CONTROL SYSTEM

Filed March 15, 1939 2 Sheets-Sheet 1

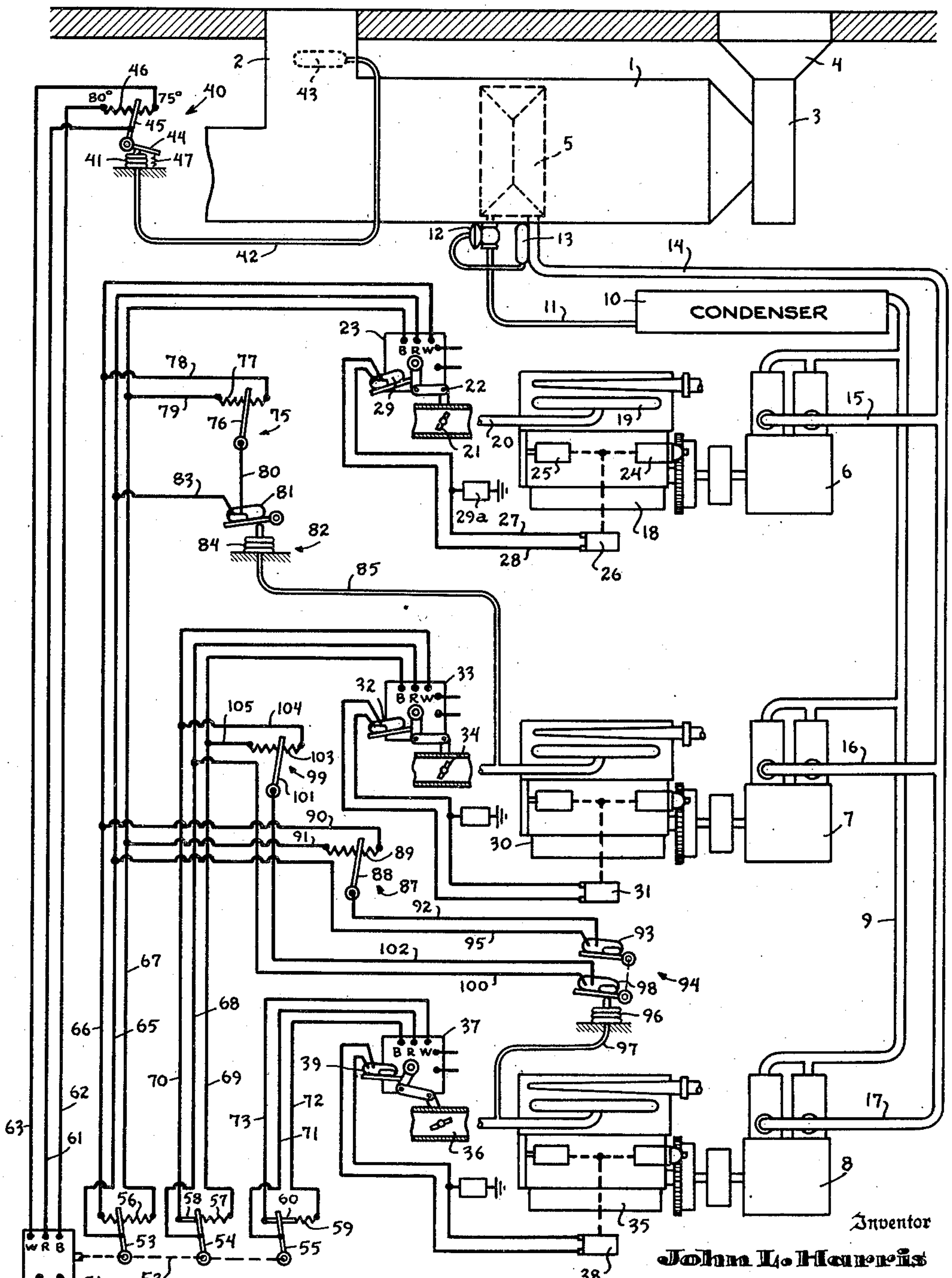

Fig. 1

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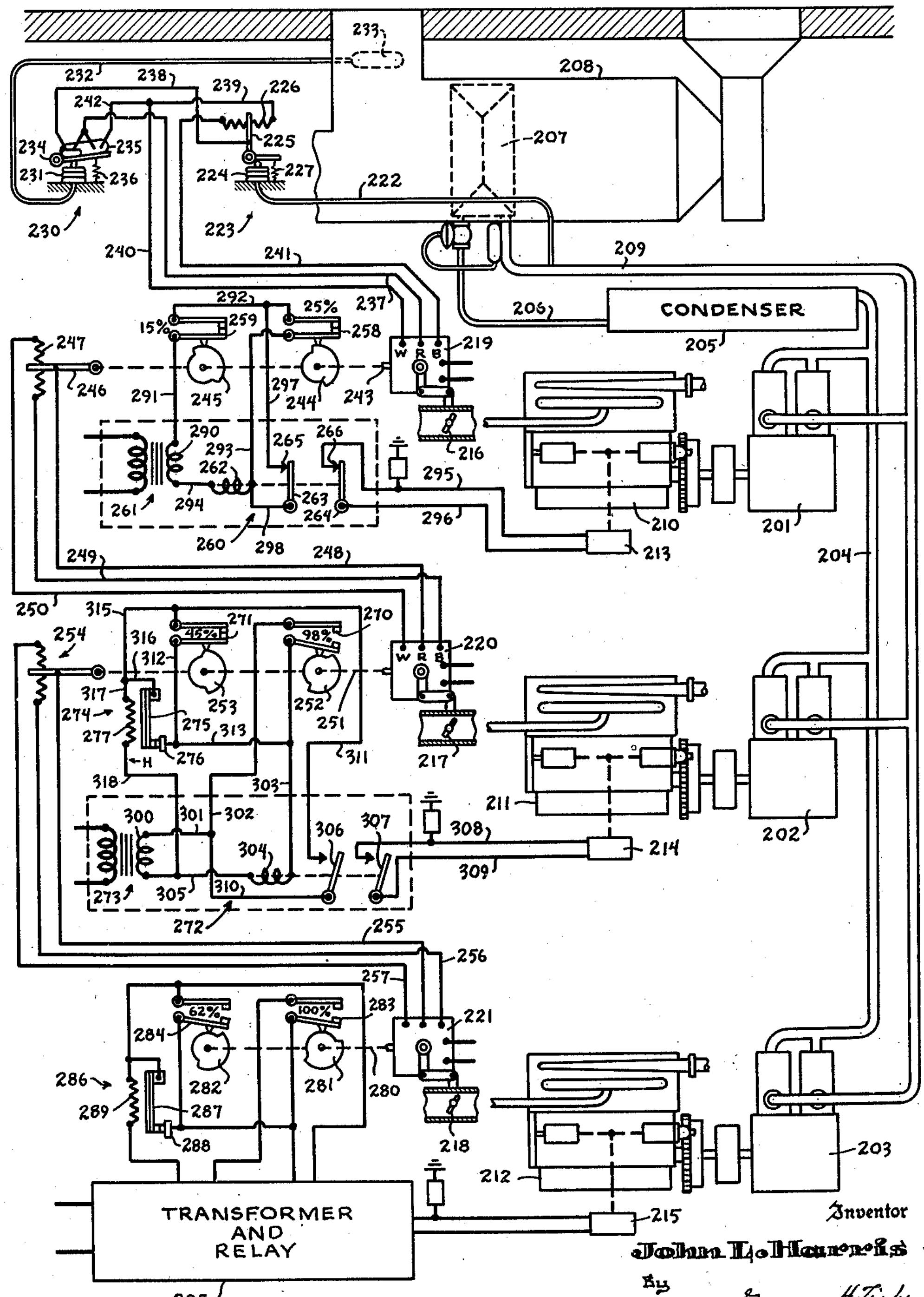

