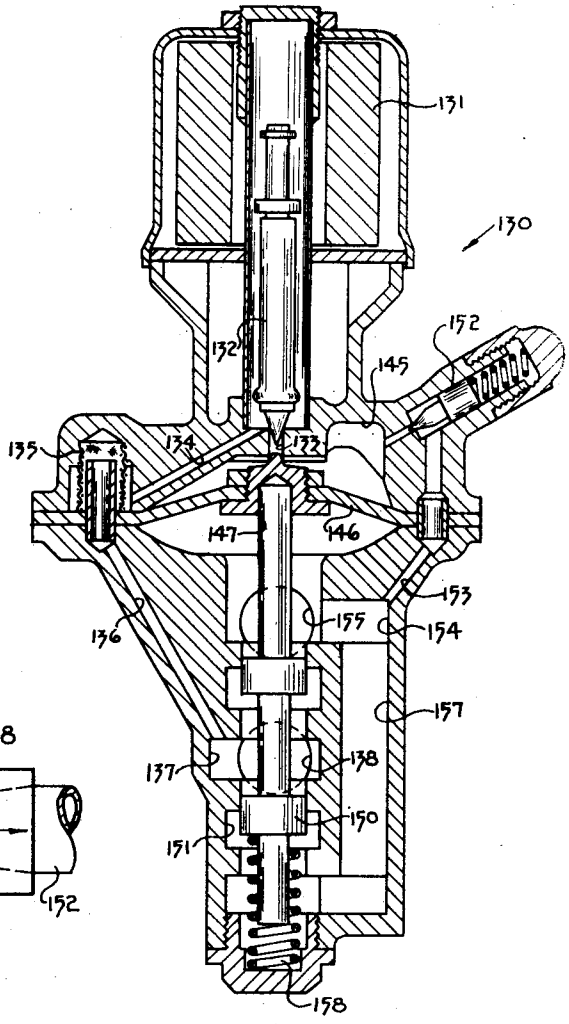


FIG 8

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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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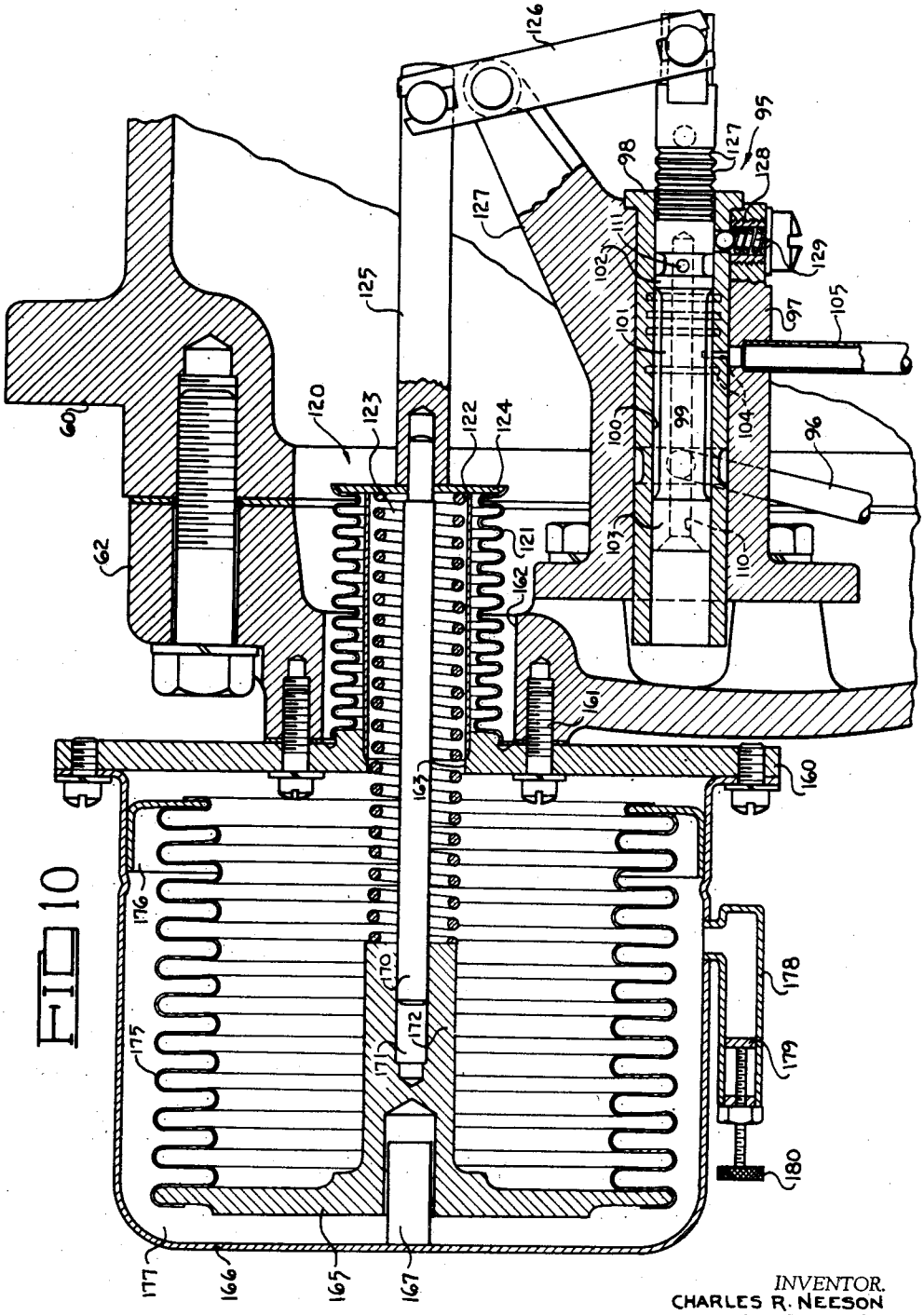


