May 5, 1942. H. F. SMITH 2,281,626

REFRIGERATING APPARATUS

Filed March 31, 1939

Fig. 1

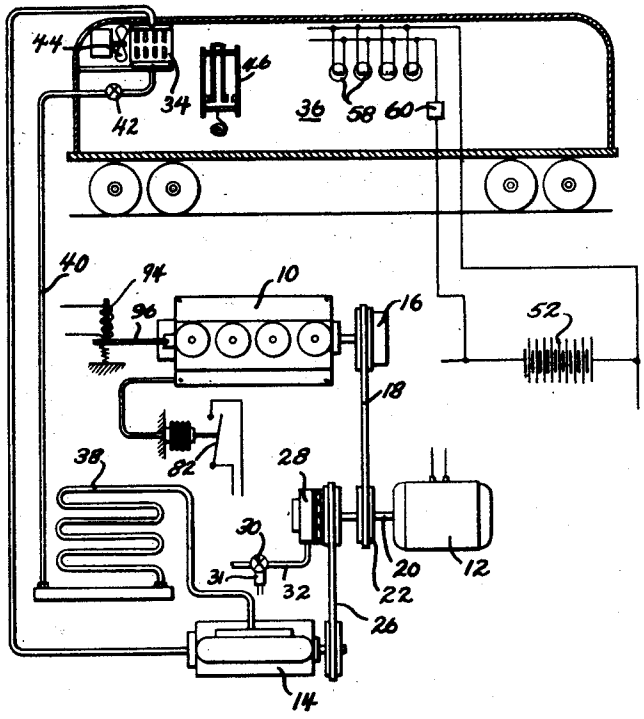
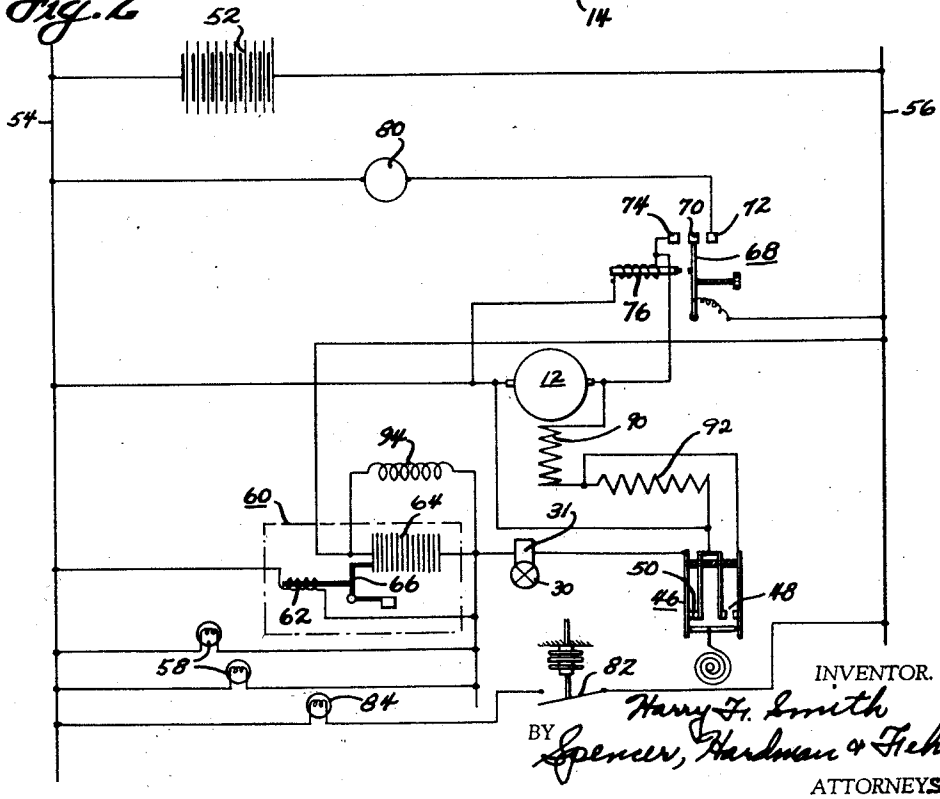


Fig. 2



INVENTOR.
Harry F. Smith
BY Spencer, Hardman & Fehr.
ATTORNEYS.