Fig. 2

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Patented Feb. 11, 1941 **2,231,069**

UNITED STATES PATENT OFFICE

2,231,069

CONTROL SYSTEM

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Application March 15, 1939, Serial No. 261,950

21 Claims. (Cl. 62—4)

This invention relates in general to automatic controls for multiple unit power installations and more particularly to control of systems utilizing a plurality of internal combustion engines and to air conditioning systems of the type employing a plurality of variable speed compressors.

In air conditioning and refrigeration practice, it has become usual to drive compressors by means of internal combustion engines which have the advantage of low cost operation and flexibility of output. For larger installations, it has been proposed to utilize a number of engine-compressor units and to control the engines in a manner to vary the speed of one engine from a minimum to a maximum, then to start a second engine and increase its speed from a minimum to a maximum. An arrangement of this type is shown in the copending application of William L. McGrath, Serial No. 218,577 filed July 11, 1938. This type of arrangement while being generally satisfactory and providing for extreme flexibility in output control however is subject to certain disadvantages which it is the object of the present invention to avoid.

With the type of output control heretofore proposed, in obtaining a system output which is slightly above the output of a single unit, one unit is caused to operate at substantially full speed while a second unit operates at low speed. This type of operation causes the second unit to operate inefficiently, and with certain types of prime movers will cause the first unit to operate substantially below maximum efficiency also. In addition, this type of control causes the wear and tear of the units to be very different, also, due to the compressors operating at different speeds, the compressor operating at the higher speed has a lower inlet pressure than the compressor operating at the lower speed which presents difficulties in maintaining the crankcase oil levels in the various compressors uniform.

It is an object of the present invention to provide a control system for multiple unit power installations which varies both the capacity of units in operation and the number of units in operation, and which also acts to cause operation of the units at equal speeds or capacity.

Another object of this invention is the provision of a multiple unit power installation utilizing internal combustion engines with a control system which acts upon increase in load to increase the speed of one engine from a minimum to a maximum, then to place a second engine in operation, and to reduce the speed of the first engine so that the two engines operate at substantially the same speed.

A further object of this invention is the provision of an internal combustion control system which places the engine into and out of operation and which locks the engine in operation for a predetermined period after starting to thereby prevent any surges in the power system of which the engine forms a part from causing the engine to stop.

While the invention is particularly applicable for the controlling of multiple unit internal combustion engine air conditioning or refrigeration systems, its utility is not limited to systems of this type. Other objects of this invention will appear from the following description and the appended claims.

For a full disclosure of this invention reference is made to the following detailed description and to the accompanying drawings, in which—

Figure 1 diagrammatically shows an air conditioning system in which the engines are controlled in accordance with one embodiment of this invention, and in which

Figure 2 shows a modified control arrangement.

Referring to Figure 1, reference character 1 indicates an air conditioning chamber which may be connected by a return duct 2 to the space being conditioned. This chamber is also connected to a fan 3 which in turn is connected to the conditioned space by a discharge duct 4. Located within the chamber 1 is a direct expansion cooling coil 5.

Connected to the cooling coil 5 are compressors 6, 7, and 8, these compressors having their discharges connected to a common discharge main 9 which conveys the compressed refrigerant to a condenser 10. This condenser is in turn connected by a liquid line 11 to a thermostatic expansion valve 12 which is located at the inlet of cooling coil 5 and which is provided with a control bulb 13 attached to the outlet of this cooling coil. This outlet is connected by a suction line 14 which is in turn connected to the compressors 6, 7, and 8 by pipes 15, 16, and 17.

The compressor 6 is driven by means of an internal combustion engine 18. This engine may be of my desired type such as a gasoline or Diesel engine and for illustrative purposes is indicated as having an intake manifold 19 which is provided with a gaseous fuel line 20 having located therein a throttle valve 21. This throttle valve is positioned through a suitable linkage 22 by a proportioning type electric motor

23. The engine 18 is also provided with a starting motor 24, a generator 25, and an automatic starting relay 26. This relay may be of any desired type, for example, such as shown in the L. K. Loehr et al. Patent No. 1,773,913. This relay is adapted to be controlled by control wires 27 and 28 which are connected to an auxiliary switch 29 actuated by the proportioning motor 23. This auxiliary switch is arranged so as to close when the throttle valve 21 is opened beyond a predetermined minimum position by the proportioning motor 23. Closure of this mercury switch 29 energizes the ignition coil 29*a* and also causes energization of the starting relay 26 which operates the starting motor 24 for starting the engine. This relay 26 also automatically deenergizes the starting motor 24 when the engine starts and maintains this starting motor deenergized so long as the engine continues to run. When the auxiliary switch 29 is opened due to closure of the throttle valve 21 by motor 23, the energizing circuit for relay 26 is broken and the ignition circuit is also broken for placing the engine 18 out of operation.

