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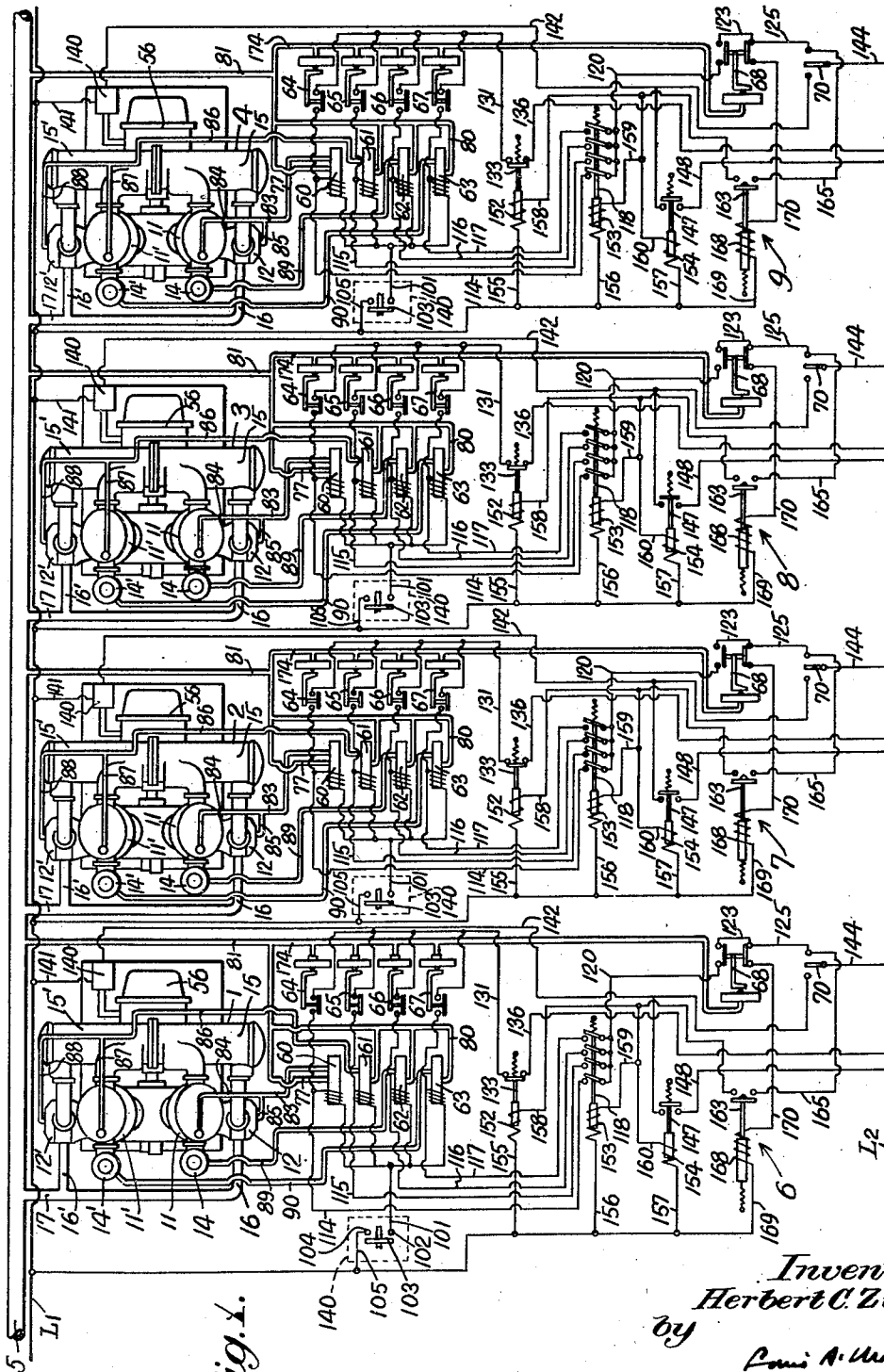
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2,432,553

