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FAN SPEED CONTROL FOR REFRIGERATION SYSTEM

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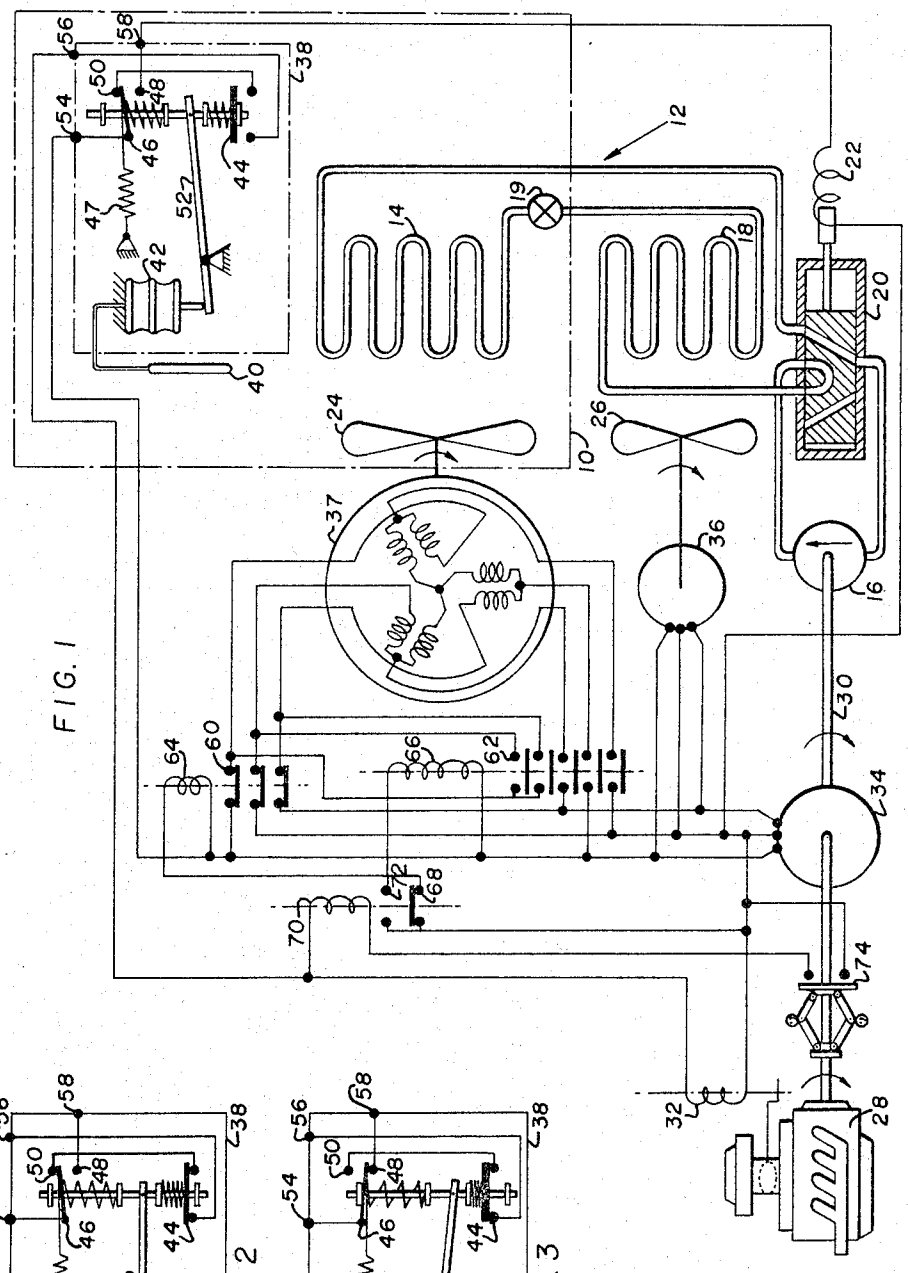


FIG. 1

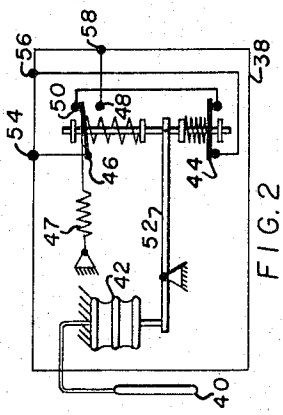


FIG. 2

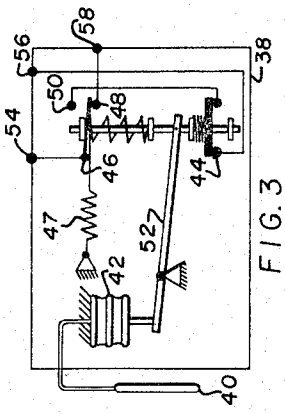


FIG. 3

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FAN SPEED CONTROL FOR REFRIGERATION SYSTEM

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This invention relates to air conditioning systems and more specifically to control means therefor.