The compressor 7 is driven by means of an internal combustion engine 30 which is the same as engine 18. This engine is provided with an automatic starting relay 31 controlled by an auxiliary switch 32 which is actuated by the proportioning motor 33 which also actuates the engine throttle valve 34. The switch 32 also controls the energization of the ignition coil for this engine. The compressor 8 is driven by an internal combustion engine 35 having a throttle valve 36 which is positioned by means of a proportioning motor 37. This engine is also provided with an automatic starting relay 38 which is controlled by means of an auxiliary switch 39 actuated by the proportioning motor 37, this auxiliary switch also controlling the ignition circuit.

Reference character 40 indicates a thermostat for controlling the engine speed. This thermostat is of the potentiometer type and may include a bellows 41 which is connected by capillary tube 42 to a control bulb 43 located within the return air duct 2. The bellows 41 may actuate a bell crank lever having an actuating arm 44 and a control arm or slider 45 which cooperates with a resistance 46 to form a control potentiometer. It will be apparent that upon increase in return air temperature the bellows 41 will expand for rotating the slider 45 to the left across the resistance 46 against the action of a biasing spring 47. Upon decrease in return air temperature the bellows 41 will contract under the action of the spring 47 for rotating the slider 45 to the right. This instrument may be so designed and adjusted that the slider 45 engages the right-hand end of resistance 46 when the return air temperature is at 75° F. or below while engaging the left-hand end of this resistance when the temperature rises to 80° F.

The thermostat 40 controls a step controller generally indicated as 50, this step controller comprising a proportioning motor 51 having an operating shaft 52 which actuates sliders 53, 54, and 55. The slider 53 cooperates with a resistance 56 while the slider 54 cooperates with a resistance 57 and contact strip 58, and the slider 55 cooperates with a resistance 59 and a contact strip 60. By this arrangement, as the sliders 53, 54, and 55 are shifted from their extreme left-hand positions, the slider 53 will wipe the left-hand end of resistance 56 while sliders 54 and 55 will wipe the contact strips 58 and 60 respectively. Upon continued movement of these sliders to the right the slider 54 will engage the resistance 57 while the slider 55 will still remain in engagement with the contact strip 60. Upon still further movement of the sliders the slider 55 will finally engage the resistance 59. The sliders 53, 54, and 55 therefore sequentially engage their respective resistances.

The motor 51 of the step controller 50 may be of any desired type but is preferably of the type shown and described in the Taylor Patent 2,028,110. Upon reference to this patent it will be found that motor 51 is of the reversible type and is provided with three control terminals which are marked R, B, and W. This motor is adapted to assume various angular positions of its operating shaft in accordance with the relationship between resistance which is connected between terminals R and B and between terminals R and W. Thus if equal values of resistance are connected between these terminals the shaft 52 will assume its intermediate angular position in which the slider 53 engages the center of resistance 56. However, if the resistance between terminals R and B is increased while the resistance between terminals R and W is decreased, the motor will rotate its shaft 42 in a direction for moving the sliders to the left. Conversely if the resistance between terminals R and B is decreased without corresponding decrease in resistance between terminals R and W, the shaft 52 will rotate the sliders 53, 54, and 55 to the right an amount proportionate to the change in resistance. Terminal R or motor 51 is connected to the slider 45 of thermostat 40 by wire 61 while terminal B is connected to the left-hand end of resistance 46 by wire 62 and terminal W is connected to the right-hand end of this resistance by the wire 63. The return air thermostat 40 is therefore in control of the step controller proportioning motor 51 and therefore positions the sliders 53, 54 and 55 in accordance with the return air temperature. Thus as the return air temperature increases the thermostat 40 will cause operation of the motor 51 for shifting the sliders 53, 54, and 55 to the right an amount proportionate to the increase in return air temperature.

The throttle valve proportioning motors 23, 33, and 37 are of the same type as the proportioning motor 51, each of these motors having terminals marked R, W, and B. Terminal R of proportioning motor 23 is connected by means of wire 65 to the slider 53 while terminal W is connected by wire 66 to the left-hand end of resistance 56, and terminal B is connected by wire 67 to the right-hand end of resistance 56. It should now be apparent that when the space temperature increases, the thermostat 40 will cause rotation of the shaft 52 of proportioning motor 51 which will cause movement of the slider 53 to the right across resistance 56 thereby decreasing the amount of resistance between terminals R and B of motor 23 while increasing the amount of resistance between terminals R and W. This will cause the proportioning motor 23 to open the throttle valve 21 an amount proportionate to the rise in return air temperature.

Terminal R of proportioning motor 33 is connected to the slider 54 by wire 68, terminal B of this motor being connected to the right-hand end of resistance 57 by wire 69 and terminal W being connected to the contact strip 58 by wire 70. Terminal R of motor 37 is connected to the slider 55 by wire 71 while terminal B is connected to resistance 59 by wire 72 and terminal W is connected to the contact strip 60 by wire 73. The thermostat 40 therefore controls the throttle valve proportioning motors 23, 33 and 37, but due to the sequence control arrangement of the step controller 50 these motors are controlled in sequence.

Connected into the control circuit of the proportioning motor 23 is a manually operated potentiometer 75, this potentiometer having a slider 76 and a resistance 77. The right-hand end of resistance 77 is connected to wire 66 by wire 78 and the left-hand end of this resistance is connected to wire 67 by wire 79. The slider 76 is connected by wire 80 to a mercury switch 81 of a pressure responsive device 82 and this mercury switch is connected by wire 83 to the wire 65. It will be apparent that when mercury switch 81 is closed, the potentiometer 75 is connected into the control circuit of motor 23 in parallel with the step controller potentiometer formed of slider 53 and resistance 56. However, when mercury switch 81 is open the slider 76 is disconnected from the control circuit and thus its position on resistance 77 has no effect upon the motor 23. The pressure responsive device 82 includes a bellows 84 which actuates the mercury switch 81, this bellows being connected by a tube 85 to the intake manifold of the engine 30. When the engine 30 is out of operation, the manifold pressure will be atmospheric, which will permit the bellows 84 to expand and thus open mercury switch 81 for disconnecting the potentiometer 75 from the control circuit of motor 23. However, when engine 30 is in operation, a vacuum will occur in the intake manifold thereby contracting the bellows 84 and closing the mercury switch 81.