COMPRESSOR SYSTEM

Filed April 21, 1943

4 Sheets-Sheet 1



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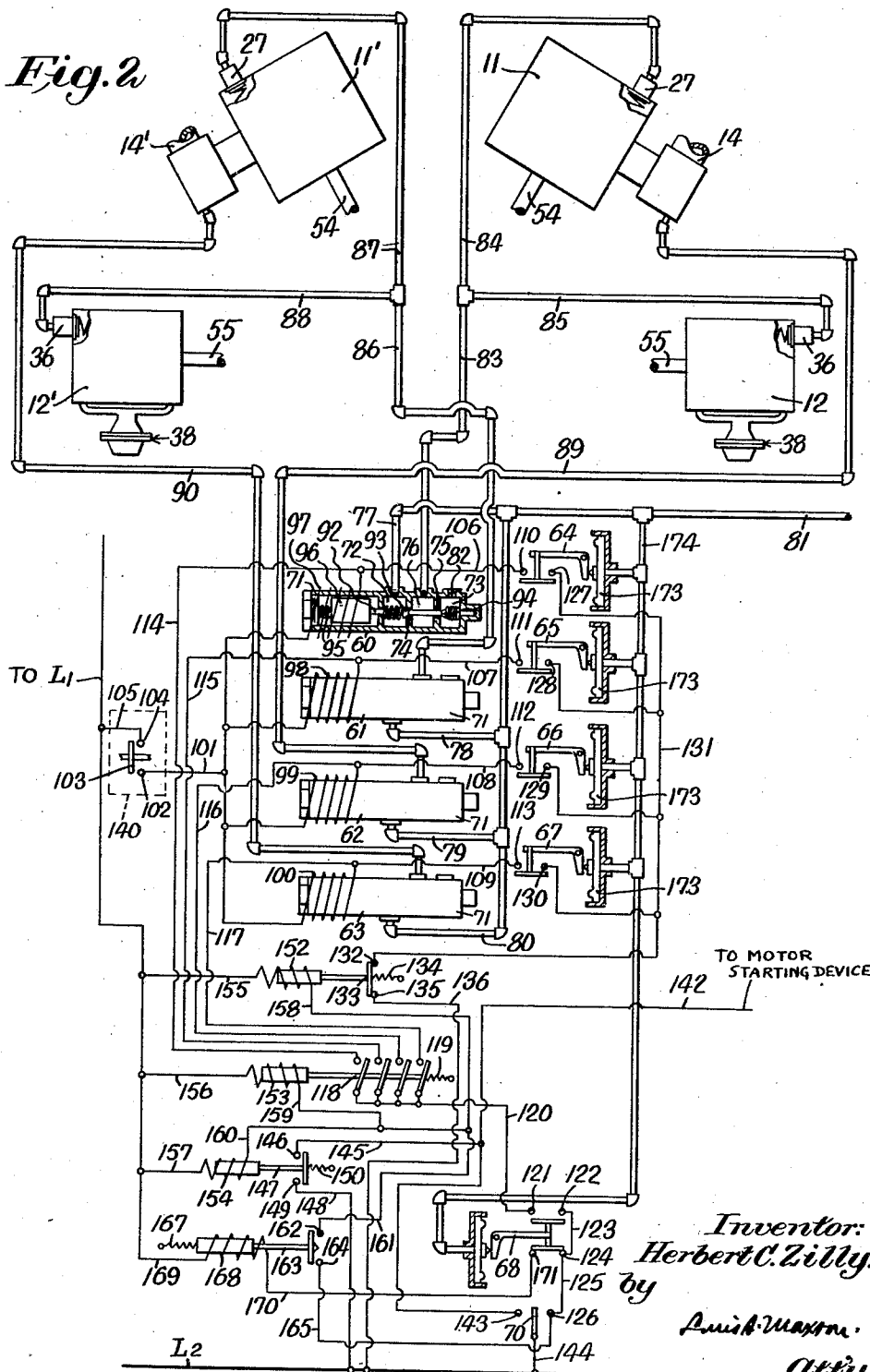
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COMPRESSOR SYSTEM

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Fig. 3.

