

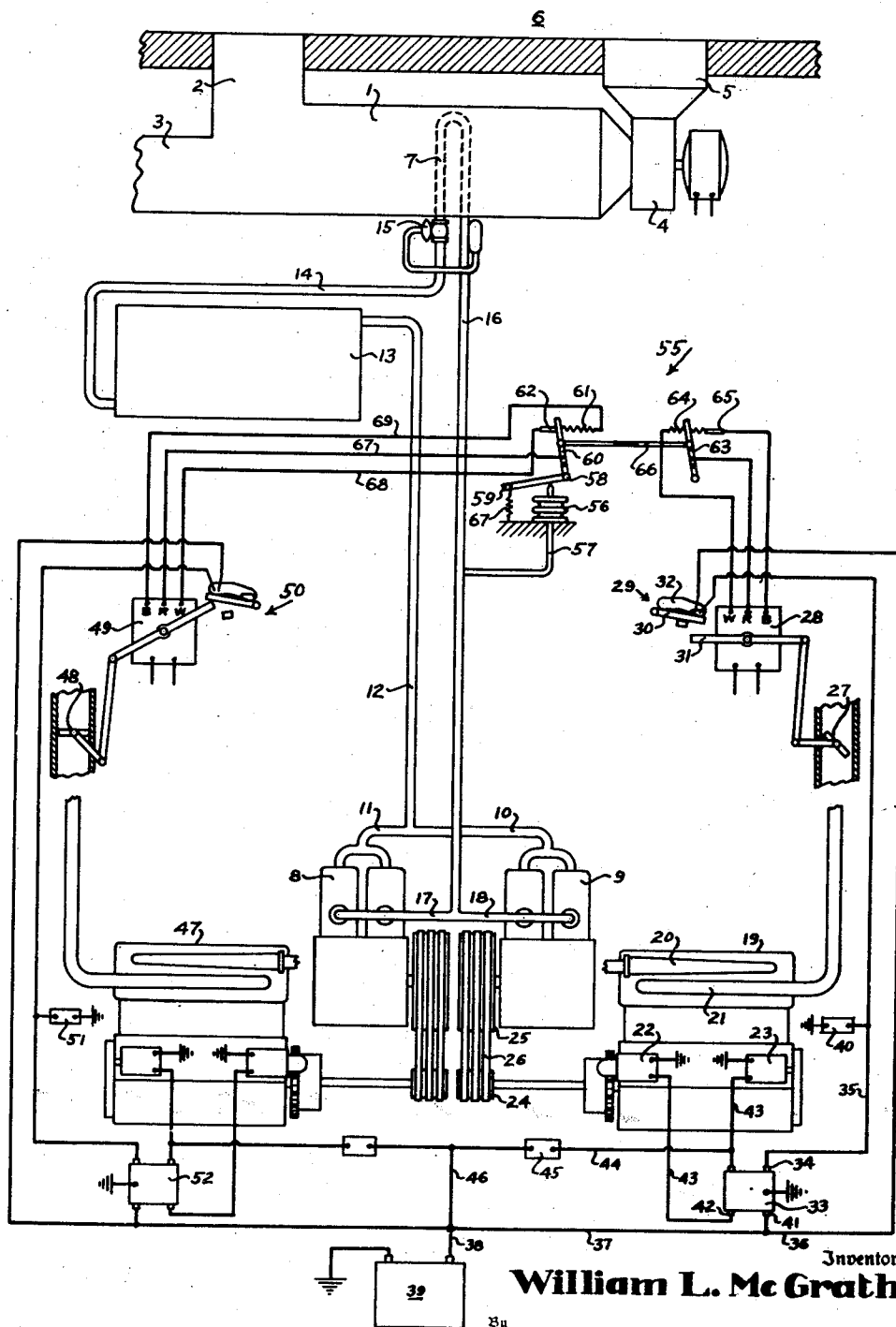
Feb. 17, 1942.