Also connected to the control circuit of motor 23 is a manual potentiometer 87 having a slider 88 cooperating with a resistance 89, the right-hand end of this resistance being connected to wire 66 by wire 90 and the left-hand end thereof being connected to wire 67 by wire 91. The slider 88 is connected by wire 92 to a mercury switch 93 forming part of a pressure responsive device 94. This mercury switch is in turn connected by wire 95 to the wire 65 of the motor control circuit. The pressure responsive device 94 responds to the intake manifold pressure of the engine 35 and includes a bellows 96 which is connected to this manifold by a tube 97. This bellows actuates the mercury switch 93 and also actuates a second mercury switch 98. When the engine 35 is at rest both of these mercury switches will be open as shown, while when the engine 35 is operating the vacuum produced in the intake manifold thereof will contract the bellows 96 for causing the mercury switches 93 and 98 to close. The mercury switch 98 is provided for the purpose of placing a potentiometer 99 into and out of control relationship with the throttle valve motor 33 of engine 30. This switch is connected by wire 100 to the wire 68 and is connected to the slider 101 of potentiometer 99 by wire 102. The right-hand end of resistance 103 of this potentiometer is connected by wire 104 to wire 70 while the left-hand end of this resistance is connected to the wire 69 by wire 105.

The proportioning motor 23 is adjusted so that a movement of slider 53 over but one-third of resistance 56 will cause a change in position of the motor 23 from one extreme to the other. Thus when slider 53 engages the left-hand end of resistance 56 the motor 23 will assume a position completely closing the throttle valve 21 while when the slider 53 moves to the right one-third of the way across resistance 56 the throttle valve 21 will be wide open. This arrangement therefore permits the speed of engine 18 to be increased to a maximum before the slider 54 begins traversing the resistance 57. Therefore engine 18 may operate at full speed even when the engines 30 and 35 are at rest. The throttle valve motor 33 is adjusted so that it moves the throttle valve 34 from a position corresponding to one-half capacity to full capacity for a movement of slider 54 over but half of resistance 57. Consequently when the slider 54 engages the center of resistance 57 the engine 30 may operate at full speed even though the slider 55 is engaging the left-hand end of resistance 59 for causing the throttle valve 36 of motor 35 to be closed sufficiently for opening the auxiliary switch 32. The purpose of the potentiometers 75, 87 and 99 and the controllers 82 and 94 will become apparent from the following statement of operation.

Operation of Figure 1

Assuming that the space temperature is below 75° F., the slider 45 of thermostat 40 will engage the right-hand end of resistance 46 which causes the step controller motor 51 to position the sliders 53, 54, and 55 in their extreme left-hand positions. At this time terminals R and W of motors 23, 33, and 37 will all be substantially short-circuited, which will cause these motors to open their respective auxiliary switches so that all of the engines are out of operation.

As the space temperature rises above 75° F. the slider 45 will begin moving to the left across resistance 46 thereby causing the motor 51 to shift sliders 53, 54, and 55 to the right. At this time the sliders 54 and 55 will remain in engagement with the contact strips 58 and 60 and thus the motors 33 and 37 will remain stationary. However, the slider 53 will be traversing the resistance 56 and thus insert a portion of the resistance 56 into the short-circuit between terminals R and B while removing this same portion from the circuit between terminals R and W. This will cause the proportioning motor 23 to begin opening the throttle valve 21. When the throttle valve 21 opens to the minimum position, the auxiliary switch 29 will close for placing the engine 18 into operation. Now as the space temperature continues to increase, the slider 53 will shift further to the right on resistance 56 thus operating motor 23 for opening the throttle valve 21 further for increasing the engine speed. When the space temperature increases to a point wherein the slider 53 is one-third of the way across resistance 56, the throttle valve 21 will be wide open and thus engine 18 will operate at maximum capacity.

If the space temperature continues to increase, the slider 54 will begin traversing resistance 57 thus causing the throttle valve motor 33 to begin opening movement of throttle valve 34. Upon opening of the throttle valve 34 to its minimum position, the auxiliary switch 32 will close thus energizing the relay 31 and the ignition coil for placing the engine 30 into operation. At this time the slider 55 will still remain in engagement with the contact strip 60 and thus the engine 35 will continue to remain at rest. The throttle valve 34 is adjusted relative to the mercury switch 32 so that the engine 30 when started operates at slightly above 50% capacity. When this engine starts, the mercury switch 81 of the manifold pressure responsive controller 82 closes due to the occurrence of a vacuum within the intake manifold of this engine. This connects the slider 76 to the wire 65 of the control circuit for the throttle valve motor 23. The slider 76 is therefore connected to terminal R of motor 23 and acts to place the right-hand portion of resistance 77 in circuit between terminals R and W and the left-hand portion of this resistance between terminals R and B of motor 23. The slider 76 is adjusted so that the right-hand portion of resistance 77 is smaller than the left-hand portion. Consequently the connecting of slider 76 to terminal R of motor 23 due to starting of engine 30, reduces the amount of resistance between terminals R and W as compared to the resistance between terminals R and B. This causes operation of the proportioning motor 23 to a position wherein the throttle valve 21 limits the engine speed to slightly over half capacity. It will be apparent that by adjusting the slider 76 the speed of the engine 18 may be reduced to approximately the same speed that engine 30 is now operating.

It will now be apparent that as the cooling load increases from zero to one-third load, the engine 18 will be started and its speed graduatingly increased to a maximum. When the cooling load rises above one-third full load, the engine 30 is placed into operation at approximately one-half capacity and the speed of engine 18 is simultaneously reduced so that the two engines operate at the same speed and slightly over one-half capacity.