This invention has particular utility in transport air conditioning systems used in the transportation of goods which must be maintained at controlled temperatures such as frozen foods and produce. Such systems employ refrigeration systems having the usual refrigerant compressor, condenser, and evaporator serially connected. Fans are generally employed to circulate air within the conditioned space and through the evaporator heat exchanger which is arranged in fluid communication with the conditioned space.

Where heating is required, electrical heaters may be employed or the refrigerant cycle may be reversed or otherwise arranged to pump heat to the heat exchanger associated with the conditioned space.

Generally, a prime mover such as an internal combustion engine with an electric generator is employed to drive the compressor and fans, and the electrical heaters if used.

Of course, the thermal load on the air conditioning system will vary from time to time depending upon several factors including variations in ambient temperatures. It therefore is necessary to control the capacity of such conditioning systems during cooling and heating cycles.

One successful method of control has been to vary the speed of the prime mover. While it has not been found practical to continually match the prime mover speed to the air conditioning load, it is practical to use a continuously running prime mover which is operated at several different speeds to obtain capacity control of the refrigeration system. A two-speed control cycle is most frequently employed. In addition to obtaining a satisfactory capacity control, such systems have the inherent advantage of fewer failures due to starting difficulties as the prime mover runs continuously while the unit is in use.

A disadvantage that has accompanied refrigeration systems employing speed control has been the existence of substantial temperature variations within the conditioned space. These variations present themselves as hot or cold spots in the load which can be particularly detrimental in the case of frozen goods that thaw or chilled produce which freezes.

The theory upon which this invention was conceived is that such hot and cold spots in the conditioned space do not result from the changes in capacity of the conditioning system, but rather from the lack of adequate circulation while the system is operating at reduced speed.

Accordingly a principal object of my invention is to provide an air conditioning system driven by a prime mover operated in at least two distinct speed ranges wherein said prime mover is arranged to circulate air within the conditioned space at a sufficient rate, when the system is operated at the reduced speed.

Another object of the invention is to provide an air conditioning system including a mechanical refrigeration system wherein the compressor and evaporator fan are powered by a prime mover which is varied from one speed range to another in response to the thermal load at the evaporator and wherein means is provided to maintain substantially uniform fan speed in spite of variations in prime mover speed. The term "uniform speed" used with respect to the fan in this specification and attached claims is intended to have reference only to operating conditions

and not to momentary periods during which the prime mover is changing from one speed range to another.

A further object of my invention is to provide a mechanical refrigeration system, employing a variable speed prime mover and generator, with an evaporator fan motor which may be reconnected to present a varying number of active poles whereby the evaporator fan motor may be driven at a uniform speed in spite of variations in speed of the prime mover and generator.

Other objects and advantages will become apparent as this specification proceeds to describe the invention with reference to the accompanying drawing in which like reference numerals designate like parts wherein:

FIGURE 1 is a schematic diagram of an air conditioning system embodying our invention and shown in a high speed cooling cycle;

FIGURE 2 shows the low speed cooling position of the thermostatic control of FIGURE 1; and

FIGURE 3 shows the high speed heating position of the thermostatic control of FIGURE 1.

Now referring to FIGURE 1 it will be seen that an air conditioned space **10**, which may be the cargo space of a railway refrigerator car or refrigerator truck, is provided with a refrigeration system generally designated by numeral **12**. The refrigeration system may be of the conventional reversible heat pump type which includes a first heat exchanger **14** arranged in fluid communication with the conditioned space **10** and preferably is located therein and normally functions as a refrigerant evaporator during the cooling cycle, a refrigerant compressor **16**, a second heat exchanger **18** which may be located outside the conditioned space which normally functions as a refrigerant condenser during the cooling cycle, and a refrigerant throttling means **19** connected respectively in series forming a closed refrigerant circuit. Throttling means **19** may take the form of a capillary tube or a variable orifice expansion valve. The particular refrigeration system shown includes a refrigerant flow reversing valve **20** for reversing the direction of refrigerant flow in the first and second heat exchangers whereby the first heat exchanger **14** may be operated as a refrigerant condenser and the second heat exchanger **18** as a refrigerant evaporator. This system when operating in this reverse manner will hereinafter be referred to as the reverse flow heating cycle or more generically as the heating cycle. Valve **20** is actuated to the reverse flow heating cycle position by energization of cycle selector solenoid **22**.