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2,273,281

CONTROL SYSTEM

Filed July 11, 1938



UNITED STATES PATENT OFFICE

2,273,281

CONTROL SYSTEM

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Application July 11, 1938, Serial No. 218,577

17 Claims. (Cl. 62—4)

This invention relates in general to automatic controls and is more particularly concerned with automatic controls for systems utilizing a plurality of prime movers.

In large refrigeration systems it is desirable to utilize a number of independently driven compressors. For providing economy in operation and flexibility of control, it is desirable to utilize internal combustion engines for driving the compressors. Thus by varying the engine speed and the number of engines in operation, the compressor displacement may be varied over a very wide range.

It is the primary object of this invention to provide an automatic control system for refrigeration systems of this general character and which will automatically increase the speed of the first engine to a maximum and then start the second engine as the load increases. Thus as the cooling load on the system increases as evidenced by increased suction pressure, the speed of the first engine will be increased and then the second engine will be started, this action being obtained by the use of a suction pressure responsive device.

One problem encountered in control systems of this nature is short-cycling of the second compressor. Thus as the suction pressure rises to a value at which the second compressor is placed into operation, this compressor will provide more displacement than is necessary due to the fact that the output of the second engine cannot economically be reduced below 25 per cent of its capacity. Thus when the second compressor is placed into operation, it will cause the suction pressure to be reduced quickly to a value for placing the compressor out of operation and this cycle will repeat continuously until such time as the load is high enough to retain both engines in operation.

It is a further object of my invention to provide an arrangement for avoiding the above mentioned difficulty. In accordance with my invention, I provide for sequential control of the two engines in accordance with suction pressure and arrange the suction pressure controlling means in a manner to cause the operating ranges of the first and second engines to overlap to a predetermined extent. With this arrangement, when the second engine is started, the reduction in suction pressure resulting therefrom will cause the speed of both engines to be decreased an amount necessary to just balance the compressor displacement against the load. This arrangement eliminates short-cycling of the second com-

pressor and additionally provides for a continuous unbroken range of compressor capacities from a minimum to the maximum.

Another object of my invention therefore is the provision of a control arrangement for a pair of prime movers which controls the prime movers in sequence and in which the control ranges for the two prime movers overlap.

A further object of this invention is the provision of a control system for a pair of internal combustion engines which varies the output of the engines in sequence and which utilizes a wide differential switching mechanism for placing the second engine into operation, this wide differential switching mechanism permitting slowing down of the second engine after it has been started without stopping the engine.

Another object of this invention is the provision of a sequential control arrangement for a pair of prime movers which operates to first place one prime mover into operation and then to place a second prime mover into operation and which provides for reducing the capacity of the first prime mover when the second prime mover is placed into operation.

Other objects of this invention will become apparent from the following description and the appended claims. While this invention is particularly adaptable to refrigeration systems utilizing internal combustion engine driven compressors, the invention is applicable to other types of systems and to other types of prime movers.

For a full disclosure of my invention, reference is made to the following detailed description and to the accompanying drawing, the single figure of which illustrates a refrigeration system including two internal combustion engine driven compressors which are controlled in accordance with one form of my invention.

Referring to the drawing, reference character 1 indicates an air conditioning chamber having a return or inlet duct 2 leading from a space being conditioned, and a fresh air inlet duct 3. The chamber 1 is connected to a fan 4 which causes air to flow through the chamber and to be discharged through a duct 5 to a space to be conditioned 6. Located within the conditioning chamber 1 is a direct expansion cooling coil 7. This cooling coil forms a part of a refrigeration system including compressors 8 and 9 which are connected by pipes 10, 11 and 12 to a condenser 13. This condenser, in turn, is connected by a liquid line 14 to a thermostatic expansion valve 15 located at the inlet of cooling coil 7. The out-

let of this cooling coil is connected by a suction line 16 and pipes 17 and 18 to the compressors 8 and 9. The compressors 8 and 9, it will be noted, are connected in parallel relationship.