Upon continued increase in cooling load, the sliders 53 and 54 will traverse the resistances 56 and 57 for increasing the speeds of engines 18 and 30 simultaneously until both engines are operating at full speed. If the space temperature still continues to increase, the slider 55 will begin traversing resistance 59 which will cause the proportioning motor 37 to close its auxiliary switch 39 for thus energizing relay 38 and the ignition coil to start the engine 35. The throttle valve 36 and auxiliary switch 39 are adjusted so that the switch 39 closes when the throttle valve 36 is positioned for causing the engine 35 to operate at slightly over two-thirds capacity. When this engine starts, it causes the mercury switches 93 and 98 of the manifold pressure responsive device 94 to close which respectively connect the potentiometers 87 and 99 into the control circuits of throttle valve motors 23 and 33. The connecting of potentiometer 87 into the control circuit of motor 23 causes this motor to close the throttle valve to a position causing operation of the engine 18 at slightly over two-thirds capacity in a manner which will now be apparent. Also the connecting of potentiometer 99 into the control circuit of motor 33 causes this engine to be slowed down from full speed to reduce its capacity to slightly over two-thirds. Therefore all three engines will now be operating at slightly over two-thirds capacity which provides slightly more capacity than can be obtained by operating two engines at full speed. Upon continued rise in space temperature it will be apparent that the three engines will be speeded up simultaneously so that when the space temperature rises to 80° F. all three engines will be operating at full speed. Upon a fall in space temperature it will be apparent that the operation as described above will take place in reverse order. Thus the speeds of the engines will be reduced to approximately two-thirds capacity at which time the engine 35 is placed out of operation and the engines 18 and 30 are increased in speed to operate at full capacity. Then upon further temperature drop the speeds of engines 18 and 30 are decreased until the two engines are operating at approximately 50% capacity. At this time the engine 30 will be stopped and the engine 18 speeded up to operate at full capacity. Then upon continued temperature drop this engine will be slowed down until finally it is placed out of operation entirely.

Figure 2

Referring to Figure 2, this figure shows a modified control arrangement. In this figure the compressors 201, 202, and 203 are connected to a common discharge line 204 which is connected to a condenser 205 having a liquid line 206 leading to the cooling coil 207 located within the air conditioning chamber 208. The outlet of this coil is connected to the suction line 209 which is connected in turn to the intake of each compressor. These compressors are driven respectively by means of internal combustion engines 210, 211, and 212 having automatic starting relays 213, 214, and 215 respectively, these engines also having ignition coils connected so as to be energized with the starting relays. The engines 210, 211, and 212 are also provided with throttle valves 216, 217, and 218 which are positioned by proportioning motors 219, 220, and 221 respectively.

Connected to the suction line 209 by means of a tube 222 is a suction pressure controller generally indicated as 223. This controller may include a bellows 224 which actuates a bell crank lever having an actuating arm or slider 225 cooperating with a resistance 226. It will be apparent that if the suction pressure increases, the bellows 224 will expand against the action of spring 227 thereby causing movement of the slider 225 to the left across resistance 226. Upon decrease in suction pressure the bellows 224 will contract for causing movement of the slider 225 to the right.

Also controlling the throttle valve motor 219 is a two-position type return air thermostat 230. This thermostat may include a bellows 231 connected by a capillary tube 232 to a control bulb 233 which is located in the return air duct leading to the chamber 208. This bellows 231 actuates a switch carrier 234 carrying a double electrode type mercury switch 235. When the return air temperature rises above a predetermined value such as 75° F. the bellows 231 will expand sufficiently against the action of a biasing spring 236 for bridging the left-hand electrodes of mercury switch 235. However, when the return air temperature is below this value the bellows 231 will be contracted thereby causing the right-hand electrodes of switch 235 to be closed.

It will be noted that terminal R of throttle valve motor 219 is connected by wire 237 to the common terminal of mercury switch 235 and the left-hand terminal of this switch is connected by wire 238 to the slider 225 of the suction pressure controller 223. The right-hand end of resistance 226 is connected by wires 239 and 240 to terminal W of motor 219, while the left-hand end of resistance 226 is connected by wire 241 to terminal B. Therefore when the space temperature is above 75° F. which causes the left-hand electrodes of mercury switch 235 to be bridged, the suction pressure controller 223 is placed in control of the throttle valve motor 219. This controller acts to control motor 19 in a manner to open the throttle valve 216 as the suction pressure increases while closing this throttle valve after the suction pressure decreases. However, when the space temperature falls below 75° F., the left-hand electrodes of mercury switch 235 will be unbridged for disconnecting the suction pressure controller 223 from the control circuit of motor 219. At this same time the right-hand electrodes of mercury switch 235 will be bridged which will complete a circuit from terminal R through wire 237, right-hand electrodes of switch 235, wire 242, and wire 240 to terminal W of motor 219 which will cause this motor to completely close the throttle valve 216.

The throttle valve motor 219 is provided with an operating shaft 243 which carries cams 244 and 245 and a slider 246 which cooperates with a resistance 247. The slider 246 is connected by wire 248 to terminal R of the throttle valve motor 220 while the resistance 247 is connected to terminals B and W by wires 249 and 250. It will be apparent that the potentiometer formed of slider 246 and resistance 247 acts to control the position of the throttle valve motor 220 in accordance with the position of the motor 219. This arrangement provides for controlling the motors 219 and 220 in unison by a single suction pressure controller 223. The motor 220 is provided with an operating shaft 251 which actuates cams 252 and 253 and also actuates the slider of a potentiometer 254 which is connected to the throttle valve motor 221 by wires 255, 256, and 257. The suction pressure controller 223 therefore controls the throttle valve motors 219, 220 and 221 in unison.

Referring again to the throttle valve motor 219, the cam 244 actuates a switch 258 while the cam 245 actuates a switch 259. The cam 244 is adjusted upon the operating shaft 243 so that the switch 258 remains open until the throttle valve 216 is opened to a point corresponding to 25% capacity of engine 210. The cam 245 is adjusted so as to maintain the switch 259 closed so long as the throttle valve 216 is adjusted for more than 15% engine capacity.

The switches 258 and 259 control a relay generally indicated as 260, this relay being indicated as in a housing with transformer 261. The relay 260 is of usual form consisting of a pull-in coil 262 which actuates through a suitable armature the switch arms 263 and 264 cooperating with contacts 265 and 266 respectively. When pull-in coil 262 is energized, the switch arms 263 and 264 engage their respective contacts while when this coil is deenergized the switch arms are disengaged from their contacts by the action of gravity or springs, not shown.