A fan means **24** is arranged to circulate air in the conditioned space and through heat exchanger **14**. A second fan means **26** may be arranged to circulate air through heat exchanger **18** for the purpose of heat transfer.

Compressor **16** is driven by an internal combustion engine **28** via torque transmitting means **30**. Engine **28** is arranged to operate at two distinct and separate speed ranges, a speed selector solenoid **32** being provided to shift the engine to low speed range when energized. The specifics of the speed control means are well known to those having ordinary skill in the art of engine speed control and do not per se constitute part of the present invention.

Engine **28** in addition to driving compressor **16** also drives a three phase alternating current generator **34**. It is particularly desirable that the change in the generator output voltage due to change in speed be substantially proportional to the change in frequency resulting from changes of speed of the engine **28** within the normal speeds of operation. It is well within the scope of those having ordinary skill in the art of generator design to provide such generator characteristics. A model YE–5294 Delco 230 volt 3 phase 60 cycle A.C. 1200 r.p.m. generator constructed by General Motors Corporation is

suitable for this purpose. This generator may be operated at about 600 r.p.m. to produce 115 volt 30 cycle alternating electric current. Generator 34 is arranged to drive electric motor 36 drivingly connected to fan means 26 and to drive a two speed variable torque reconnected single winding induction motor 37 drivingly connected to fan means 24.

The air conditioning system herein disclosed is provided with a control system which is responsive to temperatures of the conditioned space as by thermostat 38 which is schematically shown. Thermostat 38 functions, as will be seen, to operate the engine speed selector solenoid 32 and the cycle selector solenoid 22 in response to temperatures at the conditioned space. Thermostat 38 includes a temperature sensing bulb 40 disposed in heat exchange relation with the conditioned space and in fluid communication with bellows actuator or thermal motor 42. Thermostat 38 also includes a first switch 44 and a second switch 46, the latter of which may be of the single pole double-throw snap acting type having contacts 48 and 50. Bellows actuator is operatively connected to switches 44 and 46 via appropriate connecting means 52. While thermostat 38 is shown schematicaly, it will be understood that switch 46 has but two positions and that transfer from one position to the other is accomplished substantially instantaneously in a snap action, such as for example via an over center spring 47. Type F43A remote bulb thermostat manufactured and sold by United Electric Controls is suitable for this purpose. Thermostat 38 receives electrical power at terminal 54 from generator 34 and delivers it to the speed selector solenoid 32 via terminal 56 and to the cycle selector solenoid 22 via terminal 58.

Generator 34 is electrically connected to supply electric current to motors 36 and 37. Motor 37 is arranged to be connected for either two pole or four pole operation. A first set of contacts 60 is arranged when closed to connect motor 37 to generator 34 for 4 pole operation. A second set of contacts 62 is arranged when closed to connect motor 37 to generator 34 for two pole operation. Said first and second sets of contacts are closed by energization of coils 64 and 66 respectively.

Coils 64 and 66 are controlled in accordance with the speed of the prime mover 28, i.e. motor 37 is connected for four pole operation when the prime mover and generator are operated at high speed and for two pole operation when the prime mover and generator are operated at low speed.

While motor 37 has been described as a two and four pole three phase motor, it will be understood that the number of poles used for each prime mover speed range may be selected so that the fan means 24 may be driven at substantially uniform speed. Of course, the number of phases used is purely a matter of choice.

Coil 64 is connected to generator 34 for energization through normally closed contact 68 of relay 70. Coil 66 is connected to generator 34 for energization through normally open contact 72 of relay 70. Relay 70 is connected in parallel with speed selector solenoid 32 and in series with governor switch 74 operatively connected to torque transmitting means 30. Governor switch 74 is normally open at high speed operation and closed at low speed operation. The operation of these members will be more fully explained hereinafter with the operation of the entire control system.

Prior to explaining the operation of the control system, it should be mentioned that cycle selector solenoid 22, speed selector solenoid 32, coils 64, 66, and relay 70 all draw their operating power from generator 34 and preferably from one phase thereof. It should be understood, however, that power for this control circuit may be derived from sources other than the generator such as a battery which may be used for starting engine 28. In any event if a source of power is used having a variable frequency and/or voltage such as the generator, elements 22, 32, 64, 66 and 70 may be designed to operate properly in spite of such variations.