The compressor 9 may be driven by an internal combustion engine 19 which may be of the usual type including an exhaust manifold 20, an intake manifold 21, a starting motor 22, and a generator 23. This engine is indicated as driving the compressor 9 through pulleys 24 and 25 over which run belts 26. The engine 19 may be provided with a suitable form of speed controller such as the throttle valve 27. This throttle valve is positioned through a suitable linkage by means of a proportioning motor 28 which may be of the type shown and described in Patent No. 2,028,110, issued to Daniel G. Taylor on January 14, 1936. This type of proportioning motor is provided with control terminals indicated as R, B and W, and is adapted to assume intermediate positions depending upon the relative values of resistances connected between terminals R and B and R and W. Due to this characteristic, the proportioning motor 28 is adapted to be controlled by means of a potentiometer controller and will assume positions corresponding to the position of the potentiometer slider upon its resistance.

The proportioning motor 28 in addition to actuating the throttle valve 27 also actuates an auxiliary switch 29 which is diagrammatically illustrated as comprising a switch carrier 30 which is adapted to be actuated by a lever 31 attached to the proportioning motor shaft. This switch carrier 30 carries a mercury switch 32 of the wide angle type. This mercury switch, it will be noted, is bent at its center so as to require tilting through a considerable angle to cause its globule of mercury to travel from one end to the other. The purpose of this wide angle type switch 32 is to control the ignition circuit and an automatic starting circuit for the engine 19. While this auxiliary switch has been illustrated as taking the form of a mercury switch, it will be understood that this switch may take other forms, and may be provided with adjustments for varying the positions of the throttle valve at which the switch is opened and closed.

Referring now to the electrical circuit for the engine 19, this may be of any suitable type and is herein illustrated as of a type similar to that utilized in automobile engines. Reference character 33 indicates an automatic starting relay for controlling the starting motor 22. This relay may be of any suitable type and if desired may be of the type shown and described in the Loehr et al. Patent 1,773,913, dated August 26, 1930. This type of starting relay is adapted to energize the starting motor when the ignition circuit is closed and is provided with a control terminal 34 which is connected by a wire 35 to the mercury switch 32. This mercury switch, in turn, is connected by wires 36, 37 and 38 to a storage battery 39. The wire 35 is also connected to the engine ignition coil 40. It will be apparent that when mercury switch 32 is closed due to the proportioning motor 28 opening the throttle valve 27 to a predetermined position, parallel circuits will be established for energizing the ignition coil 40 and the relay 33. This energization of relay 33 will cause it to complete a circuit from storage battery 39 through wires 38, 37, terminal 41, terminal 42, and wire 43 to the starting motor 22. The engine will thus automatically be started upon closure of the mercury switch 32. When the engine starts, the

relay 33 will automatically deenergize the starting motor 22 and will maintain the starting motor 22 deenergized so long as the engine is in operation as evidenced by operation of generator 23. For this purpose the relay 33 is provided with a terminal connected by wire 43 to the generator 23. The wire 43 is also connected by a wire 44, reverse current relay 45, wire 46, and wire 38 to the storage battery 39 for charging this battery when the engine 19 is in operation. It will be apparent that when mercury switch 32 opens, the ignition coil 40 will be deenergized and also the relay 33 will be deenergized thus stopping the engine 19.

The compressor 8 is driven by means of an internal combustion engine 47 which is provided with a throttle valve 48, this throttle valve being positioned by a proportioning motor 49 which is of the same type as the proportioning motor 28 which operates the throttle valve 27. This proportioning motor also operates an auxiliary switch 50 which is also of the wide differential type. This switch is arranged so as to open when the throttle valve 48 reaches substantially closed position and so as to close when the throttle valve is moved to a predetermined open position. This auxiliary switch 50 controls the energization of an ignition coil 51 and a starting relay 52 for the engine 47. This arrangement is exactly the same as for engine 19 previously described and accordingly is not described here in detail.