Patented May 5, 1942

2,281,626

UNITED STATES PATENT OFFICE

2,281,626

REFRIGERATING APPARATUS

Harry F. Smith, Lexington, Ohio, assignor to General Motors Corporation, Dayton, Ohio, a corporation of Delaware

Application March 31, 1939, Serial No. 265,284

14 Claims. (Cl. 62—4)

This invention relates to refrigeration and more particularly to a refrigeration and generation system for use in railway cars and other installations where it is desirable to both generate electricity and condition air.

One object of this invention is to provide an improved system in which an internal combustion engine such as a Diesel engine or the like is used for driving a generator and a compressor.

A further object of this invention is to provide fully automatic controls for a prime mover whereby the output of the prime mover is at all times equal to the load requirements.

Still another object of this invention is to provide a novel control system for starting and stopping the operation of a dynamo-electric machine.

A further object is to provide a novel control system for controlling the operation of a compressor.

Another object of this invention is to provide an improved arrangement for controlling the speed and output of a Diesel engine.

Another object of this invention is to provide an improved power transmitting system.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawing, wherein a preferred form of the present invention is clearly shown.

In the drawing:

Fig. 1 diagrammatically shows a system embodying features of my invention; and

Fig. 2 diagrammatically shows the circuit arrangement used with the system shown in Fig. 1.

In conditioning air for railway cars, it has been common practice to provide a refrigerating system including a compressor driven from the live axle of the car. These systems are not entirely satisfactory for various reasons, one of which was that it was difficult to properly compensate for the changes in the speed of the vehicle and the power available.

In order to overcome the difficulties which were encountered with the old arrangements, I have devised the system shown in the drawing in which a Diesel engine 10 is provided for driving the dynamo-electric machine 12 and the compressor 14. The Diesel engine 10 is provided with a free-wheeling clutch 16 which may be of any conventional and well-known design. The clutch 16 drives the dynamo-electric machine through a belt 18. The dynamo-electric machine shaft 20 carries a first pulley 22 which is driven by the belt 18 and a second pulley 24 which drives the compressor by means of the belt 26. Inasmuch as it is desirable to operate the dynamo-electric machine independently of the compressor, a pneumatic clutch 28 has been provided which makes it possible to operate the dynamo-electric machine as a generator without operating the compressor as will be more fully explained hereinafter. The clutch is controlled by a solenoid valve 30 placed in the air line 32. The compressor 14 is operated whenever refrigeration is required and is in refrigerant flow relationship with the evaporator 34 mounted within the space to be conditioned which, for purposes of illustration, has been shown as a railway car 36. The refrigerant which is compressed by the compressor 14 discharges into a condenser 38 which is connected to the evaporator by means of the liquid refrigerant line 40 in which is placed an expansion valve 42 or any other conventional control for controlling the flow of refrigerant into the evaporator 34. A fan 44 is provided for circulating air over the evaporator. In order to simplify the illustration no control has been shown for the fan 44. However, the flow of air over the evaporator may be maintained constant or it may be varied in response to changes in the psychrometric condition of the air within the conditioned enclosure in any of several well-known ways.

The electrical control system for the Diesel engine 10, the dynamo-electric machine 12 and the compressor 14 comprises a double contact control thermostat generally designated by the reference character 46. The control thermostat 46 includes a first pair of contacts 48 which remain open when full load refrigeration is required and a second pair of contacts 50 which remain closed at all times when the temperature is above a predetermined value at which conditioning is required. The arrangement is such that the contacts 48 close before the contacts 50 open for a purpose to be described more fully hereinafter.