Operation

The control system thus described functions to operate the air conditioning system in one of three cycles (high speed heating, low speed cooling and high speed cooling), the cycle of operation being selected by thermostat 38.

FIGURE 1 shows thermostat 38 in the high speed cooling position, i.e. the conditioned space is excessively warm and sensing bulb 40 has expanded bellows 42 to its fully extended condition. Engine 28 is operating at high speed and generator 34 may be for example producing 230 volt, 60 cycle, three phase electric current. Electrical power from one phase is delivered to terminal 54 of thermostat 38. While switch 46 which is connected to terminal 54 is in the position briding contact 50, the circuit including speed selector solenoid 32, relay 70, and contact 50 remains de-energized as switch 44 in series therewith remains open. Speed selector solenoid 32 which is not energized allows the engine 28 to operate at high speed. Since contact 48 of switch 46 is open, no power is delivered by way of terminal 58 to cycle selector solenoid 22 and the system remains in the cooling cycle. Normally closed contact 68 of relay 70 remains closed thus energizing coil 64 closing set of contacts 60 which connect fan motor 37 for four pole operation. Fan motor 37 may operate for example at 1800 r.p.m. on 230 volt, 60 cycle per second electric power delivered from generator 34. Fan motor 36 and compressor 16 operate at high speed and the refrigeration system thus functions at maximum cooling capacity.

As the temperature in the conditioned space falls, sensing bulb 40 and bellows actuator 42 move the thermostat switch 46 to the low speed cooling position as schematically illustrated in FIGURE 2.

In the low speed cooling position speed selector solenoid 32 and relay 70, which are connected in parallel with each other and in series with terminal 56 of thermostat 38, are energized via a circuit including closed switch 44, switch 46 bridging contact 50, and thermostat terminal 54 connected to one phase of generator 34. Cycle selector 22 remains de-energized and in the cooling position.

Since speed selector solenoid 32 thus is energized, the speed of engine 28 is reduced to the low speed range. Compressor 16 is reduced to low speed for low capacity and the electrical output of generator 34 is reduced for example to 115 volts and 30 cycles per second. Fan motor 36 runs at a proportionately lower or reduced speed.

Although speed selector 32 has been energized, it will be noted that relay 70 in parallel therewith becomes energized only after the speed of the engine 28 has been reduced to a predetermined value at which time governor switch 74 which is in series with relay 70 closes. The energization of relay 70 opens contact 68 and closes contact 72 thus switching motor 37 from four pole to two pole operation, but only after the generator has been reduced to a safe speed for connecting motor 37 for two pole operation. In this condition, fan motor 37 may operate for example at 1800 r.p.m. on 115 volts 30 cycles per second electric power from generator 34. Fan means 24 is thus driven at the same speed as when the other portions of the system were operating at high speed.

It should be noted that switch 74 prevents motor 37 from being energized in the two pole operating condition until the generator has reached a sufficiently low speed so as not to momentarily operate motor 37 at excessively high speeds during the transition period.

Should the system thus operating at low capacity cooling be inadequate to maintain the conditioned space at a sufficiently low temperature, thermostat 38 will move

back to its high speed operating position shown in FIGURE 1, actuating engine 28 to high speed, immediately reconnecting motor 37 from two pole operation to four pole operation.

However, should the system be operating at low speed cooling and the temperature in the conditioned space become excessively cool, thermostat 38 will move into the position shown in FIGURE 3 for high speed heating, opening the circuit including contact 50, switch 44, terminal 56, speed selector solenoid 32, and relay 70 and closing the circuit including contact 48, terminal 58, and cycle selector solenoid 22. De-energization of solenoid 32 and relay 70 respectively actuate the engine 28 to high speed and immediately reconnect motor 37 for four pole operation. Energization of cycle selector solenoid 22 places the system on the reverse flow heating cycle by actuating reversing valve 20.

The system now operates at high speed heating. Should the temperature of the conditioned space become excessively high, the thermostat 38 will move into the low speed cooling position shown in FIGURE 2 as previously described. Again it will be noted that during this transition, fan motor 37 is delayed by governor switch 74 from being connected for two pole operation until the engine and generator speed have been sufficiently reduced so that fan motor 37 is not momentarily operated at excessively high speeds.