The proportioning motors 28 and 49 may be controlled by means of a suction pressure controller generally indicated as 55. This suction pressure controller is diagrammatically illustrated as including a bellows 56 connected by a tube 57 to the suction line 16. This bellows 56 actuates a bell-crank lever 58 having an actuating arm 59 and a control arm or slider 60 which cooperates with a resistance 61 and a contact strip 62 for forming a control potentiometer. The controller 55 also includes a second slider 63 which cooperates with a resistance 64 and a contact strip 65 for forming a second control potentiometer. The slider 63 is actuated simultaneously with the slider 60 by any suitable means such as an insulated link 66. When the suction pressure is below a predetermined value, the bellows 56 will be collapsed by the biasing action of spring 67 sufficiently to cause slider 63 to engage the left-hand end of resistance 64, the slider 60 engaging the left-hand end of contact strip 62 at this time. As the suction pressure increases, the bellows 56 will expand, thus causing movement of the sliders 60 and 63 to the right. Upon movement of the sliders to the right, the slider 63 will traverse its resistance 64 while slider 60 merely travels on contact strip 62. Upon further increase in suction pressure, the slider 60 will traverse the left-hand portion of resistance 61 while the slider 63 will traverse the right-hand portion of the resistance 64. Then upon still further increase in suction pressure, the slider 60 will traverse the right-hand portion of resistance 61 while the slider 63 will traverse the contact strip 65.

The controller formed of slider 60, resistance 61, and contact strip 62 controls the proportioning motor 49 and is connected to this motor by wires 67, 68, and 69. The controller formed of slider 63, resistance 64, and contact strip 65 controls the proportioning motor 28. As the slider 63 moves to the right across resistance 64 the proportioning motor 28 will open the throttle

valve 27, to cause the position of throttle valve 27 to correspond to the position of slider 63 on resistance 64. Similarly, as slider 60 moves to the right across resistance 61, the proportioning motor 49 will open throttle valve 48 an amount proportionate to the movement of slider 60 on resistance 61.

Operation

With the parts in the positions shown, the suction pressure is at an intermediate value as indicated by the slider 63 engaging the center of resistance 64 and the slider 60 engaging the left-hand end of resistance 61. Due to slider 63 engaging the center of resistance 64, the proportioning motor 28 has positioned the throttle valve 27 at approximately half-open position. This has permitted closing of the auxiliary switch 29 which causes operation of the engine 19 at half speed. Due to slider 60 engaging the contact strip 62, the proportioning motor 49 has completely closed the throttle valve 48 and also opened the auxiliary switch 50 for maintaining the engine 47 out of operation. If the load upon the system decreases, less refrigerant will be evaporated within cooling coil 7 and this will cause the suction pressure to decrease. This decrease in pressure will cause slider 63 to move to the left across resistance 64, thus causing the proportioning motor 28 to move throttle valve 27 towards closed position for decreasing the engine speed. Thus as the load upon the system decreases, the speed of engine 19 will be decreased. It will be apparent that as the load upon the system continues to decrease, the motor 28 will completely close throttle valve 27 and open the auxiliary switch 29, thus placing the engine out of operation.

The engine will then remain at rest while refrigerant will continue to evaporate within cooling coil 7, this causing the suction pressure to increase. This will cause movement of the slider 63 to the right across resistance 64 for opening the throttle valve 27. Due to the wide differential action of the auxiliary switch 29, this switch will not close immediately upon the throttle valve 27 beginning to open, but will remain open until the throttle valve 27 opens to a predetermined minimum position. When the suction pressure rises to a value sufficient for causing closing of the auxiliary switch 32, the engine 19 will be replaced into operation. Immediately upon the engine starting, the action of compressor 10 will reduce the suction pressure which will cause the controller 55 to start moving throttle valve 27 towards closed position. However, due to the wide differential of the auxiliary switch 29, this switch will not be opened and consequently the engine will remain in operation for a considerable period of time even at light loads. The wide differential of the auxiliary switch 29 thus prevents short-cycling of the compressor.