FIG 10

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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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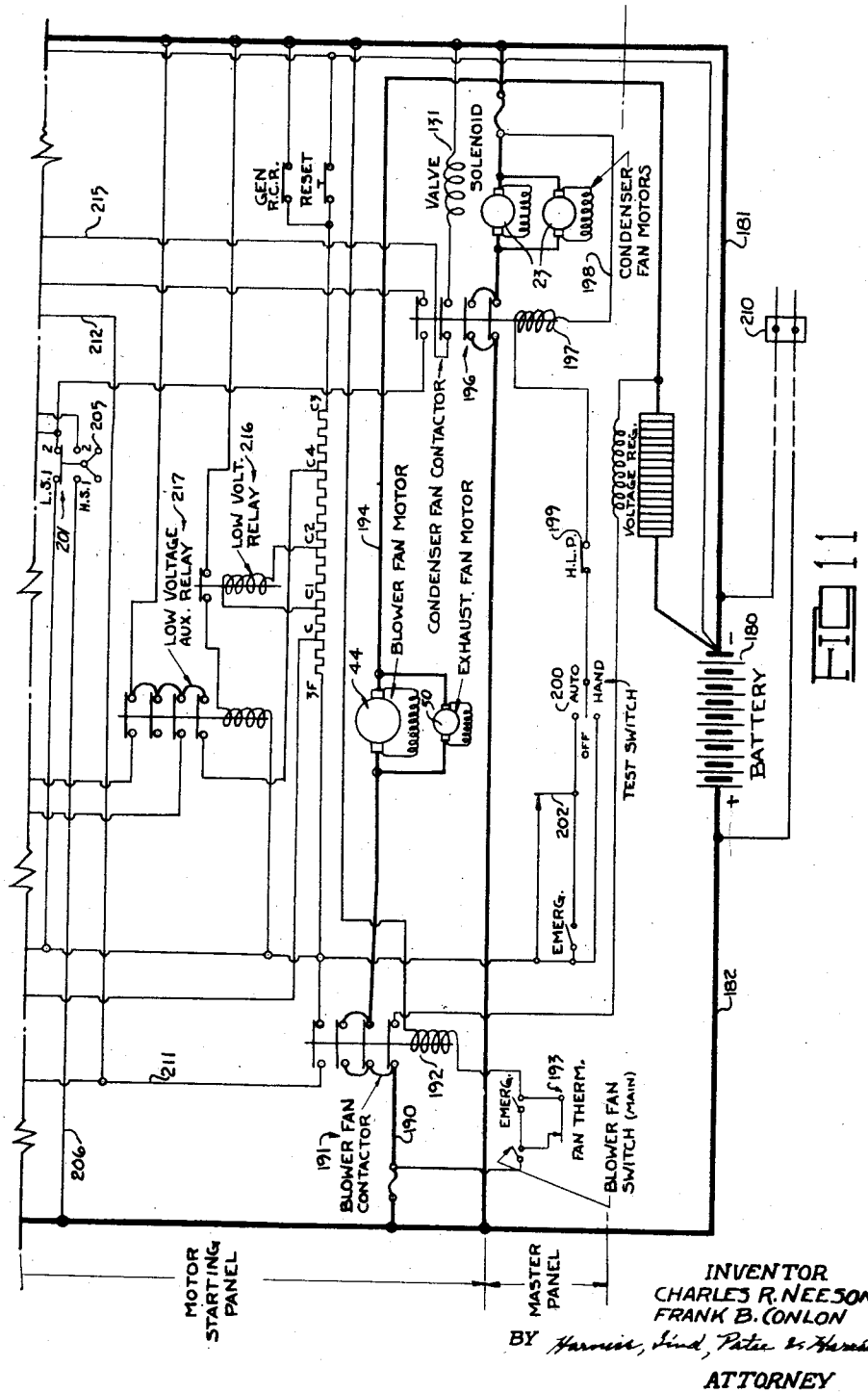


FIG 11

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RAILROAD REFRIGERANT COMPRESSOR DRIVE

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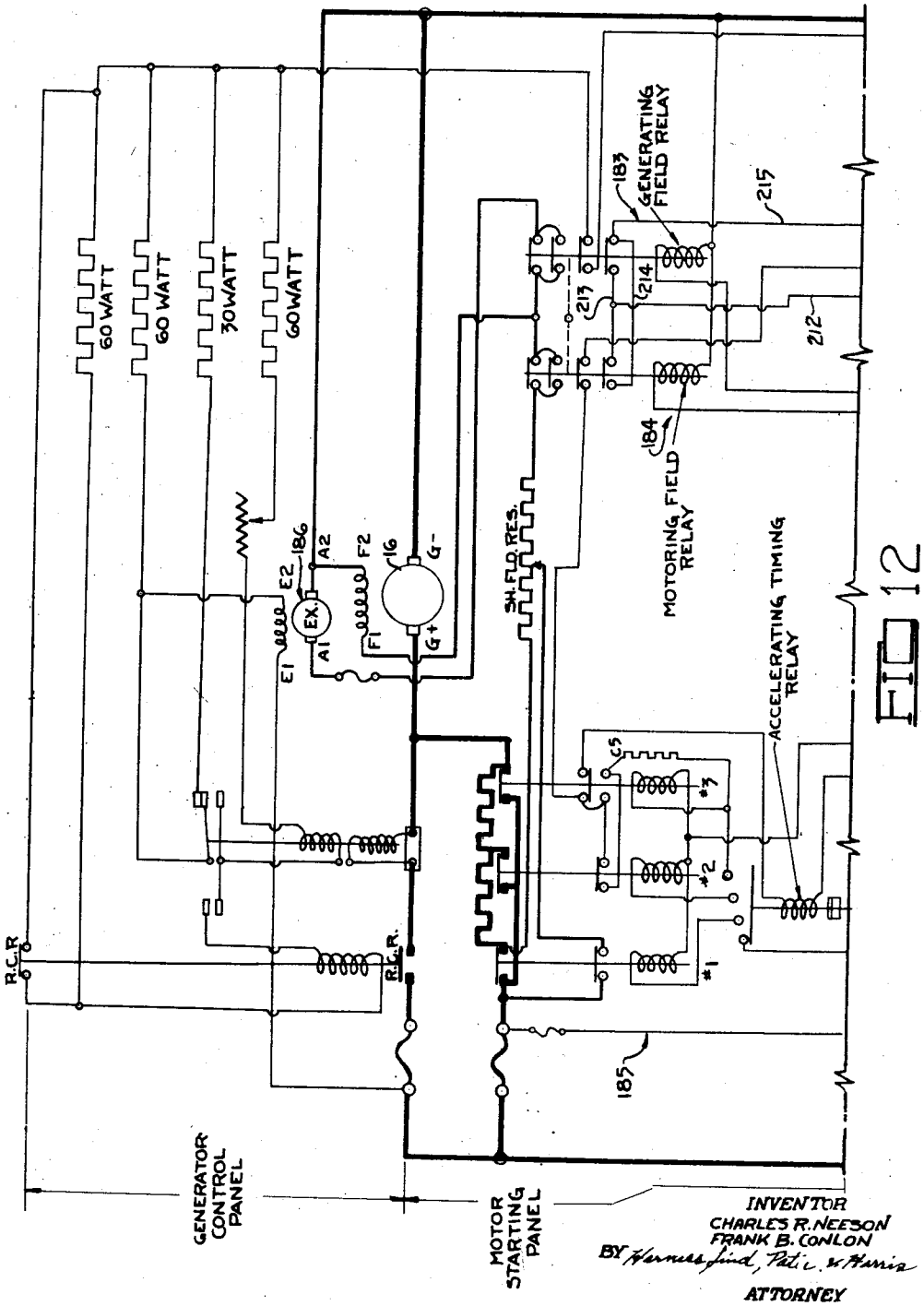


FIG 12

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Patented Sept. 19, 1939 2,173,285

UNITED STATES PATENT OFFICE

2,173,285

RAILROAD REFRIGERANT COMPRESSOR DRIVE

Charles R. Neeson and Frank B. Conlon, Dayton, Ohio, assignors, by mesne assignments, to Chrysler Corporation, Highland Park, Mich., a corporation of Delaware

Application December 2, 1937, Serial No. 177,695

15 Claims. (Cl. 62—6)

The subject of our invention is the provision of means for driving a compressor located on a vehicle such as a railroad car, particularly for use in compressing a refrigerant. Although the invention is particularly designed for air conditioning passenger cars it is within the purview of our invention to refrigerate commodities in refrigerator cars, or to air condition other vehicles or stationary enclosures, or to refrigerate commodities therein, by the use of part or all of the present invention. Accordingly the term "refrigeration" may be used herein to denote any or all of the aforementioned functions.