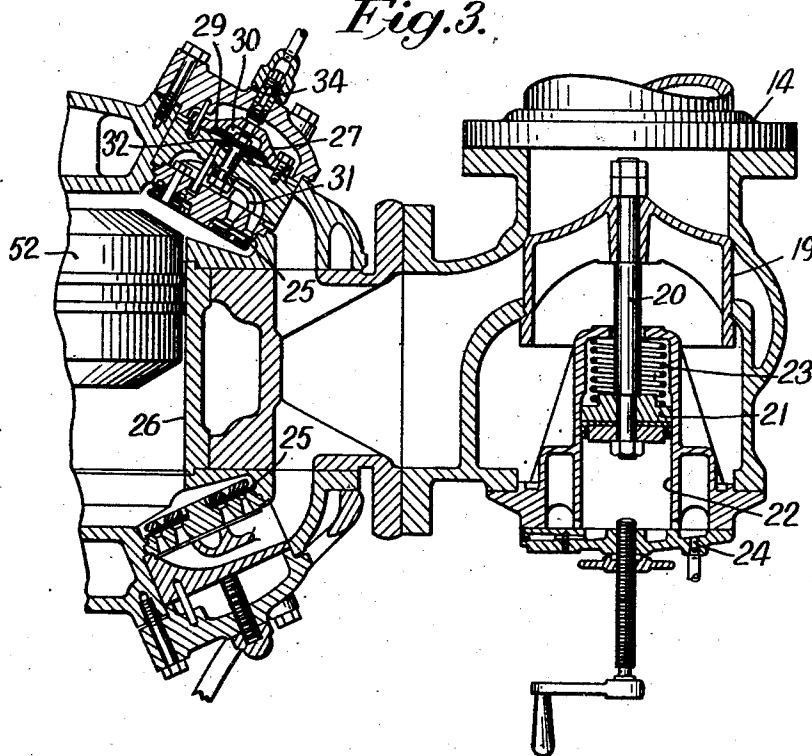
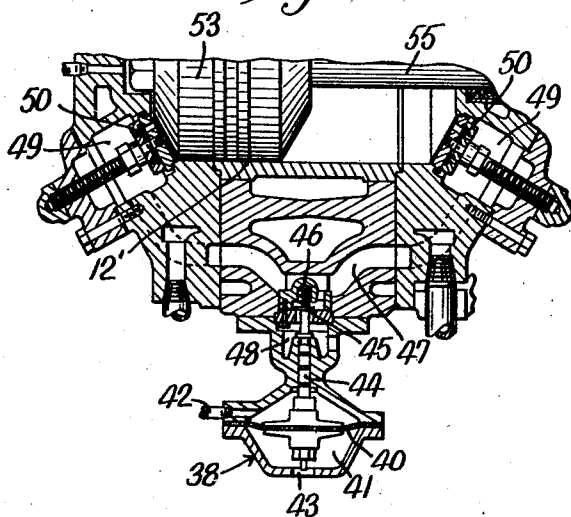


Fig. 4.



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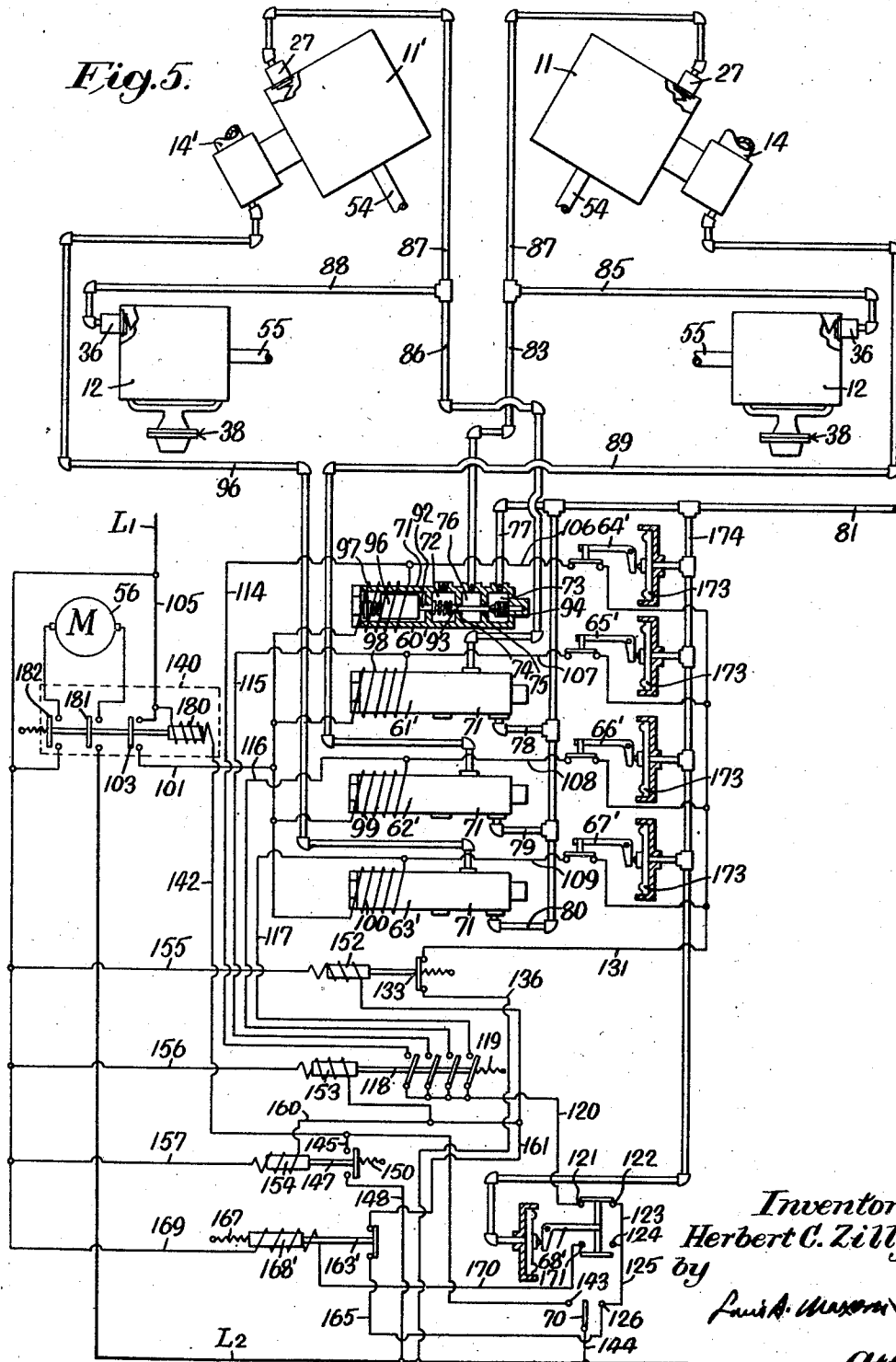
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COMPRESSOR SYSTEM