The cams 252 and 253 of the throttle valve motor 220 control switches 270 and 271 respectively. The cam 252 is adjusted on shaft 251 so as to close the switch 270 when the throttle valve motor 220 is positioned corresponding to 98% of engine capacity. The cam 253 is adjusted so as to maintain the switch 271 closed so long as the throttle valve 217 is opened beyond a point corresponding to 45% engine capacity. The switches 270 and 271 control a relay 272 which is associated with a transformer 273. The relay 272 is also in part controlled by means of a thermo-electric timer 274 which may consist of a bimetallic element 275 carrying a contact which cooperates with a contact 276. This timer also includes a heating element 277 for influencing the bimetallic element 275.

The throttle valve motor 221 is provided with an operating shaft 280 carrying cams 281 and 282 which operate switches 283 and 284 respectively. The cam 281 is adjusted so as to close switch 283 only when the throttle valve motor 221 opens the throttle valve 218 wide open. The cam 282 is adjusted so as to maintain the switch 284 closed so long as the throttle valve 218 is open beyond 62% capacity position. The switches 283 and 284 control a relay 285 which is the same as relay 272. This relay 285 is also in part controlled by a thermo-electric timer 286 having a bimetallic element 287 cooperating with contact 288 and also having a heating element 289. The various circuit connections will be described in the following statement of operation.

Operation of Figure 2

Assuming that the space temperature controller 230 is in the position shown for placing the suction pressure controller 223 in control of the throttle valve motors 219, 220, and 221; for a relatively low value of suction pressure this controller will cause the throttle valves 216, 217, and 218 to be substantially closed. When the suction pressure rises to a point sufficient to cause closing of the switch 258 of motor 219, the relay 260 will be energized as follows: transformer secondary 290, wire 291, switch 259, wire 292, switch 258, wire 293, pull-in coil 262, and wire 294 to secondary 290. Engagement of the switch arm 264 with contact 266 will complete the energizing circuit through wires 295 and 296 for the relay 213 and the ignition coil, thus placing the engine 210 into operation. Engagement of the switch arm 263 with contact 265 will complete a holding circuit for coil 262 as follows: transformer secondary 290, wire 291, switch 259, wire 292, wire 297, contact 265, switch arm 263, wire 298, coil 262 and wire 294 to secondary 290. Thus the relay 260 will be maintained energized independently of the switch 252 and this relay will remain energized until the throttle valve 216 is closed to a point where the switch 259 is opened. The switch 258 is thus a switch for starting the engine and the switch 259 is a switch for stopping the engine.

As the load on the system increases, the suction pressure will rise which will cause the suction pressure controller 223 to operate motors 219, 220, and 221 in the direction for opening the throttle valves 216, 217, and 218. However, at this time the relays 272 and 285 and the ignition coils for engines 211 and 212 will not be energized and consequently these engines will not be in question. Therefore as the load first begins increasing, only the engine 210 will be in operation and the speed of this engine will be increased progressively as the load increases.

When the load upon the system becomes such that the value of suction pressure causes the suction pressure controller 223 to open the throttle valves beyond 98% capacity positions, the switch 270 of the throttle valve motor 220 will close thus energizing the relay 272 as follows: transformer secondary 300, wires 301 and 302, switch 270, wire 303, pull-in coil 304, and wire 305 to secondary 300. This will cause the switch arms 306 and 307 to engage their respective contacts. Engagement of the switch arm 307 with its contact will complete an energizing circuit for the starting relay 214 and the corresponding ignition coil through wires 308 and 309 thereby placing the engine 211 into operation. Engagement of switch arm 306 with its contact will complete a maintaining circuit for the pull-in coil 304 through switch 271 as follows: secondary 300, wire 301, wire 310, switch arm 306, wire 311, switch 271, wires 312, 313, and 303, coil 304 and wire 305 to secondary 300. Consequently the relay 272 will remain energized for maintaining the engine 211 in operation until the throttle valve 217 is closed to a point wherein the switch 271 opens.

Due to the starting of engine 211, both engines 210 and 211 will now be operating at substantially full capacity. This will cause the suction pressure to begin to fall and in response to this falling suction pressure the slider 225 of the suction pressure controller will begin moving to the right across its resistance 226 which in turn causes the throttle valve motors 219, 220, and 221 to begin closing the throttle valves 216, 217, and 218. The engines 210 and 211 will therefore begin to slow up and in fact will slow up until the suction pressure stops falling. At this time the capacity of the engines will just exactly balance the cooling load upon the system.

When the engine 211 starts, it is possible for the suction pressure to be reduced faster than the controls slow up the engine speed and it is therefore possible at this time for the suction pressure to fall to such a point that the suction pressure controller 223 closes the throttle valves sufficiently to open the switch 271 and thus drop out engine 211. In order to prevent the initial surges in the system caused by starting of engine 211 from stopping this engine, the thermoelectric timer 274 is provided. This timer is arranged so that as long as the bimetallic element 275 is cold, it engages contact 276 and thus provides a maintaining circuit for the coil 304 which is independent of switch 271 as follows: transformer secondary 300, wire 301, wire 310, switch arm 306, wires 311, 315, and 316, bimetallic element 275, contact 276, wire 313, wire 303, coil 304 and wire 305 to secondary 300. Consequently during the initial surges produced when the engine 211 first starts, this engine is locked in operation by the timer 274. During this time, the heating element 277 of the timer 274 is energized by a circuit through the switch arm 306 as follows: transformer secondary 300, wire 301, wire 310, switch arm 306, wires 311, 315, and 317, heating element 277, and wires 318 and 305 to secondary 300. This energization of heating element 277 will after a predetermined period cause the bimetallic element to disengage from contact 276 and thus render the switch 271 operative to stop the engine 211 when the throttle valve 217 is closed to a point where this switch is opened.

As the load continues to increase, the suction pressure will rise for causing the throttle valves 216, 217, and 218 to open simultaneously for increasing the speeds of engines 210 and 211. It will be noted that the throttle valves are adjusted so that they are all open approximately equally so that the two engines operate at equal speeds, the speeds being increased simultaneously upon increase in suction pressure. When the suction pressure rises to a point wherein all three throttle valves are wide open the switch 283 of the throttle valve motor will close thereby energizing the relay 285 which in turn energizes the starting relay 215 and corresponding ignition coil for placing engine 212 in operation. All three engines will therefore now be operating at full speed and consequently the suction pressure will begin to fall. At this time the thermo-electric timer 286 will short-circuit the switch 284 and thus prevent any surges in suction pressure which occur upon starting of engine 212 from stopping this engine. Due to the falling suction pressure, the engines will be simultaneously slowed down until the suction pressure stops falling, which will occur when each engine is operating at substantially two-thirds capacity. Upon continued increase in cooling load the suction pressures will begin increasing thereby causing the engines to be speeded up simultaneously for carrying the increased load.