Referring now to Fig. 2 in which is shown the circuit diagram, the battery 52 is connected across the main lines 54 and 56. For purposes of illustration, the lights 58 represent the load on the electrical system. The usual form of carbon pile voltage regulator 60 has been provided and includes the solenoid 62 which is responsive to the voltage across the load 58. The solenoid 62 controls the voltage drop across the carbon pile 64 by means of the usual linkage mechanism 66.

The starting switch 68 comprises a first contact 70 which cooperates with contact 72 in one

extreme position and contact 74 in the other extreme position. The contact 70 is connected directly to the main line 56. The starting switch 68 also comprises the solenoid 76 which is placed directly across the dynamo-electric machine 12. The circuit shown in Fig. 2 illustrates the position of the various switches prior to the starting of the system and with the temperature sufficiently high to require full refrigeration. In order to initiate operation of the system, the starter switch is manually held with contacts 70 and 72 in engagement whereby current flows from the line 56 through the contacts 70 and 72 to the Diesel engine starter 80 and to the line 54. The starting switch is held in this position until the engine 10 has been started at which time a pressure change has been created within the engine chambers. This pressure change causes operation of the pressure responsive switch 82 which is placed in series with the signal lamp 84 across the lines 54 and 56. When the signal lamp 84 is lighted, the starter switch 68 is permitted to return to neutral position.

With the thermostat 46 in the position in which it is shown, it is necessary to supply full capacity refrigeration to the system. Ordinarily, when a system of this type is first placed in operation following a period of idleness, the load on the compressor driving means is higher than usual for a period of time until the pressures in the refrigeration system reach normal operating pressures. This latter period is referred to hereinafter as the period of initial pull-down on the refrigeration system. The engine 10, having been started, will drive the compressor through the freewheeling clutch 16, the generator shaft 20, and the clutch 28. The engine will operate slowly to begin with, but will rather quickly pick up speed until the load capacity of the compressor 14 balances the maximum output of the Diesel engine 10, this maximum output having been adjusted to balance against the maximum refrigeration requirement needed for initial pull-down of the conditioned space. As the car temperature falls due to the operation of the refrigeration system, the refrigeration requirement will become less, whereby the Diesel engine 10 will tend to increase its speed due to the decreased load on the compressor. The increase in speed of the engine 10 results in an increase in the speed of the dynamo-electric machine which now functions as a generator. During this initial pull-down on the refrigeration system, the generator has been running as a free member without imposing any appreciable load upon the engine. However, as the refrigeration load decreases and the speed of the generator increases, the potential across the same increases until the voltage across the generator approaches the battery charging voltage at which time the solenoid 76 will be sufficiently energized to cause the contact 70 of the starting switch 68 to engage the contact 74. When contact 70 engages contact 74 the generator is connected across the battery in battery charging relationship. Closing of the contacts 70 and 74 places the solenoid 76 directly across the battery with the result that the contacts 70 and 74 will be held in engagement permanently until they are manually separated. By virtue of this arrangement, the dynamo-electric machine or generator 12 which is also capable of functioning as a motor is automatically brought up to generating or motoring speed, as the conditions require, without the necessity of a special motor starting control. This is true since, once the generator 12 has been placed across the battery 52 by means of the solenoid 76, the generator will act as a generator if its speed is sufficiently high for it to generate the required voltage, and it will act as a motor at such times when the speed of the same drops sufficiently so that the potential across the generator is less than the potential across the battery. Thus, the generator may either generate or motor without the use of any additional changeover control system.