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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COMPRESSOR SYSTEM

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21 Claims. (Cl. 230—26)

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This invention relates to control systems for controlling automatically the operation of pumps or compressors.

It is sometimes necessary, where the demand for pressure fluid varies considerably, to provide several compressors with control systems which operate automatically to control the operation of the various compressors in accordance with the demand. The control of the compressors should be such that the capacity of the system may be changed in small increments between a fraction of the output of one compressor and the maximum output of the combined compressors, and such that efficient operation is obtained regardless of the quantity of pressure fluid supplied.

The control systems of this invention are adapted to such control. If a large quantity of pressure fluid is needed and there is but little change in the need, all of the compressors are connected to operate, but the control system for one of the compressors operates automatically to unload and reload its compressor in steps as the demand varies. If the need for pressure fluid decreases and the discharge pressure increases even when the compressor on step control is completely unloaded, then the other compressors are unloaded completely one at a time. The control systems are adapted to effect a reloading of the latter compressors if the discharge pressure drops certain amounts within predetermined time periods, but otherwise cause their driving motors to be stopped. After the driving motors have been stopped, they are not started again until minimum discharge pressures have been reached. The compressor operating on step loading and unloading is driven continuously, and is reloaded in steps at pressures somewhat above the minimum pressures at which the driving motors for the other compressors are started. This compressor then operates alone or in combination with any of the other compressors whose driving motors were not stopped, to carry the load. In order that each of the compressors may be subjected to the same amount of wear, means are provided for making the control systems selectively operative to effect step control by any one of the compressors while the others operate on complete loading and unloading with a starting and stopping of their driving motors.

An object of this invention is to provide an improved control system for pumps or compressors. Another object is to provide an improved control system for a plurality of pumps or compressors delivering fluid to a common discharge

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line, said control system operating automatically to control the operation of the pumps or compressors in accordance with the pressures in the discharge line. Still another object is to provide for a plurality of compressors delivering fluid into a common discharge line and an improved control system for each compressor, with each control system being selectively adjustable to provide different controlled operations of its respective compressor. Yet another object is to provide an improved compressor system including a plurality of compressors and automatic control means therefor, said control means providing stepped loading and unloading for at least one of the compressors and complete loading and unloading at different discharge pressures for the other compressors. Still another object is to provide improved control means for a plurality of compressors discharging into a common discharge line, said control means being selectively operative to effect stepped loading and unloading during continuous operation of any one of the compressors, and complete loading and unloading at different pressures of the other compressors with a starting and stopping of their driving motors. Yet another object of this invention is to provide improved control systems for a plurality of compressors, said control systems being selectively operative to provide stepped loading and unloading or complete loading and unloading of the compressors, with unloading taking place when control circuits of the systems are de-energized so that a gradual stopping of the compressors may be assured at all times. These and other objects of my invention will hereinafter more fully appear.