The principal object of the present invention is to devise a refrigerating system capable of delivering maximum refrigeration at low car speeds and also capable of delivering the same amount of refrigeration at very high car speeds without, however, attempting to control the speed of rotation of the compressor crank shaft. Several types of compressor drives are at present on the market which derive energy from the motion of the car and which include means to translate the variable speed of the car axle into a constant speed for the compressor crank shaft, which constant speed is equal to the speed at which the compressor is operated by a motor for stand by service. Such systems require expensive and in many respects delicate mechanisms which need constant servicing and often fail. With our invention the car speed and, hence, the axle speed from which mechanical energy is obtained is directly translated to the speed of the compressor crank shaft, the control of refrigeration being achieved by utilizing a compressor such as set forth in the co-pending application of Charles R. Neeson, Serial No. 177,694 filed concurrently herewith, wherein a function of the load on the compressor is caused to control the number of cylinders of the compressor which are permitted to compress refrigerant. In applying the compressor of the aforesaid application to the present invention, it is obvious that the load is a variable factor which affects the number of cylinders in operation, but the speed is a far greater variable factor which also affects the number of cylinders in operation. If the load remains constant the cubic feet per minute of vaporized refrigerant exhausted from the compressor will rise in substantially direct proportion to an increase in speed of the car axle, which results in greater rarification and decreased pressure within the crank case causing operation of means responsive to the pressure within the crank case to reduce the number of cylinders permitted to operate. Other cylinders will continue to exhaust refrigerant from the interior of the crank case until such time as a variation in the load or the speed of the car axle causes an increase or decrease in the number of cylinders in operation.

It is a feature of our invention that many details of railroad air conditioning systems have been eliminated or extremely simplified, an object of the present invention being to devise a system having relatively few operating parts, all of which are extremely rugged, easy to assemble and disassemble for inspection and repair, and unlikely to fail in service. The advantages of our invention will be fully apparent following an inspection of the specification and accompanying drawings wherein like numerals refer to like parts throughout.

In the drawings Fig. 1 is a schematic representation of a railway vehicle having our present invention applied thereto; Fig. 2 is a bottom view of the vehicle shown in Fig. 1; Fig. 3 is a cross section through the body of the vehicle taken along line 3—3 of Fig. 2, showing a form of air conditioning unit and duct system and the manner of air distribution thereof which may be found desirable in certain types of cars; Fig. 4 is a plan view of the end of a vehicle having the foregoing air conditioning unit and ducts applied thereto, the roof and half-decks of the vehicle being removed for the sake of simplicity; Fig. 5 is a schematic representation of the driving mechanism and the compressor as applied to a car body; Fig. 6 is an end elevation of apparatus such as shown in Fig. 5; Fig. 7 is a cross section through the body of a compressor made in accordance with our present invention; Fig. 8 is a vertical cross section through a solenoid valve of a type found suitable to form a portion of the control system for the present invention; Fig. 9 is an end elevation of the lower portion of the solenoid valve detailed in Fig. 8; Fig. 10 is an enlarged partial section showing a portion of the control for the present invention including a master valve for controlling the number of pistons in operation and a master valve regulating and modulating device, the view being taken along line 10—10 of Fig. 7; Fig. 11 is a portion of a schematic representation of the electrical circuit required by our present invention; and Fig. 12 is the remainder of the wiring diagram, Fig. 12 being a continuation of Fig. 11.

Referring to Fig. 1 there is shown a vehicle body 10 mounted upon wheels 11, one of the pairs of which is provided with an axle 12 upon which is mounted a gear housing 13 enclosing gears deriving motion from the car axle, which drive a flexible, extensible shaft 14. A suitable type of gear drive is set forth in the patent to Spicer, No. 2,026,076, dated Dec. 31, 1935, although other types of driving means including belt drives, several of which are well known, may be substituted therefor. The shaft 14 extends through a centrifugal clutch 15 of any well known type, the

driven member of which is connected to the armature of a variable speed, shunt machine 16 which may act as a motor or as a generator, several makes of which are obtainable in the open market. The opposite end of the armature of the shunt machine 16 carries a pulley 17 which drives belts 18 passing about a pulley 19 mounted upon a multiple-cylinder, radial compressor of the type set forth in the aforementioned co-pending application of Charles R. Neeson. Refrigerant compressed by the compressor 20 passes through pipe 21 into a heat exchanger 22 through which cooling air is blown or drawn by fans 23, the heat exchanger thereby constituting an air cooled condenser. The compressed refrigerant is liquefied in the condenser and is accumulated in a receiver 24 from which the liquid passes through a liquid pipe 25 extending to the evaporator 26 located in the vehicle body. From the evaporator, in which expansion of the refrigerant causes cooling of air drawn therethrough, the refrigerant passes in expanded condition through a suction pipe 27 into the compressor 20 by which it is again forced through the refrigerating cycle.

A form of conditioning unit is illustrated in the drawings comprising a casing 30 mounted upon the floor of the car at one end thereof, preferably at one side of the closed vestibule, the casing being preferably enclosed within partitions to conceal the same and to confine the air treated by the unit. The unit may be mounted elsewhere such as in the ceiling area of the car or upon the floor in other parts of the car, the present disclosure being of a preferred embodiment in a preferred location. The unit may comprise a heating coil 31 in addition to the evaporator coil 26 for the purpose of heating air in winter, and as is ordinary practice in railroad air conditioning, other conditioning means may be incorporated therein such as humidifying sprays. Condensed moisture extracted from the air may fall into a drain pan 32 from which the moisture may be removed through an outlet 33 having a suitable connection thereto for the collection or waste of condensed moisture.