It will be noted that, with the temperature responsive switch 46 in the position shown in Fig. 2, the generator field winding 90 and the resistance 92 are connected in series. By virtue of this series circuit arrangement, the field strength of the generator is reduced, necessitating a higher speed of the generator before its voltage will equal or exceed the battery voltage for charging purposes. Consequently, more power is available for operating the compressor when the resistance 92 is in series with the field 90. This arrangement is especially desirable at the start of the refrigeration cycle in order to permit the use of a greater refrigeration capacity at such times when the refrigerating load is high. By providing means for cutting in and out this resistance, it is possible to more closely control the refrigerating and generating load conditions. In order to control the speed of the engine 10, a solenoid coil 94 has been placed directly across the carbon pile 64. This solenoid 94 controls the engine throttle 96. When the resistance 92 is in series with the generator field winding 90, a higher speed of the engine is obtainable before the solenoid 94 will affect the speed of the engine. Consequently, the compressor is operated at a higher speed during this time when the need for refrigeration is greatest. As the car temperature begins to fall, the contacts 48 will close whereby the resistance 92 is short-circuited. Short-circuiting of the resistance 92 increases the field strength of the generator which, in turn, increases the voltage output of the generator. This increase in generator voltage will influence the voltage regulator 60 which controls the voltage to the load 58. The change in potential across the voltage regulator causes the solenoid 94 to reduce the speed of the engine 10 to a point at which the generator voltage will be equal to the desired charging voltage. This speed will be somewhat lower than the former speed and will serve to reduce the refrigeration capacity due to the reduction of the compressor speed. This, however, is desirable since the amount of refrigeration required has been lessened. However, at this reduced speed, the generator will be operating at its full capacity. The load on the engine, therefore, will remain substantially the same as under the higher speed condition except for the reduction in the refrigeration load.

By virtue of the fact that one of the inherent characteristics of a Diesel engine is that upon an increase in speed a corresponding increase in horsepower is available, it is possible to balance the load conditions of the above described system under different speeds of the Diesel engine. The above described system makes it possible to properly distribute the power between the refrigerating load and the generating load. It will also be noted that under both high and low speed conditions the generating load remains substantially constant while the battery is being charged. Inasmuch as more power is required to operate

the compressor under high speed conditions, the high load factor at this high speed is offset by the increased horsepower output of the Diesel engine at this high speed.

Assuming now that the Diesel engine has been operating the generator so as to charge the battery and at the same time operating the compressor so as to cool the air within the compartment being conditioned and further assuming that the temperature of the compartment has dropped below that normally desired, the thermostatic switch **46** will operate to open the contacts **50**, thereby deenergizing the solenoid **31** which controls the operation of the valve **30**. The deenergization of the solenoid **31** serves to shut off the air supply to the pneumatic clutch **28** with the result that the compressor **14** is disconnected from the dynamo-electric machine **12**, and consequently the Diesel engine **10**. By disconnecting the compressor from the Diesel engine, the load on the Diesel engine is reduced with the result that the engine will tend to increase its speed and this, in turn, will tend to increase the generator output to the battery above the desired generator charging rate. Inasmuch as an increase in the generator voltage momentarily changes the voltage drop across the coil **94**, the throttle **96** of the Diesel engine is operated so as to decrease the speed of the engine **10**.

The voltage regulator **60** controls the voltage output from the battery **52** to the car lighting system **58** which, in this case, represents the load; and, as the voltage impressed upon the battery increases, the voltage control **60** causes a change in the carbon pile resister so as to maintain the line voltage at the desired level. The potential across the carbon pile **64**, therefore, provides an indication of the voltage being impressed upon the battery by the generator. Consequently, when the voltage from the generator to the battery increases above a desired charging level, the solenoid coil **62** will cause an expansion of the carbon pile **64** with the result that the solenoid **94** will cause a reduction in the speed of the engine **10**. The engine **10** will run at sufficient speed to cause generation as long as the voltage drop across the carbon pile **64** indicates the need for generation. The solenoid **94** operates between a maximum and minimum voltage so that when the battery has become fully charged, the voltage across the carbon pile **64** is at a maximum and the solenoid **94** will have throttled the engine **10** so as to maintain the generator voltage equal to the battery voltage, thereby permitting the generator to float upon the battery in the well-known manner. When the engine **10** is operating the generator only and it becomes necessary to start the compressor, the increase in load on the engine, due to the compressor's being connected, serves to momentarily cause the engine to slow down. As the engine slows down, the potential across the coil **94** is instrumental in operating the throttle **96** so as to increase the speed of the engine until the engine speed is properly balanced with the load.