In the accompanying drawings in which two illustrative forms of the invention have been shown:

Fig. 1 is a schematic view of a compressor system having the improved control means incorporated therein.

Fig. 2 includes a schematic diagram of one of the compressors and an enlarged view of the control system therefor, parts being shown in section.

Fig. 3 is an enlarged sectional view through a portion of a lower pressure cylinder and its intake connection.

Fig. 4 is an enlarged sectional view through a portion of a high pressure cylinder and unloading means therefor.

Fig. 5 is a view similar to that of Fig. 2 but showing a modification of the invention.

In the illustrative embodiment of the invention

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shown in Figs. 1 to 4, compressors 1, 2, 3 and 4 discharge into a common discharge line 5 and have individual control systems, generally designated 6, 7, 8 and 9. It will be understood that the number of compressors and control systems is not at all necessarily limited to four, but this number has been shown because it indicates conveniently the variations of control that may be obtained.

Each of the compressors is multi-stage and includes a pair of double acting low pressure cylinders 11, 11' and a pair of double acting high pressure cylinders 12, 12'. Fluid is supplied to the low pressure cylinders through intake connections 14, 14', and is compressed in the low pressure cylinders and is then delivered through intercoolers 15, 15' to the high pressure cylinders where it is compressed again and then delivered through connections 16, 16' to a common conduit 17 communicating with the discharge line 5. These compressors are merely illustrative of a type of compressor that is suitable for use with the control systems of this invention. Any compressor that is capable of step controlled loading and unloading may be used.

As shown in Fig. 3, an intake closure valve 19 is provided in each of the intake connections to the low pressure cylinders. Each valve 19 is provided with a stem 20 carrying a piston 21 which is reciprocally mounted in a bore 22. Surrounding the valve stem is a coiled spring 23 acting against the piston 21 for holding the valve normally in its open position. Pressure fluid may be supplied through a port 24 to the outer end of the bore 22 where it acts on the piston 21 and forces the latter, against the spring 23, to close the valve 19. At the ends of each low pressure cylinder are inlet valves 25 for controlling the flow of fluid between the intake connection and the bore 26 of the cylinder, and discharge valves, not shown, for controlling the flow of fluid between the cylinder bore 26 and the intercooler. The inlet valve at the head end of each low pressure cylinder is adapted to be held open by a suitable fluid actuated device 27 for unloading that end of the cylinder.

The unloading device 27 herein comprises a diaphragm 29 clamped within a chamber 30 and carrying fingers 31 which are adapted to engage the inlet valve and move the latter from its seat. The fingers 31 are normally held out of engagement with the valve by a spring 32 acting on the lower surface of the diaphragm, and may be moved in a valve opening direction by pressure fluid supplied through passage means 34 to the outer side of the diaphragm.

The high pressure cylinders 12, 12' are provided with suitable inlet and discharge valves, not shown, and one of the inlet valves in the head end of each of the high pressure cylinders is adapted to be held open, as shown in Fig. 2, by an unloading device 36 similar to the unloading device 27. The high pressure cylinders are also provided, as shown in Fig. 4, with pressure responsive means, generally designated 38, for effecting an unloading, herein shown as by venting to the atmosphere, of the ends of the high pressure cylinders when their respective intercoolers have been pumped down until a subatmospheric pressure exists therein.

The unloading means 38 comprises a diaphragm 40 clamped within a chamber 41 and subjected on its upper side to intercooler pressure through a connection 42 and on its lower side to atmospheric pressure through an opening 43. A stem 44 is clamped to the diaphragm 40 and is

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adapted to engage a valve 45 and move the latter from its seat against the action of a spring 46 for connecting a passage 47 to atmosphere through a chamber 48. The passage 47 communicates at opposite ends of the high pressure cylinder with chambers 49 containing check valve mechanisms 50, herein a pair of the regular discharge valves of the high pressure cylinder.