As the load upon the system increases, the suction pressure will continue to increase. When the suction pressure reaches a value at which the slider 60 engages the resistance 61, the proportioning motor 49 will begin opening the throttle valve 48. At the same time, the proportioning motor 28 will open throttle valve 27 wider for increasing the speed of engine 19. Due to the wide differential of auxiliary switch 50, this switch will not close immediately upon the throttle valve 48 beginning to open. However, when the suction pressure increases to a value at which the

engine 19 is operating at full speed, the proportioning motor 49 will have opened valve 48 sufficiently for closing auxiliary switch 50. This closing of auxiliary switch 50 will place the engine 47 into operation for thus aiding engine 19 in carrying the load. When engine 47 starts, the additional action of compressor 8 will cause the suction pressure to begin falling. At this time, the sliders 60 and 63 will both be traversing their respective resistances 61 and 64. Thus as the suction pressure decreases, the slider 60 will move to the left upon resistance 61 for slowing down engine 47, and the slider 63 will move to the left across resistance 64 for slowing down engine 19. Due to the wide differential of the auxiliary switch 50, this switch will remain closed while throttle valve 48 is being shifted for slowing the engine 47. The engine 47 will therefore remain in operation even though the throttle valve 48 is being moved towards closed position. Due to this simultaneously slowing down of engines 19 and 47, the dropping of the suction pressure due to the starting of engine 47 will be overcome and thus both engines will assume speeds for just balancing the compressor displacement against the prevailing load. Upon continued increase in the cooling load, it will be apparent that the suction pressure will increase thus causing the speed of both engines to be simultaneously increased. After the speed of engine 19 has been increased to a maximum, continued increase in cooling load will cause further increase in the speed of engine 47 for thereby carrying the cooling load.

From the foregoing description, it will be apparent that my invention provides for the sequential control of the pair of internal combustion engines and which increases the speed of one engine to a maximum and then places the second engine into operation. As the placing of the second engine into operation will provide more cooling action than necessary, the speeds of the first engine and of the second engine are decreased just enough so that the combined effect of the engines just carries the load. These results are obtained by the use of sequentially actuated controllers for the two engines, the ranges of the sequentially actuated controllers being overlapped in part for providing simultaneous control of both engines when the second engine has just been started. This arrangement in which the speed of the first engine is reduced when the second engine is started, provides for operating the second engine at a reasonably high capacity while at the same time providing for a smooth and unbroken range of power from a minimum to a maximum. This feature provides for operating the second engine over long periods of time instead of causing the second engine to continuously start and stop when the load upon the system is just slightly more than can be carried by one engine.

While I have shown and described my invention as applied to a refrigeration system utilizing a pair of internal combustion engine driven compressors, it will be apparent that my invention is of broader scope and is applicable to other types of systems and to other types of prime movers. Also, while the invention is illustrated as controlling only a pair of prime movers in sequence, it will be understood that as many prime movers as necessary may be sequentially controlled by enlarging the control system. As many modifications and adaptations of my invention will occur to those skilled in the art, I desire

to be limited only by the scope of the appended claims.