Thus, it is seen that while engine 28, generator 34, fan motor 36 and compressor 16 are operated at two distinct speed ranges to obtain capacity control to accommodate the air conditioning load, fan means 24 which is driven by engine 28 is operated at substantially uniform speed to effect uniform circulation in the conditioned space.

It will be evident that it is possible to place governor switch 74 in series with coil 66. The desirability of this arrangement will depend largely upon the coasting time for motor 37.

Sets of contacts 60 and 62 may also be actuated directly by relay 70 and in such case contacts 60 would be of the normally closed type.

Although I have described in detail the preferred embodiments of my invention, I contemplate that many changes may be made without departing from the scope or spirit of the invention and I desire to be limited only by the claims.

I claim:

1. An air conditioning system comprising in combination with a conditioned space; an air conditioning apparatus disposed in heat exchange relationship with said space; fan means for circulating air in the conditioned space; prime mover means for providing power to said air conditioning apparatus and said fan means; means responsive to the temperature of the conditioned space for varying the speed of the prime mover and thereby varying the capacity of the air conditioning apparatus; and means raising the ratio of fan speed to prime mover speed at reduced prime mover speeds.

2. The structure of claim 1 wherein said air conditioning apparatus includes means for heating said conditioned space.

3. The structure of claim 1 wherein said air conditioning apparatus includes a mechanical refrigeration mechanism.

4. An air conditioning system comprising in combination with a conditioned space; an air conditioning apparatus disposed in heat exchange relationship with said space; fan means for circulating air in the conditioned space; prime mover means for providing power to said air conditioning apparatus and said fan means; means responsive to the temperature of the conditioned space for varying the speed of the prime mover and thereby varying the capacity of the air conditioning apparatus; and means tending to maintain said fan means at a uniform speed in spite of said variations in prime mover speed.

5. An air conditioning system comprising in combination with a conditioned space; a mechanical refrigeration system including a first heat exchanger, a refrigerant throttling means, a second heat exchanger and a refrigerant compressor serially connected in a closed refrigerant circuit; fan means for passing air in heat exchange relation with said first heat exchanger to said conditioned space; electric motor means for driving said fan means; a prime mover; means for drivingly connecting said prime mover to said electric motor means and said compressor; said last named means including an electric generator; means for varying the capacity of said compressor at least in part by cycling said prime mover among at least two distinct and separate speed ranges; means for connecting said generator to said electric motor; and means for changing the ratio of generator speed to electric motor speed upon a change in prime mover speed from one speed range to another.

6. The device as defined by claim 5 wherein said means for changing the ratio of generator speed to electric motor speed includes means for reconnecting said electric motor for changing the number of active poles thereof.

7. The device as defined by claim 6 wherein said means for reconnecting said electric motor includes switch means responsive to the speed of said prime mover which prevents said motor from being reconnected for operation with a reduced number of active poles until the speed of said prime mover has been reduced to a predetermined minimum.

8. The device as defined by claim 6 wherein said electric motor is a two-speed variable torque reconnected single winding induction motor.

9. The device as defined in claim 5 wherein said electric generator is of the alternating current type wherein the change in output voltage due to change in speed is substantially directly proportional to the change in frequency resulting from changes in speed within the normal speeds of operation.

10. A refrigeration system comprising an evaporator, refrigerant throttling means, a condenser and compressor serially connected to define a closed refrigerant circuit, a first fan means for circulating a fluid medium in heat exchange relation with said evaporator, second fan means for passing a cooling medium over said condenser, means for reducing the speed of operation of said compressor and said second fan means when the load on said evaporator is low, and means for maintaining the speed of said first fan means in spite of the reduction of speed of said compressor and second fan means.

11. In a refrigeration system including a compressor adapted to be operated in at least two distinct and separate speed ranges, a condenser, a refrigerant throttling means and an evaporator serially connected in a closed refrigerant circuit and fan means disposed in fluid flow communication with said evaporator for passing air in heat exchange relation therewith; the improvement comprising an electric motor adapted to be supplied alternating current of at least two distinct frequencies; means drivingly connecting said motor to said fan means; and means for reconnecting said motor to present at least two different numbers of active poles whereby said fan may be operated at a uniform speed in spite of said variations in frequency supplied to said motor.

References Cited by the Examiner

UNITED STATES PATENTS

2,039,240	4/1936	Frese	62—181
2,887,853	5/1959	Talmey	62—323
3,010,289	11/1961	Kuklinski	62—323
3,214,931	11/1965	Petranek	62—323

WILLIAM J. WYE, *Primary Examiner.*