The compressors may be individually unloaded in steps as follows: Pressure fluid is supplied first, as shown in Fig. 2, to the unloading devices 27 and 36 in the head ends of the low pressure cylinder 11 and the high pressure cylinder 12. At a predetermined increase in discharge pressure the head ends of the low pressure cylinder 11' and the high pressure cylinder 12' are unloaded by opening the inlet valves in these ends. The third step of unloading is effected by supplying pressure fluid to close the intake closure valve 19 in the intake connection for the low pressure cylinder 11. The fourth step of unloading takes place when the intake closure valve in the intake connection 14' to the low pressure cylinder 11' is closed. The loaded ends of the high pressure cylinders continue to pump fluid from their intercoolers to the supply line 5 even after the supply of fluid to the intercoolers has been completely cut off by the closing of the intake closure valves. When the pressure in the intercooler is reduced to sub-atmospheric, the diaphragm 40 of the unloading device 38 is forced inwardly by the atmospheric pressure acting on its outer side and causes the valve 45 to be unseated by the stem 44. The passage 47 then communicates past the valve 45 to atmosphere through the chamber 48, and any pressure fluid in the chambers 49 escapes through the passage 47 so that the valves 50 are opened when the pressures at the ends of the high pressure cylinder bore exceed atmospheric by a small amount, and the small amounts of fluid that may be compressed in the high pressure cylinders during unloading operation are discharged to atmosphere.

Reciprocally mounted within the low and high pressure cylinders are pistons 52 and 53 having piston rods 54 and 55 connected to a common crankshaft, not shown, for actuation thereby. A separate power unit 56, shown herein as an electric motor, is provided for driving each crankshaft.

The control systems 6, 7, 8 and 9 are herein identical, and each comprises, as shown in Figs. 1 and 2, solenoid controlled valves 60, 61, 62 and 63 having control circuits which may be opened and closed separately respectively by pressure responsive switches 64, 65, 66 and 67 when the compressor operates on step loading and unloading, and which may be opened and closed simultaneously by a pressure responsive switch 68 when the compressor operates on complete loading and unloading. A manually operated switch 70 is provided to enable selective step control or complete loading and unloading control.

Each of the solenoid controlled valves 60, 61, 62 and 63 includes a casing 71 having chambers 72 and 73 communicating, respectively, through ports 74 and 75 with a chamber 76. The chambers 72 are connected by branch conduits 77, 78, 79 and 80 to a common conduit 81 opening into the compressor discharge line 5, and the chambers 73 are connected to atmosphere through exhaust ports 82. The chamber 76 of the valve 60 is connected by a conduit 83 and branch conduits 84 and 85 to the unloading devices 27 and 36 of the low and high pressure cylinders 11 and 12.

The chamber 76 of the valve 61 is connected through a conduit 86 and branch conduits 87 and 88 to the unloading devices 27 and 36 of the low and high pressure cylinders 11' and 12'. The chambers 76 of the valves 62 and 63 are connected, respectively, by conduits 89 and 90 to the ports 24 in the intake closure valve operating cylinders associated with the intake connections 14 and 14'. Extending through the ports 74 and 75 is a valve stem 92 carrying valve members 93 and 94 which are adapted to engage valve seats surrounding the ports 74 and 75 and cut off communication between the chamber 76 and the chambers 72 and 73. The valve stem is held normally by a spring 95 in a position to seat the valve member 93 and unseat the valve member 94. Attached to one end of the valve stem is a plunger 96 which is pulled by the magnetic force of an associated solenoid, later described, when the latter is energized, in a direction to seat the valve member 94 and unseat the valve member 93.

Solenoid windings 97, 98, 99 and 100 are provided for the valves 60, 61, 62 and 63 respectively; and these windings are connected at one end to a common conductor 101 leading to a terminal 102 of a switch 103 which forms part of a motor starting device later described. The other terminal 104 of the switch is connected by a conductor 105 to one side L₁ of a power line. The opposite ends of the solenoid windings 97, 98, 99 and 100 are connected, respectively, to conductors 106, 107, 108 and 109 leading to contacts 110, 111, 112 and 113 of the pressure responsive switches 64, 65, 66 and 67. These same ends of the solenoid windings are also connected by conductors 114, 115, 116 and 117 to contacts of a solenoid operated switch 118 which is normally held in an open position by a spring 119. The other contacts of the switch 118 are connected by a conductor 120 to a contact 121 of the pressure responsive switch 68. Another contact 122 of the switch 68 is connected by a conductor 123 to a third contact 124 of the switch 68, and the contact 124 is connected by a conductor 125 to a contact 126 of the manually operated switch 70. The pressure responsive switches 64, 65, 66 and 67 are provided with contacts 127, 128, 129 and 130 connected by a common conductor 131 to a contact 132 of a solenoid operated switch 133 which is normally held in a closed position by a spring 134. The switch 133 is provided with another contact 135 which is connected by a conductor 136 to the other side L₂ of the power line.