A preferred manner of obtaining air for treatment and of distributing the same within the car after treatment is schematically indicated as follows: The bodies of most cars usually comprise double walls 34 and 35, at some suitable portion of which the outer wall is provided with louvres 36 through which outside air may be drawn. The inner wall has an opening adjacent the louvres and a filter 37 is suitably mounted adjacent the opening to remove soot and dust from the air drawn into the unit. The partition 40 which separates the unit from the remainder of the car interior is likewise provided with louvres 41 adjacent which a filter 42 may be placed in order to remove dust or other foreign matter from the air recirculated through the body of the car. The two streams of air which are admitted through filters 37 and 42 mix within the lower portion of the unit and the mixed air is drawn upwardly through the conditioning means by a suitable blower 43 driven by a motor 44 mounted upon the top of the unit. The discharge from the blower is conducted through a vertical duct 45 extending upwardly toward the overhead space within the car body and the air is delivered therethrough into a central duct 46 running longitudinally of the car adjacent the ceiling thereof. The duct 46 is provided with a series of openings 47 at suitable intervals for permitting the entrance of conditioned air into the passenger space. A suitable number of exhaust fans 50 may be provided adjacent the ceiling of the car at the edge of the half-deck area to exhaust a sufficient quantity of vitiated air to cause the induction of sufficient fresh air, such as 10 C. F. M. per passenger. The air delivered from the duct 46 passes downwardly and laterally over and into the passenger space, some of the air eventually finding its way out of the car through cracks and the exhaust fans 50, and the remainder of the air returning through the passenger area to be recirculated through the unit.

As more clearly illustrated in Figs. 5 and 6, we prefer to attach the motor-generator to the centersill 55 by means of clamps 56 and to attach the compressor 20 to a support 57 suitably mounted beneath the car body at one side of the centersill. We also prefer to mount the condenser 22 at the side of the car body in such position as to cause air to be drawn from adjacent the centersill and to be discharged towards the side of the car since the development of high-speed trains has created the problem of combating so-called curtain air at the side of the car which might prevent sufficient air from being drawn through the compressor if the air movement were in the opposite direction, and also the high velocity air stream past the outside of the car aids in drawing air through the condenser from the comparatively quiet area near the center of the car.

Fig. 7 illustrates in considerable detail the form of compressor fully set forth and claimed in the aforementioned co-pending application. The compressor comprises a main casting 60 having a rear cover 61 and a front cover 62 bolted thereto to form a hermetically sealed enclosure for the operating parts of the compressor. The crank shaft 63 (to which pulley 19 is attached) extends through the rear cover 61, a shaft seal 64 being provided to prevent leakage between the crank shaft and the bearings therefor. The crank shaft is provided with a crank pin 65 from which extend radial piston rods 66 attached to pistons 67 operating in sleeve liners 68 extending through a suction manifold 69. A suction and discharge valve assembly 70 is provided for each piston, the same being held in place by a safety spring 71 and cylinder cap 72. Expanded refrigerant which is admitted through pipe 27 fills the interior of the crank case and the suction manifold 69, is admitted to the cylinder spaces, and is discharged in compressed condition through a series of discharge passages 75 leading to a discharge manifold 76 extending circumferentially about the rear cover 61. A discharge tube 77 extends into an oil separator 78 provided with suitable baffles and screens which tend to accumulate any droplets of oil carried with the refrigerant, causing the same to drop to the bottom of the separator 78 and to be returned to the compressor through the medium of a valve 79 controlled by a float 80. The separated refrigerant passes from the oil separator into pipe 21 which leads to the condenser 22 as previously described. The compressor is suitably lubricated by a force pump (not shown) driven by the crank shaft which forces lubricant under pressure into a passage 85 having suitable branches leading to various portions of the compressor. The oil which is returned to the interior of the crank shaft is removed from the crank case by a suitable scavenger pump 86 driven by gears 87 which rotate in unison with the crank shaft 63 and which also drive the force pump. The scavenger pump forces the lubricant through a pipe 88 into

an oil tank 89 from which it is drawn through the oil suction pipe 90 into the force pump and thence into the passage 85. Further details of the compressor, oil separator, lubricant system and all other parts associated therewith, may be ascertained from the aforementioned application together with the co-pending applications of Charles R. Neeson, Serial Nos. 145,586 and 145,589, filed May 29, 1937.

As detailed in the aforesaid application, Serial No. 177,694, lubricant under pressure is admitted to a master unloader valve assembly 95 which is mounted upon the inner surface of the front cover 62. The lubricant is admitted to the valve through a pipe 96 connected to the passage 85 so that the interior of the valve may contain oil under pressure if the compressor is operating. The valve comprises a housing 97, through which tube 96 extends, and a valve liner 98 having an opening 99 in communication with the tube 96, the opening admitting lubricant under pressure to an annular space 100 surrounding the stem of a plunger 101 having a closely fitting head 102 at one end, and a closely fitting head 103 at the other end. The oil is thus confined within the annular space 100 unless permitted to flow outward through slots in the liner 98, such as slot 104 which communicates with a tube 105 leading to an individual cylinder unloading mechanism exemplified by the piston 106 (Fig. 7) and piston rod 107. Further details of the individual cylinder unloading mechanism may be ascertained from the aforesaid application, Serial No. 177,694, the same comprising means to hold the suction valve of the cylinder continuously in open position when urged to do so by oil under pressure whereby refrigerant admitted to the cylinder space is forced back into the suction manifold 69 without substantial compression thereof. Lubricant which may seep past the head 103 returns to the interior of the compressor through the open end of the liner 98. Lubricant which may tend to seep past the head 102 will be returned to the crank case through a bore 110 extending longitudinally of plunger 101 and an opening 111 in the side of the plunger.

There are five slots 104 illustrated, each of which communicates with a tube 105 leading to the unloading mechanism for an individual cylinder of a five-cylinder compressor as illustrated. As long as the compressor, and hence the force pump, is not operating there will be no pressure within the tubes 105 with the result that the springs 115 of the cylinder unloading mechanism will hold all of the suction valves in open position thereby unloading the entire compressor. If the compressor should start, the force pump will soon create sufficient pressure within space 100 and tubes 105 to cause all of the cylinder unloading means to become inoperative, thereby permitting the suction valves to operate in the normal fashion and the compressor to operate at full capacity for the particular speed of rotation of the crank shaft.

The tubes 105 may be cut off from communication with the force pump by the master valve when moved by a master valve controlling mechanism 120 comprising a flexible metallic bellows 121 extending inwardly into the interior of the crank case and surrounding a guiding sleeve 122 which encloses a spring 123 compressed against a disc 124 fastened to the end of the bellows and thereby causing the same to hermetically seal the crank case. A rod 125 fastened to the disc 124 is pivoted to one end of a lever 126 mounted upon an arm 127 extending from the master valve housing 97. The opposite end of lever 126 is pivoted to the free end of the master valve plunger 100 which is provided with a series of spaced notches 127 adapted to be engaged by a ball 128 urged against the side of the plunger by a spring 129 mounted in the wall of the valve housing 97. As the lever 126 is rocked about its support, the plunger will move in and out, thereby causing head 102 successively to block or open the slots 104 leading to the tubes 105. The ball 128 is a check device for applying sufficient friction to cause the plunger to move in a series of steps thereby eliminating fluttering of the mechanism.