I claim as my invention:

1. In a system of the class described, in combination, a first prime mover, a second prime mover, load condition responsive means, a first controller for graduately varying the speed of said first prime mover, a second controller for starting and graduately varying the speed of said second prime mover, said first and second controllers being sequentially and partially overlappingly actuated by said condition responsive means in a manner to increase progressively the speed of one of said prime movers, and then to start and increase progressively the speed of said other prime mover upon increase in load.
2. In a system of the class described, in combination, a first prime mover, a second prime mover, a first controller for varying the speed of said first prime mover in accordance with variations in load as the load varies through a predetermined range and a second controller for varying the speed of said second prime mover as the load varies through a predetermined different range, the ranges of said first and second controllers partially overlapping.
3. In a system of the class described, in combination, a first prime mover, a second prime mover, load condition responsive means for sequentially controlling said prime movers, said load condition responsive means including means for graduately varying the speed of said first prime mover as the load varies through a predetermined range in a manner to increase the speed of said first prime mover upon increase in load, said load condition responsive means also including means for starting and graduately varying the speed of said second prime mover as the load varies through a predetermined different range, in a manner to increase the speed of said second prime mover upon increase in load, said ranges partially overlapping to provide for simultaneous variation in speed of both of said prime movers within a predetermined load range.
4. In a system of the class described, in combination, a first prime mover, a second prime mover, load responsive means for sequentially controlling said prime movers in accordance with variations in load, said load responsive means being arranged to increase the speed of said first prime mover to a predetermined maximum and then to place said second prime mover into operation, and means for appreciably reducing the speed of said first prime mover as soon as said second prime mover is placed into operation.
5. In a system of the class described, in combination, a first prime mover, a second prime mover, load responsive means for sequentially controlling said prime movers in accordance with variations in load, said load responsive means being arranged to increase the speed of said first prime mover to a predetermined maximum and then to place said second prime mover into operation, and means for reducing the speed of said second prime mover to a value lower than its initial value while maintaining said second prime mover in operation.
6. In a system of the class described, in combination, a first internal combustion engine, a second internal combustion engine, a speed controller for said first engine, a speed controller for said second engine, a starting circuit for said second engine, load condition responsive means for actuating said speed controllers in a manner

to first increase the speed of the first engine and then to increase the speed of the second engine, and switching means actuated with said speed controllers for closing said starting circuit when the speed of the first engine is increased to a predetermined value.

7. In a system of the class described, in combination, a first internal combustion engine, a second internal combustion engine, a speed controller for said first engine, a speed controller for said second engine, load condition responsive means for actuating said speed controllers in a manner to increase the speed of said first engine as the load varies through a predetermined range, and to increase the speed of said second engine as the load varies through a predetermined higher range, said ranges overlapping in part, an electric circuit for said second engine, and means for closing said electric circuit when the load increases to a predetermined value, and for maintaining said electric circuit closed until the load falls to a predetermined lower value.

8. In a system of the class described, in combination, a first pumping means, a second pumping means connected to said first pumping means, a first prime mover for driving said first pumping means, a second prime mover for driving said second pumping means, means responsive to the pressure at a point in said system affected by both of said pumping means for controlling said prime movers, said pressure responsive means including means for graduately varying the output of said first prime mover as said pressure varies through a predetermined range, said pressure responsive means also including means for graduately varying the output of said second prime mover as said pressure varies through a predetermined different range, said ranges partially overlapping to provide for simultaneous variation in output of both of said controllers through a predetermined intermediate load range, and said pressure responsive means being operative whenever said pressure lies within said predetermined ranges to control the respective prime mover regardless of what value said pressure previously has had.

9. In a refrigeration system, in combination, an evaporator, a first compressor connected to said evaporator for withdrawing evaporated refrigerant therefrom, a second compressor also connected to said evaporator, a first prime mover for driving said first compressor, a second prime mover for driving said second compressor, means responsive to the pressure of the evaporated refrigerant for controlling said prime movers, said pressure responsive means including means for varying the output of said first prime mover as said pressure varies through a predetermined range, and means for varying the output of said second prime mover as said pressure varies through a predetermined different range, said ranges partially overlapping to provide for simultaneous variation in output of both of said compressors through a predetermined intermediate load range.