Upon falling cooling load from this point, the engines will be slowed down simultaneously until a point is reached at which all three engines are operating at substantially 62% capacity. Upon further decrease in load the switch 284 of throttle valve motor 221 will open thereby placing the engine 212 out of operation. Due to the placing of engine 212 out of operation the suction pressure will gradually increase thus causing the suction pressure controller 223 to begin opening the throttle valves for speeding up engines 210 and 211 until the increased speed prevents further rise in suction pressure. Thus now only two engines will be operating but at higher speed in order to carry the load. Upon further fall in cooling load, the suction pressure will continue to decrease which will cause the throttle valves to be graduatingly closed for thereby decreasing the speeds of engines 210 and 211. When the cooling load falls to a point at which both engines are operating only at 45% capacity, the switch 271 of throttle valve motor 220 will open for placing the engine 211 out of operation. As a result the suction pressure will once more begin rising which will cause the speed of engine 210 to be increased until the rise in suction pressure is arrested. Then upon further decrease in load the suction pressure will once more begin decreasing for slowing down the engine 210 and when this engine is slowed down to its minimum desired rate of operation the switch 259 will open for stopping this engine.

It will be understood that whenever the space temperature is below the setting of the return air thermostat all of the engines are placed out of operation irrespective of the value of suction pressure.

In the foregoing description, it has been assumed that the engines described are gasoline engines, and that the throttle valves are associated with the usual carburetors. If the invention is applied to gas engines, it will be understood that suitable valves may be provided in the gas lines in advance of the throttle valves for shutting off the flow of gas when the corresponding engine is not in operation. It will also be understood that the engines may be provided with suitable automatic choking devices for obtaining proper starting action.

From the foregoing it will be apparent that this invention providing a control arrangement for multiple compressor refrigeration units wherein the compressors are driven at variable speeds in accordance with the cooling load and in which the number of engines in operation is also varied in accordance with the cooling load. Also it will be apparent that irrespective of the number of engines in operation, all of the engines in operation will operate at equal speeds, this result being achieved by slowing down the engines already in operation whenever another engine is placed into operation. While I have shown only two embodiments of this invention, it will be apparent that the invention may take various other forms. Also while the invention has particular utility as applied to air conditioning systems and to multiple internal combustion engine power systems, it will be apparent that the invention is of broader scope. Furthermore, while for illustrative purposes specific values of temperature and pressure and capacities have been mentioned, it will be understood that these values are illustrative only. As the invention may take various forms and be applied to various applications, 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 plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, means responsive to the load on the system for varying the speed of one of said engines from a predetermined minimum to a maximum, means actuated upon the load on the system rising above the capacity of said one engine for starting another of said engines, and means for causing said engines to operate at substantially equal speeds after starting of said other engine.

2. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, means responsive to the load on the system for varying the speed of one of said engines from a predetermined minimum to a maximum, means actuated upon the load on the system rising above the capacity of said one engine for starting another of said engines, and means actuated upon starting of said other engine for slowing down said one engine an amount sufficient to cause said engines to operate at substantially equal speeds.

3. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, control means responsive to a condition indicative of the load on the system for controlling said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, and means for sequentially placing said engines into and out of operation.

4. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, control means responsive to a condition indicative of the load on the system for controlling said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, and means operated by said motor means for placing corresponding engines into and out of operation sequentially.

5. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, means for sequentially placing said engines into and out of operation, a speed controller for each engine, motor means for actuating said speed controllers, and control means responsive to a condition indicative of the load on the system for controlling said motor means and hence said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, said control means including means responsive to the number of engines in operation for adjusting the speed maintained by at least one of said engines.

6. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, control means responsive to a condition indicative of the load on the system for controlling said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, said control means including a condition responsive device, a motor controlled thereby, a plurality of controllers actuated by said motor for controlling said speed controller motor means, and means for adjusting said controllers in accordance with the number of engines in operation.

7. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, means actuated by said individual motor means for placing said engines into and out of operation, control means responsive to a condition indicative of the load on the system for controlling said motor means and hence said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, said control means including means responsive to the number of engines in operation for adjusting the speed maintained by at least one of said engines.

8. In a system of the class described, a first internal combustion engine, a second internal combustion engine, both of said engines being adapted to operate at variable speed and being connected to a common load, load responsive means for graduatingly increasing the speed of one of said engines from a minimum to a maximum to increase the load which said one engine carries as the load on the system increases, means for starting the other of said engines when the load increases to a value which is more than desirable for said one engine to carry, means actuated when said one engine is started for reducing the speed of said other engine to a value wherein both engines operate at substantially equal speeds and therefore carry substantially equal loads, and means for increasing the speed of said one

engine as the load continues to increase, said last mentioned means being arranged to increase the speed of said other engine proportionately to the increase in speed of said one engine.

9. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, control means responsive to a condition indicative of the load on the system for controlling said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, said control means comprising a load condition responsive controller for controlling one of said motor means and a controller actuated by said one motor means for controlling another of said motor means, and means for sequentially placing said engines into and out of operation.

10. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speed, the speed of each load device being indicative of the load which said device is carrying, an internal combustion engine for each of said load devices for driving the same, a speed controller for each of said engines, individual motor means for actuating each of said speed controllers, control means responsive to a condition indicative of the load on the system for controlling said speed controllers in a manner to operate said engines at substantially equal speeds and to increase the engine speeds upon increase in load, said control means comprising a load condition responsive controller for controlling one of said motor means and a controller actuated by said one motor means for controlling another of said motor means, and means also actuated by said motor means for placing corresponding engines into and out of operation sequentially.

11. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speeds, the speed of each load device being indicative of the load which said device is carrying, said devices being connected to a common load, an internal combustion engine for each of said load devices for driving the same, a speed controller for each engine, means responsive to a condition varying in accordance with the relationship between the engine output and the load on the system for controlling said speed controllers in a manner tending to increase the speeds of the engines simultaneously when the change in the condition indicates that the load is increasing above the output of the engines while decreasing the speed of said engine when the change in said condition indicates that the load is decreasing below the output of the engines, said speed controllers being adjusted for operating said engines at substantially equal speeds, and means for placing at least one of said engines in operation upon increase in load while placing said one engine out of operation upon decrease in load.

12. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable speeds, the speed of each load device being indicative of the load which said device is carrying, said load devices being connected to a common load, an internal combustion engine for each of said load devices for driving the same, a speed controller for each engine, means responsive to a condition varying in accordance with the relationship between the engine output and the load on the system for controlling said speed controllers in a manner tending to increase the speeds of the engines simultaneously when the change in the condition indicates that the load is increasing above the output of the engines while decreasing the speeds of said engine when the change in said condition indicates that the load is decreasing below the output of the engines, said speed controllers being adjusted for operating said engines at substantially equal speeds, a controller for each engine for starting and stopping the same, and means controlled by said condition responsive means for controlling said starting and stopping means sequentially in a manner to sequentially place said engines in operation upon increase in load while sequentially placing said engine out of operation upon decrease in load.

13. In a system of the class described, in combination, a pair of load devices adapted to be driven at variable speeds, the speed of each load device being indicative of the load which said device is carrying, said load devices being connected to a common load, an internal combustion engine for each of said load devices for driving the same, a speed controller for each engine, means responsive to a condition varying in accordance with the engine output and the load on the system for controlling said speed controllers in a manner tending to increase the speeds of the engine simultaneously when the change in the condition indicates that the output is below the actual load while decreasing the engine speeds when the change in said condition indicates that the output is below the actual load while decreasing the engine speeds when the change in said condition indicates that the output is above the actual load, a controller for one of said engines for starting the same, said controller being controlled by said condition responsive means and operating to start the engine when said condition reaches a predetermined value, and a controller for said one engine for stopping the same, said last mentioned controller being controlled by said condition responsive means in a manner to stop said one engine when said condition falls to a predetermined value which is lower than said first mentioned value.

14. In a system of the class described, in combination, a pair of load devices adapted to be driven at variable speeds, said load devices being connected to a common load, an internal combustion engine for each of said load devices for driving the same, a speed controller for each engine, means responsive to a condition varying in accordance with the engine output and the load on the system for controlling said speed controllers in a manner tending to increase the speeds of the engines simultaneously when the change in the condition indicates that the output is below the actual load while decreasing the engine speeds when the change in said condition indicates that the output is above the actual load, a controller for one of said engines for starting the same, said controller being controlled by said condition responsive means and operating to start the engine when said condition reaches a predetermined value, a controller for said one engine for stopping the same, said last mentioned controller being controlled by said condition responsive means in a manner to stop said

one engine when said condition falls to a predetermined value which is lower than said first mentioned value, and timing means for rendering said last mentioned controller inoperative to stop said one engine for a period following starting thereof to thereby prevent stopping of said engine due to surges in said condition caused by starting of said one engine.

15. In a system of the class described, in combination, a pair of load devices adapted to be driven at variable speeds, said load devices being connected to a common load, an internal combustion engine for each of said load devices for driving the same, a speed controller for each engine, means responsive to a condition varying in accordance with the engine output and the load on the system for controlling said speed controllers in a manner tending to increase the speeds of the engines simultaneously when the change in the condition indicates that the output is below the actual load while decreasing the engine speeds when the change in said condition indicates that the output is above the actual load, control means responsive to said condition for starting and stopping one of said engines, and means for preventing said control means from stopping said engine until a timed period following starting of said engine.

16. In a system of the class described, in combination, a load device, an internal combustion engine for driving said load device at variable speed, means responsive to a condition varying in accordance with the engine output and the load on the system for increasing the speed of said engine when the change in said condition indicates that the engine output is smaller than the actual load upon the system and for decreasing the speed of the engine when the change in said condition indicates that the engine output is greater than the actual load, means for starting and stopping said engine also controlled in accordance with said condition, and timing means for preventing said last mentioned means from stopping said engine for a timed period following starting of said engine.

17. In a system of the class described, in combination, a load device, an internal combustion engine for driving said load device at variable speed, a speed controller for said engine, load responsive means for controlling said speed controller in a manner to vary the engine speed in accordance with the load on the system, control means for starting and stopping said engine, means responsive to a condition varying as a resultant of the engine output and the actual load on the system for controlling said control means, and timing means for preventing said control means from stopping the engine until a timed period following starting of the engine.

18. In an air conditioning system, in combination, refrigeration system means for cooling the air and including a plurality of compressors, an internal combustion engine for each of said compressors for driving the same, means responsive to the load on the system for varying the speed of one of said engines from a predetermined minimum to a maximum, means actuated upon the load on the system rising above the capacity of said one engine for starting another of said engines, and means for causing said engines to operate at substantially equal speeds after starting of said other engine.

19. In an air conditioning system, in combination, refrigeration system means for cooling the air and including a plurality of compressors, an internal combustion engine for each compressor for driving the same, a speed control means for each engine, means responsive to a condition of the air in said space which is affected by the operation of said compressors for controlling said speed control means in a manner to actuate said speed controllers in sequence, means for starting and stopping one of said engines, and means actuated with starting of said one engine for adjusting the speed control means of another of said engines in a manner to reduce the speed thereof.

20. In an air conditioning system, in combination, refrigeration system means for cooling the air and including a plurality of compressors connected to a common suction line, an internal combustion engine for each compressor for driving the same, a speed controller for each engine, means responsive to suction pressure for actuating said speed controllers simultaneously in a manner to increase the speeds of said engines upon increase in suction pressure and to decrease the speeds of said engines upon decrease in suction pressure, said speed controllers being arranged so as to cause operation of said compressors at substantially equal speeds, and means actuated with said speed controllers for starting and stopping one of said engines.

21. In a system of the class described, in combination, a plurality of load devices adapted to be driven at variable capacities, a variable speed prime mover for each of said load devices for driving the same, the capacity of each load device being dependent upon its speed, means responsive to the load on the systems for varying the capacity of one of said prime movers from a predetermined minimum to a maximum, means actuated when the load on the system rises above the capacity of said one prime mover for starting another of said prime movers, and means actuated upon starting of said other prime mover for reducing the capacity of said one prime mover an amount sufficient to cause said prime movers to operate at substantially equal capacities.

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