It is apparent that the interior of the crank case will exert a varying load upon the operating device comprising bellows 121, which as seen in Fig. 10, has the fullest load exerted thereon causing the bellows to be compressed so as to bring disc 124 into engagement with the end of guiding sleeve 122. At this point the plunger is retracted to its fullest extent thereby causing all of the tubes to be in communication with the annular space 100. This high pressure exists when the compressor is at rest with the result that the high and low sides of the refrigerating system have substantially balanced. If the compressor now starts, the force pump will likewise start and oil in all of the tubes 105 will soon be under sufficient pressure to cause all of the individual cylinder unloading means to be rendered inoperative, thereby causing the compressor to operate at full capacity. If the capacity at this speed is too great, the refrigerant within the crank case will be rarified to such an extent as to lower the interior pressure below the force exerted by spring 123 with the result that the master valve plunger is moved inward thereby preventing the exertion of pressure within certain of the tubes 105, with the result that the cylinders to which such tubes extend become unloaded. As the speed of the crank shaft increases, the number of cylinders necessary to maintain a given load decreases with the result that at very high car speeds one cylinder may be sufficient and even that one cylinder may operate intermittently.

I have found it advisable to use a five-cylinder compressor since the motor-generator sets commonly used on railroad passenger cars motor at such a speed as to require five cylinders of a certain capacity in order to render maximum required refrigeration. However, when the car axle is rotating fast enough to drive the compressor faster than the speed imparted thereto by the motor, the number of cylinders required will be decreased so that in ordinary fast operation of modern trains only two or three cylinders will be in operation under maximum load conditions.

A feature of the present invention not found in the aforesaid application, Serial No. 177,694, is illustrated in Figs. 7, 8 and 9, and comprises a solenoid valve 130 inserted between the tube 96 and the passage 85 leading to the force pump which, when operated to close the oil line, will result in the entire unloading of the compressor due to the lack of sufficient oil pressure to overcome any of the cylinder unloading means. There is thus provided a means of control which when operated will render the compressor entirely inoperative regardless of the speed of rotation of the crank shaft so that the compressor need not be disconnected from its driving means when no refrigeration is required, thereby eliminating

one of the clutches heretofore found necessary in railroad service. The valve 130 comprises a solenoid 131 surrounding a needle valve plunger 132 which, when the solenoid is deenergized, closes a passage 133. Passage 133 communicates with the main gate of the valve through a passage 134, sieve 135, passage 136 and chamber 137. Chamber 137 leads to an opening 138 from which extends pipe 139 connected to a pipe 140, inside of the crank case, which leads to the oil passage 85. When the force pump is operating, oil under pressure tends to leave passage 85 through tube 140 and pipe 139 into the chamber 137. Some oil under pressure tends to leave chamber 137 and enter the passage 133 after flowing through passage 136, sieve 135 and passage 134 which, however, is prevented if the solenoid 131 is deenergized thereby causing plunger 132 to block the passage under the influence of gravity. If, however, the solenoid 131 is energized, the plunger 132 will be raised causing oil under pressure to fill a chamber 145 in which is situated a diaphragm 146 to which is attached a valve plunger 147. The oil under pressure moves the valve of plunger 147 downward, causing an enlargement 150 on the plunger 147 to be removed from the position shown in Fig. 9 to a lower position such as to permit communication between chamber 137 and delivery chamber 151 from which extends a pipe 152 connected to the tube 96 within the compressor which leads to the master valve. When the solenoid is again deenergized, the plunger 132 closes opening 133 thereby removing pressure from the upper surface of diaphragm 146. A check valve 152 which is open as long as pressure exists within chamber 145, permits lubricant to flow through passage 153 into an exhaust chamber 154 provided with an opening 155 connected to a pipe 156 which drains the oil back into the compressor crank case. Oil which may be trapped beneath the head 150 is permitted to escape through a bypass 157 into the exhaust chamber 154 which also prevents the trapping of the plunger 147 in lowered position when urged to return to its upper position by a spring 158. Other types of valves are suitable for the purpose, but the foregoing type has been found satisfactory. The solenoid valve comprises means to prevent the operation of the compressor whenever the solenoid is energized by suitable means subsequently described.

The foregoing mechanism serves to control the amount of refrigeration in accordance with the demand therefor as indicated by suitable means such as a thermostat located within the body of the car. If the thermostat in the car should indicate that cooling was desired, the compressor will deliver the proper amount of refrigerating medium to maintain a certain difference between the temperature of the air in the passenger area and the temperature of the air immediately after the same has been treated by the cooling surfaces such as the evaporator coil 26. The master valve controlling bellows 121 serves to maintain this temperature differential since the temperature of the air within the passenger area is reflected in the superheat, and hence the pressure, of the expanded refrigerant entering the compressor. However, it is well known that in order to prevent shock to humans it is necessary to maintain a variable differential between inside and outside temperatures, in other words, the hotter the day, the higher the temperature should be within the passenger car in order to maintain a feeling of comfort and to prevent nervous shocks upon entering or leaving the car. Various systems have been devised to control this differential which operate upon the principle of varying the effective point of the controlling thermostat. We have devised a system whereby the variance is achieved by varying the effective point of the master valve 95, which mechanism comprises the following:

The bellows 121 is attached to cap piece 160 which is fastened to the cover plate 62 by means of bolts 161, the cap piece serving to close an opening 162 through the cover plate 62. The guiding sleeve 122 is fastened to the side of an opening 163 extending through the cap piece 160 through which the spring 123 extends. The spring is compressed between the disk 124 at one end, and a movable pressure regulating plate 165 at the other end, which plate is located within a hood 166 fastened to the plate to form therewith an enclosure, and which is guided by a guide pin 167 attached to the inner surface of the hood 166. A guide rod 170 is fastened at its inner end to the pressure disc 124 and to the operating rod 125 and moves therewith, its outer end being guided in a loosely fitting bore 171 in the stem 172 of the pressure regulating member 165. The spring 123 is so proportioned as to be overcome by high pressure existing within the crank case and to move the master valve plunger against the friction of ball 128 in definite increments of movement according to the suction pressure existing in the crank case during the operation of the compressor. The initial compression of the spring 123 is obviously controlled by the distance between the end of stem 172 and the end of guide sleeve 122. This initial compression may be small if the guide pin 167 bears against the inner end of its socket, or may be adjustably larger depending upon the separation of the pressure regulating plate 165 from the hood 166. The pressure regulating plate 165 is fastened to one end of a flexible bellows 175, the other end of which is fastened to an annular member 176 which is fastened to the inner surface of the hood 166, the hood, pressure regulating plate, bellows and annular member forming a hermetically sealed chamber 177. A charge of some thermally expansive fluid may be placed within the chamber 166, the quantity of the charge and its pressure determining the extent of separation of pressure regulating plate 165 and the hood 166; and, therefore, determining the initial compression of spring 123. An adjusting device may be supplied, the same comprising an auxiliary cylinder 178 in communication with the chamber 177 within which is mounted a plunger 179 which may be adjustably positioned by means of a thumb screw 180. Rotation of the thumb screw results in variations of the internal space within cylinder 178 and thereby results in variation of the pressure within chamber 177 which causes a variation in the initial compression of spring 123. Other means for adjusting the pressure of the fluid charge within chamber 177 may be utilized, several such means being set forth in the patent to Dube, No. 2,095,358, October 13, 1937.