10. In a system of the class described, in combination, a first internal combustion engine, a second internal combustion engine, a first electric motor means for gradually varying the speed of said first engine, a second electric motor means for gradually varying the speed of said second engine, a load responsive device, a pair of current controllers actuated sequentially by said load responsive device for controlling said

motor means, and means actuated by said motor means for stopping and starting said engines.

11. In a system of the class described, in combination, a first prime mover, a second prime mover, a first controller for gradually varying the output of said first prime mover, a motor for positioning said first controller, a second controller for gradually varying the output of said second prime mover, a motor for positioning said second controller, a control circuit for said first motor, a control circuit for said second motor, a first variable resistance type controller in the control circuit of the first motor, a second variable resistance type controller in the control circuit of said second motor, a load condition responsive controller, and means controlled by said load condition responsive controller for actuating said variable resistance type controllers in sequence.

12. In a system of the class described, in combination, a first prime mover, a second prime mover, a first controller for gradually varying the output of said first prime mover, a motor for positioning said first controller, a second controller for gradually varying the output of said second prime mover, a motor for positioning said second controller, a first control means for said first motor, a second control means for said second motor, a device associated with said first control means for varying the position assumed by said first motor, a device associated with said second control means for varying the position assumed by said second motor, a load condition responsive controller, and means actuated by said load condition responsive controller for actuating said devices in sequence.

13. In a system of the class described, in combination, a first internal combustion engine, a second internal combustion engine, a first controller for gradually varying the output of said first engine, a second controller for gradually varying the output of said second internal combustion engine, a first motor for positioning said first controller, a second motor for positioning said second controller, a first control means for said first motor, a second control means for the second motor, a device associated with said first control means for varying the position assumed by said first motor, a device associated with said second control means for varying the position assumed by said second motor, load condition responsive means for gradually actuating said devices for thereby positioning said motors, an electric circuit for one of said engines, and switching means actuated by one of said motors for controlling said switching means.

14. In a system of the class described, in combination, a first internal combustion engine, a second internal combustion engine, a first controller for gradually varying the output of said first engine, a second controller for gradually varying the output of said second internal combustion engine, a first motor for po-

sitioning said first controller, a second motor for positioning said second controller, a first control means for said first motor, a second control means for the second motor, a device associated with said first control means for varying the position assumed by said first motor, a device associated with said second control means for varying the position assumed by said second motor, load condition responsive means for gradually actuating said devices for thereby positioning said motors, an electric circuit for starting said second engine, switching means for controlling said electric circuit, means actuated when the load on the system increases to a predetermined value for actuating said switching means to start said second engine, and means for reducing the output of said first engine upon starting of said second engine.

15. In a refrigeration system, in combination, an evaporator, a first compressor connected to said evaporator for withdrawing evaporated refrigerant therefrom, a second compressor also connected to said evaporator, a first prime mover for driving said first compressor, a second prime mover for driving said second compressor, and load condition responsive means acting upon increase in load to first increase the output of said first prime mover, to start said second prime mover, and to increase the output thereof upon continued increase in load, said load condition responsive means reducing the output of said first prime mover when the second prime mover is started.

16. In a refrigeration system, in combination, an evaporator, a first compressor connected to said evaporator for withdrawing evaporated refrigerant therefrom, a second compressor also connected to said evaporator, a first internal combustion engine for driving said first compressor, a second internal combustion engine for driving said second compressor, a controller for gradually varying the output of said first engine, a starting circuit for said second engine, switching means for controlling said starting circuit, and load responsive means for actuating said controller and switching means in sequence, said load responsive means reducing the output of the first engine when the second engine is started.

17. In a system of the class described, a first prime mover, a second prime mover, load responsive means for gradually increasing the speed of said first prime mover in response to increase in load until said first prime mover is operating at maximum speed, and means actuated by said load responsive means as a result of a further load increase for starting said second prime mover at a speed greater than its minimum speed, said load responsive means then reducing the speed of both prime movers to balance the load which caused the starting of the second prime mover.

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