There are times when it is desirable to operate the compressor without operating the engine **10**, such as when entering a terminal. Under this condition, the engine can be stopped and the dynamo-electric machine **12** will automatically operate as a motor to drive the compressor. Under this condition, the freewheeling clutch **16** on the engine shaft permits the dynamo-electric machine **12** to operate as a motor without driving the engine. The thermostatic controls **46** will, under these conditions, function as a two-speed control for the dynamo-electric machine **12** which is now operating as a motor. When the car temperature is high, the contacts **48** will be open with the result that the resistance **92** is connected in series with the field coil **90**, thereby reducing the field strength and serving to operate the motor at a higher speed. As the temperature of the car is reduced, the contacts **48** will close so as to short out the resistance **92**. By shorting the resistance **92** the field strength is increased whereby the speed of the motor is reduced so as to correspond to the lower refrigeration requirements. In the event that the car temperature is further reduced below that normally desired, the contacts **50** will open so as to operate the solenoid **31** which then disengages the clutch **28**, thereby disconnecting the compressor from the motor.

By virtue of the novel control arrangement described hereinabove, it is possible to balance the power requirements of the compressor and generator against the power of the Diesel engine so that after the system has once been started, the system will function completely automatically so as to shift the load from refrigeration to generation to motor drive and back again without a single operation being necessary on the part of the attendant, other than starting the Diesel engine once it has been stopped.

While I have illustrated a system intended to be mounted directly on a railway car for supplying necessary refrigeration on the car and at the same time supplying the necessary amount of electrical energy for operating the necessary electrical devices, it is obvious that the system is equally suitable for a number of other installations where electrical energy and refrigeration are both desired.

While the form of embodiment of the invention as herein disclosed, constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. In combination, an engine, a dynamo-electric machine, torque transmitting means between said engine and said dynamo-electric machine, a battery, load means energized from said battery, a voltage regulator for maintaining the voltage across said load substantially contant, means whereby the speed of said engine is controlled in response to the voltage drop across said voltage regulator, and means whereby said dynamo-electric machine may be energized as a motor from said battery.

2. In combination, an internal combustion engine, a driven device, torque transmitting means between said engine and said driven device, said torque transmitting means comprising a freewheeling clutch, control means for controlling the speed of said engine so as to balance the power output of said engine with the power requirements of said device, dynamo-electric means for operating said driven device independently of operation of said engine, and temperature responsive means controlling the operation of said dynamo-electric machine,

3. A refrigerating system comprising an evaporator, a condenser and a compressor connected in fluid flow relationship, an engine for operating said compressor, a battery, a dynamo-electric machine in circuit with said battery, torque transmitting means between said dynamo-electric machine and said engine, thermostatic control means controlling the operation of said en-

gine, said thermostatic control means comprising means for operating said engine at a first speed during the initial pull-down on the refrigeration system, operating the engine at a second and lower speed subsequent to the initial refrigeration system pull-down, and means for disengaging said compressor from said engine when no refrigeration is required, said thermostatic control means comprising means for varying the load imposed on said engine by said dynamo-electric machine.

4. A refrigerating system comprising an evaporator, a condenser and a compressor connected in fluid flow relationship, an engine for operating said compressor, a battery, a dynamo-electric machine in circuit with said battery, torque transmitting means between said dynamo-electric machine and said engine, thermostatic control means controlling the operation of said engine, said thermostatic control means comprising means for operating said engine at a first speed during the initial pull-down on the refrigeration system, operating the engine at a second and lower speed subsequent to the initial refrigeration system pull-down, means for disengaging said compressor from said engine when no refrigeration is required, and means for operating said dynamo-electric machine as a motor for driving said compressor when said engine is inoperative, said thermostatic control means comprising means for varying the speed of said dynamo-electric machine when operating as a motor for driving said compressor.