As will be apparent from an inspection of Figs. 2, 5 and 7, the hood 166 is located in the external air at the motor and consequently the fluid within chamber 177 is affected by the external temperatures. If the external temperature is extremely high, the fluid will be expanded to compress spring 123 to a greater extent and vice versa. Accordingly, when the tem-

perature is very high it becomes increasingly easier for spring 123 to overcome the pressure of the refrigerant within the crank case, and the individual cylinder unloaders are caused to operate at increasingly higher pressures which means that less refrigerant will be supplied to the evaporator. By the proper adjustment of thumb screw 180, the action of the compressor can be so regulated as to maintain a properly modulated temperature within the passenger area. It is to be noted that the cap piece 160 is spaced from the front cover 62 so as to be surrounded by air in motion and the cap piece 160 serves to prevent radiation from the compressor which might otherwise prevent accurate control by the modulating device.

Having described the mechanical features of our invention it is thought best to describe a form of control circuit which may be utilized to operate the same. Figs. 11 and 12 set forth in schematic fashion a complete control circuit, the details of which should be readily apparent to those skilled in the art. The circuit includes a battery 180 situated upon the vehicle from which extend main lines 181 and 182 to the shunt machine 16 which is provided with a motor-generator control comprising a generating field relay 183, motoring field relay 184, automatic starter 185, exciter 186 and other equipment. A line 190 extends from main line 82 to a blower fan contactor 191 which is operated by a solenoid 192 in series with a fan thermostat 193 and an emergency switch by means of which a circuit may be completed from line 190 to line 194 through the blower fan motor 44 and the exhaust fan motor 50, so that the blower fan and exhaust fan may be operated under control of the fan thermostat 193 to ventilate the car when the temperature is above some predetermined temperature such as 65° F., or at any time through the manual switch. A line 195 extends from the main line 182 through a condenser fan contactor 196 to the condenser fans 23 and back to battery through line 181 so that whenever condenser fan contactor is closed, the condenser fan motors will be operated. The condenser fan contactor is closed by a solenoid 197 in a line 198 which includes switches, such as high and low pressure cutouts 199 for the compressor 20, a manually operatable switch 200 for controlling the compressor and a speed switch 201, and which leads to the motoring and generating controls. When manual switch 200 is placed in the automatic position the circuit to the relay 197 may be completed by a thermostatic element 202 which may make contact at some preselected temperature, usually about 72 to 82 degrees.

If the car is stationary, the speed switch 201 will be in the position shown in Fig. 11 which means that the motor field relay 184 will be energized and the shunt machine 16 will operate as a motor whenever the thermostat 202 completes the circuit through the condenser fan contactor, low voltage relay and motor field relay to the automatic starter. Speed switch 201 is a means responsive to the speed at which the vehicle is moving and may comprise a centrifugal weight mechanism 205 driven by a belt 206 (Fig. 5) deriving motion from the car axle. Whenever sufficient speed has been attained, the centrifugal weights 205 will cause the switch 201 to open the circuit extending from main line 182 to the motoring field relay 184 and back to battery through main line 181 and to close the circuit extending from main line 182 to the generating field relay 183 and back to battery through main line 181, so that at certain critical speeds of the vehicle the motoring action may cease and the generating action may commence to charge the battery.

We may cease motoring and commence generating at some preselected speed at which the speed of rotation of the car axle is sufficient to rotate the armature fast enough to generate full load voltage. It is also within the range of the invention to have the motoring cease at one speed, such as two miles per hour, and to cause the generating field relay to be energized at another definite critical speed, such as 27 miles per hour. The latter mode of operation is preferable for several reasons; the primary reason being that the gear ratios of ordinary axle driving means are such as to cause the generator armature to rotate at such a speed that a car speed close to 27 miles per hour is necessary for the generation of full load voltage; the second reason being that the centrifugal clutch 15 would be better made if designed to engage at a speed such as 27 miles per hour rather than at a lower speed; and a third reason being that the motoring action of the machine may be stopped before clutch engagement so as not to clash with the mechanical drive in case the car starts to move in an opposite direction from the direction indicated by the direction of rotation of the armature when motoring. It is also within the range of our invention to have the motor cease operating at a low speed such as two miles per hour; to have the clutch 15 designed to engage at a higher speed, such as 10 miles per hour, so as to cause the compressor to operate through the mechanical means whenever the car is travelling at a speed equal to or above 10 miles per hour, and then to energize the generating field relay just prior to a car speed of 27 miles per hour which is necessary for the generation of full load voltage. The third mode of operation is preferred inasmuch as there are some railroad lines which operate their trains for some period of time at speeds between 5 and 20 miles per hour, in which event the cooling of air for the passengers' comfort would continue as long as some charge remained in the battery for standby service, and as long as the car moves above the cut-in speed of the clutch 15. Of course, the circuit may include a plug 210 placed in parallel with the battery 180 in order to drive the motor from a stationary source of current during standby operation in order not to excessively drain the battery.

It will be noticed that the thermostat 202 is in series with the low speed contacts of the speed switch 201, and hence is in series with the motoring field relay so that the motor can only operate in case cooling is demanded within the vehicle. The high speed contacts of speed switch 201 are placed in line 206 which extends through generating field relay 183 back to battery, hence the generating action is not under control of the thermostat and whenever the armature is mechanically rotated by the car axle above the generating speed thereof the battery will be charged thereby.

A line 211 extends from the blower fan contactor and joins a line 212 extending to an interlock 213 between the motoring field relay and the generating field relay so that current can be supplied to interlock 213 whenever and only when the blower fan contactor has been energized. If the motoring field relay is closed, a circuit will be

completed to wire 214, interlock 213, wire 215, condenser fan contactor 196 and valve solenoid 131 back to battery, if the condenser fan contactor 196 has been operated by energizing solenoid 197. As previously explained, this results in the operation of the solenoid valve to control the flow of oil under pressure to the master valve 95, so that during standby operation the motoring drive for the compressor and the solenoid valve will be energized whenever the thermostat makes contact. The motoring drive and the solenoid valve will be de-energized, completely stopping the compressor, whenever the thermostat 202 breaks contact.

If the car is in motion and the compressor is operated by means of the axle drive, the condenser fan contactor may be energized through a circuit including the thermostat 202. Therefore, the condenser fan may operate, and due to the action of speed switch 201, the generating field relay is energized and a circuit completed including wire 211, wire 212, interlock 213, generating field relay 183, wire 215 and condenser fan contactor 196 through solenoid valve 131. The solenoid valve 131 will again be energized to cause the master valve to control the action of the compressor. Whenever cooling is no longer necessary within the vehicle, the thermostat 202 may break contact, thereby opening the condenser fan contactor and closing the solenoid valve, and thereby causing the complete unloading of the compressor.

During the time that the compressor is being operated, either at a variable speed by the mechanical drive or at a constant speed by the electrical drive as controlled by the thermostat 202, the solenoid valve may be energized to permit oil under pressure to flow to the unloader master valve. As long as pressure within the crank case is so high as to indicate the necessity for all cylinders being in operation, all will operate. However, as the temperature of the air within the car drops, or the car gains speed, the superheat and pressure of the gas within the crank case will drop, thereby causing the master valve successively to cut off the oil pressure to the individual cylinder unloading means and successively decreasing the number of cylinders in operation until, conceivably, none of the cylinders will be effective. If there is continued demand for cooling as sensed by the thermostat 202, and the bellows 120, the pressure within the crank case will rise, causing the loading of cylinders in succession (or perhaps the intermittent loading and unloading of an individual cylinder or cylinders). As soon as the thermostat 202 indicates that the air within the vehicle is at a satisfactory temperature, the solenoid valve will be de-energized, thereby stopping the oil pressure to the master valve and causing the complete unloading of the compressor regardless of the superheat and pressure of the gas within the crank case. When the compressor is unloaded there will be no gas compressed thereby and the pressure within the system will balance on both sides of the evaporator thereby causing the pressure within the crank case to rise. If thermostat 202 now closes the compressor will operate through the motor when the car is standing still or moving at low speeds, or through the axle drive when the car is moving above the cut-in speed of the clutch. If the car had been standing or if the clutch had not been cut in previously the oil pump must operate for a short period of time in order to build up sufficient pressure to cause the compressor to operate under control of the master valve, but if the car had been moving above the cut-in speed of the clutch, the crank shaft of the compressor and the oil pump would have been rotating so that oil pressure would be immediately available to cause the master valve to control the operation of the compressor. As soon as oil pressure is available the compressor will be loaded and will henceforth operate under control of the solenoid valve and the master valve.

The differential regulating means comprising the chamber 177 located in the stream of external air will change the effect of the master valve so that the pressure at which individual cylinders unload and the point of complete unloading will vary in direct response to variances of outside temperature regardless of the setting of thermostat 202. Thus if thermostat 202 is set to close at a temperature of 72° F. and the outside air is about 30° F., the master valve may be so regulated as to cause complete unloading of the compressor when the air within the car is cooled to a temperature of 72° F.; but if the outside air is at a temperature of 95° F. by way of example, the compressor may become completely unloaded when the inside temperature reaches 78° and, no further refrigeration will be accomplished even though the thermostat 202 still remains in contact.

The thermostat 202 may be a direct acting thermostat which will make and break contact at a definite setting, or it may be a differential thermostat, which as is well known with respect to such devices, may operate at different points depending upon the load in the car. Thus if the outside temperature is very high, the thermostat 202 may be of the type which will have its operating point raised in accordance with a certain differential rating to be maintained between outside and inside temperatures. In either event the thermostat 202 is designed merely to act as a low-limit safety device. The reason for this will be apparent in view of the statements of the preceding paragraph and the following explanation of the function of bellows 120. It should be readily apparent to those skilled in the art that the back pressures and, hence, the suction pressure within the compressor, will vary according to the load within the car, which load is determined by the number of occupants, the outside temperature, the relative humidity, the number of lights in use, the relative clearness of the atmosphere and other factors. The bellows 120 and the associated mechanism are designed to operate at a range of back pressure of, for example 37 to 45 lbs. per square inch, which means that when the pressure drops below 45 lbs. the first cylinder will be unloaded; the second cylinder will be unloaded when the pressure is between 43 lbs. and 41 lbs; and so on until the last cylinder is unloaded if the pressure drops below 37 lbs. per square inch. It is also equally obvious that with a five-cylinder compressor and certain sizes of coils and blowers in operation a certain tonnage of refrigeration is performed. If the speed and load remain constant and one cylinder drops out of operation the tonnage performed will be reduced by twenty per cent. If the second cylinder is then unloaded the tonnage performed will be reduced by twenty-five per cent, the third cylinder will reduce the tonnage performed by thirty-three and one-third per cent, and so on. Each cylinder probably will not remain unloaded constantly even at a constant

speed with a constant load on the car since reductions in such percentages probably will reduce the capacity of the compressor below that necessary so that the performance chart of the compressor will undoubtedly present a series of rising and falling inclines, the average heights of which would follow substantially along a line representing the desired temperature conditions within the car as affected by the load. It may happen that during the course of this performance the compressor would tend to continue operation because of a temporary high pressure within the crank case whereas the air within the car would then be at the desired condition, in which case the thermostat would act as a low-limit safety device to stop the action of the compressor regardless of the back pressure condition. The bellows therefor acts as a modulating control as distinguished from a system comprising a non-variable compressor which starts and stops at the command of a thermostat and therefore, performs with much larger variances from the desired condition.

The performance of the compressor is not only affected by the operation of the low-limit thermostat **202** and the modulating action of the bellows **120**, but will also be affected by the action of the outside temperature differentiating control means comprising the chamber **177**, which may so act as to raise the range of action of bellows **120** to limits such as 39 to 47 lbs., or to lower the same to limits such as 35 to 43 lbs. The foregoing will serve to show that the present invention comprises means to regulate the temperature within the car including a low-limit control thermostat, a back-pressure responsive device acting as a modulating control, and differential control means to regulate the back-pressure responsive device.

Having described a preferred embodiment of our invention, it should be readily apparent to those skilled in the art that modifications in arrangement and detail thereof may be made without departing from the spirit of the invention as expressed in the following claims.

We claim:

1. In a vehicle refrigerating system a variable capacity refrigerant compressor located on the vehicle and cooling means located within the vehicle for lowering the temperature therein, electrical driving means for said compressor including a motor mechanically connected thereto, mechanical driving means deriving energy from the motion of the vehicle for driving said compressor at a variable speed, means associated with said compressor for partially unloading the same in response to the suction pressure of the refrigerant, means for selecting one or the other driving means for the compressor, means responsive to the temperature within the vehicle for controlling the operation of the compressor by starting and stopping said motor when the selecting means has selected the electrical driving means, and means for controlling the operation of the compressor by completely unloading or permitting the variable loading of the compressor when the selecting means has selected the mechanical driving means.