5. In combination, an internal combustion engine, a driven device, torque transmitting means between said engine and said driven device, said torque transmitting means comprising a freewheeling clutch, dynamo-electric means for operating said driven device independently of operation of said engine, and automatic control means for controlling the speed of said engine so as to balance the power output of said engine with the power requirements of said device, said control means including means for varying the speed of said dynamo-electric machine when said dynamo-electric machine operates said driven device independently of operation of said engine.

6. The method of controlling the energy output of a dynamo-electric machine which is operated as a motor driving a refrigerant compressor part of the time and as a generator driven by a separate compressor driving means part of the time which comprises increasing and decreasing the field resistance of said dynamo-electric machine so as to vary the speed of the dynamo-electric machine when operated as a motor and to vary the charging rate when operated as a generator driven by said engine.

7. In combination with a power driven vehicle, an auxiliary Diesel engine, a driven device, torque transmitting means between said engine and said driven device, said torque transmitting means comprising a freewheeling clutch, control means for controlling the speed of said engine so as to balance the power output of said engine with the power requirements of said device, dynamo-electric means for operating said driven device independently of operation of said engine, and means whereby said driven member may be operated independently of said engine.

8. In combination, a volatile refrigerant evaporator, a condenser, a compressor, refrigerant flow connections between said evaporator, condenser and compressor, a battery, a dynamo-electric machine for operating said compressor, means for energizing said dynamo-electric machine as a motor from said battery, temperature responsive means for varying the speed of said motor, means for operating said dynamo-electric machine as a generator for charging said battery, and means responsive to the output of said generator controlling the speed of said last named means.

9. In combination, a battery, a dynamo-electric machine comprising a field winding and an armature winding, circuit connections between said battery and said windings, a resistance element in series with one of said windings, a pump operated by said dynamo-electric machine, an internal combustion engine, drive means between said engine and said dynamo-electric machine whereby said dynamo-electric machine may be operated as a generator driven by said engine, and means for shunting said resistance element in response to a change in pumping requirements.

10. In combination, an engine, a dynamo-electric machine, torque transmitting means including a freewheeling clutch between said engine and said dynamo-electric machine, a refrigerant compressor, torque transmitting means between said compressor and said dynamo-electric machine, said torque transmitting means comprising a clutch for disengaging said compressor from said dynamo-electric machine, control means responsive to refrigerant requirements for varying the speed of said engine, means for energizing said dynamo-electric machine as a motor for operating said compressor independently of said engine, and temperature responsive means controlling the output of said dynamo-electric machine.

11. In combination, an evaporator, a compressor, a condenser, refrigerant flow connections between said evaporator, compressor and condenser, a battery, a generator having a field winding and an armature winding, circuit connections between said generator and said battery, an engine for driving said compressor and said generator, a clutch between said engine and said compressor, a resistance element in series with one of said windings, and thermal means for declutching said compressor at one temperature and for varying said resistance at a different temperature.

12. In a refrigerating system, an evaporator, means for circulating air to be conditioned in thermal exchange relationship with said evaporator, a condenser and a compressor connected in fluid flow relationship with said evaporator, a variable speed engine for operating said compressor, a variable speed motor for operating said compressor, and control means including a thermal element for varying the speed of said engine when said engine operates said compressor and for varying the speed of said motor when said motor operates said compressor.

13. In combination with a power driven vehicle, an auxiliary internal combustion engine, a refrigerating system including a refrigerant compressor, torque transmitting means between said engine and said compressor, said torque transmitting means comprising a clutch, control means for controlling the speed of said engine so as to balance the power output of said engine with the power requirements of said compressor, dynamo-electric means for operating said compressor independently of operation of said en-

gine, and means whereby said compressor may be operated independently of said engine.

14. In combination, a variable speed engine, a variable speed dynamo-electric machine, torque transmitting means between said dynamo-electric machine and said engine, a compressor, torque transmitting means between said compressor and said dynamo-electric machine, a clutch in said first named torque transmitting means, a clutch in said second named torque transmitting means, and means responsive to refrigeration requirements for controlling the speed of said engine.

HARRY F. SMITH.