2. In a railroad car refrigerating system a variable capacity refrigerant compressor located on the car and cooling means located within the car for lowering the temperature therein, electrical driving means for said compressor including a motor mechanically connected thereto and power generating and storing equipment having electrical connection to said motor, mechanical driving means for driving said compressor at a variable speed, means associated with said compressor for partially unloading the same in response to the suction pressure of the refrigerant, selecting means for selecting one or the other driving means for the compressor, means responsive to the temperature within the car for controlling the operation of the compressor by starting and stopping said motor when the selecting means has selected the electrical driving means, and means for controlling the operation of the compressor by completely unloading or permitting the variable loading of the compressor when the selecting means has selected the mechanical driving means.

3. In a railroad car refrigerating system a variable capacity refrigerant compressor located beneath the car and cooling means located within the car for lowering the temperature therein, electrical driving means for said compressor including a motor mechanically connected thereto and power generating and storing equipment having electrical connection to said motor, mechanical driving means deriving energy from the motion of the car for driving said compressor at a variable speed directly corresponding to the speed of the car, means associated with said compressor for partially unloading the same in response to the suction pressure of the refrigerant, speed-responsive means for selecting one or the other driving mean for the compressor, means responsive to the temperature within the car for controlling the operation of the compressor by starting and stopping said motor when the speed-responsive means has selected the electrical driving means, and means for controlling the operation of the compressor by completely unloading or permitting the variable loading of the compressor when the speed-responsive means has selected the mechanical driving means.

4. In the cooling of vehicles the combination with a vehicle of a refrigerant compressor operated at a variable speed in accordance with the speed of the vehicle, said compressor including a plurality of cylinders and means successively to unload individual cylinders in response to the suction pressure of the refrigerant, means to prevent the compression of refrigerant by any of said cylinders, and a thermostatic device for operating said last-mentioned means in response to the temperature within the vehicle.

5. In a cooling of railroad cars the combination with a car of a refrigerant compressor operated at a speed varying with the speed of movement of the car, said compressor including a plurality of cylinders and means successively to unload cylinders in response to the suction pressure of the refrigerant, means to prevent the compression of refrigerant by any of said cylinders, and a thermostatic device for operating said last-mentioned means in response to the temperature within the car.

6. In the cooling of railroad cars the combination with the car of a refrigerant compressor operated by movement of the car, said compressor comprising a crank shaft having mechanical connection to an axle of the car so as to be driven at a variable speed varying in proportion to the speed of the car, and including a plurality of cylinders and means successively to unload individual cylinders in response to the refrigerant pressure within the compressor, means to prevent the compression of refrigerant by any of said cylinders, and a thermostatic device for operating said

last-mentioned means in response to the temperature within the car.

7. In the cooling of railroad cars the combination with the car of a refrigerant compressor comprising a plurality of cylinders, means successively to unload individual cylinders in response to the suction pressure of the refrigerant, and means to regulate the action of said unloading means in response to the temperature outside of the car.

8. In the cooling of vehicles the combination with a vehicle of a refrigerant compressor comprising a plurality of cylinders, means successively to unload individual cylinders in response to the suction pressure of the refrigerant, means responsive to the temperature within the vehicle to prevent the compression of refrigerant by any of said cylinders, and means to regulate the action of said individual cylinder unloading means in response to the temperature outside of the vehicle.

9. In a refrigerating system, a refrigerant compressor comprising a plurality of cylinders, means successively to unload individual cylinders in response to the suction pressure of the refrigerant being compressed thereby, and means to regulate the action of said unloading means in response to the temperature of the air surrounding said compressor.

10. In a refrigerating system for an enclosure a refrigerant compressor comprising a plurality of cylinders, means successively to unload individual cylinders in response to the suction pressure of the refrigerant, and means to regulate the action of said unloading means in response to the temperature existing outside of the enclosure being refrigerated.

11. In a railroad car refrigerating system a variable capacity refrigerant compressor located on the car and cooling means located within the car for lowering the temperature therein, electrical driving means for driving said compressor including a motor-generator having an armature mechanically connected thereto and power storing equipment deriving a charge from said generator and having electrical connection to said motor, mechanical driving means for driving said compressor at a variable speed in accordance with the speed of the car, said mechanical means comprising a shaft deriving motion from a part of the car, said armature, and a speed-responsive clutch interposed between said shaft and said armature, means associated with said compressor for partially unloading the same in response to the suction pressure of the refrigerant, selecting means for selecting one or the other driving means for the compressor, said selecting means including said clutch and speed-responsive means for selecting either the motoring or the generating function of said motor-generator at critical speeds of the car, means responsive to the temperature within the car for controlling the operation of the compressor by starting and stopping the motoring function of said motor-generator when the selecting means has selected the electrical driving means, and means for controlling the operation of the compressor by completely unloading or permitting the variable loading of the compressor when the selecting means has selected the mechanical driving means.

12. In a railroad car refrigerating system a variable capacity refrigerant compressor located on the car and cooling means located within the car for lowering the temperature therein, electrical driving means for driving said compressor including a motor-generator having an armature mechanically connected thereto and power storing equipment deriving a charge from said generator and having electrical connection to said motor, mechanical driving means for driving said compressor at a variable speed in accordance with the speed of the car, said mechanical means comprising a shaft deriving motion from a part of the car, said armature, and a speed-response clutch interposed between said shaft and said armature, means associated with said compressor for partially unloading the same in response to the suction pressure of the refrigerant, selecting means for selecting one or the other driving means for the compressor, said selecting means including said clutch and speed-responsive means for selecting either the motoring or the generating function of said motor-generator at critical speeds of the car, means responsive to the temperature within the car for controlling the operation of the compressor by starting and stopping the motoring function of said motor-generator when the selecting means has selected the electrical driving means, means for controlling the operation of the compressor by completely unloading or permitting the variable loading of the compressor when the selecting means has selected the mechanical driving means, and means for regulating the action of said partial unloading means in response to the temperature outside of the car.

13. In a vehicle refrigerating system a variable capacity refrigerant compressor located on the vehicle and cooling means located within the vehicle for lowering the temperature therein, electrical driving means for said compressor including a shunt-wound machine having an armature mechanically connected to said compressor and operating said compressor at a constant speed, mechanical driving means including said armature deriving energy from the motion of the vehicle and driving said compressor at a variable speed, means for selecting one or the other driving means for the compressor, and means to vary the capacity of the compressor in accordance with the load thereon and the speed of operation thereof.

14. In air conditioning mechanism for a passenger vehicle, a cooling system comprising a compressor and a surface cooler for treating the air, and means to control said system comprising a low-limit thermostat for stopping said compressor when the inside air reaches a low limit of temperature, a modulating control for said compressor comprising means to vary the capacity thereof in response to the back pressure of the system, and a differential regulating device for altering the action of said modulating control in response to outside temperatures.

15. In air conditioning mechanism for an enclosure, a cooling system comprising a compressor and a surface cooler for treating the air, and means to control said system comprising a modulating control for said compressor comprising means to vary the capacity thereof in response to the back pressure of the system, and a differential regulating device for altering the action of said modulating control in response to outside temperatures.

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