Each driving motor 56 for the compressors is provided with an automatic starting device 140, as shown in Fig. 1. This starting device is of standard construction and includes the switch 103, motor switch devices and a suitable solenoid operating means, not shown, the solenoid operating means acting when energized to close the motor switch devices and the switch 103, the latter being preferably closed when the starter reaches running position. One terminal of this solenoid is connected by a conductor 141 to the power line L₁ and the other terminal is connected through one of two circuits to the power line L₂. One of the circuits includes a conductor 142 extending from the device to a contact 143 of the manually operated switch 70, the contactor of the switch 70, and a wire 144 connecting the contactor to the power line L₂. The other circuit includes the conductor 142, a conductor 145 branching from the conductor 142 and connected to a contact 146 of a solenoid operated switch 147, and

a conductor 148 extending from the other contact 149 of the switch 147 to the power line L₂. The switch 147 is normally held in an open position by a spring 150.

The solenoid operated switches 133, 118 and 147 are provided with solenoids 152, 153 and 154, respectively connected at one end by conductors 155, 156 and 157 to the power line L₁. The other ends of the solenoids are connected by conductors 158, 159 and 160 to a common conductor 161 leading to a contact 162 of a time relay 163. The other contact 164 of the time relay is connected by a conductor 165 to the contact 126 of the manually operated switch 70. The time relay 163 is normally held in an open position by a spring 167, and is provided with a solenoid 168 which effects, when energized, immediate closure of the relay and delays, on de-energizing, the opening of the relay for a predetermined period of time. One end of the solenoid 168 is connected by a conductor 169 to the power line L₂, and its other end is connected by a conductor 170 to a contact 171 of the pressure responsive switch 68.

The pressure responsive switches 64, 65, 66, 67 and 68 may be of any suitable type, and are shown herein as being actuated by diaphragms 173 to which pressure fluid is supplied from the pressure discharge line 5 through the conduit 81 and a branch conduit 174. The switches 64, 65, 66 and 67 of the control system for each compressor are adjusted to operate successively at pressures within a range of 90 to 100 pounds. In this case the switches 64, 65, 66 and 67 close successively at pressures of 94, 96, 98 and 100 pounds and open again as the pressure drops a pound or two below that at which each switch closed. The pressure responsive switches 68 of the control circuits 6, 7, 8 and 9 normally assume positions to connect the contacts 124 and 171 and operate successively at pressures exceeding 100 pounds, herein at pressures of 101, 102, 103 and 104 pounds, to connect the contact 121, 122 and to break the connection between the contacts 124, 171. After the switches 68 have once moved to their upper positions connecting the contacts 121, 122, they remain in such positions until the pressure drops to values somewhat below those at which the pressure switches 64, 65, 66 and 67 operate. The switches 68 of the circuits 6, 7, 8 and 9 herein drop successively to their lower positions connecting the contacts 124, 171 at line pressures of 86, 87, 88 and 89 pounds.

The operation of the compressor system is as follows. Assume that compressor 1 is to operate on step controlled loading and unloading with continuous operation of its motor, and that compressors 2, 3 and 4 are to operate on complete loading and unloading with a stopping and starting of their driving motors in accordance with the demand for fluid. The manually controlled switch 70 of control circuit 6 will be moved to a position connecting contact 143 to the conductor 144 leading to the power line L₂, and the switches 70 of the control circuits 7, 8 and 9 will be moved to positions connecting contacts 126 to the conductor 144.

The control circuit 6 then provides for the motor starting device 140 of compressor 1 a circuit including the conductor 141 connecting one side of the device 140 to the power line L₁, and the conductor 142, switch 70 and conductor 144 connecting the other side of the device to the power line L₂. Current flows continuously through this circuit and keeps the driving motor for compressor 1 running and the switch 103

closed. The pressure responsive switches 64, 65, 66 and 67 have their contacts 127, 128, 129 and 130 connected to the power line L₂ through the conductor 131, switch 133 and conductor 136, and, since the solenoid 152 for switch 133 will be de-energized at this time, the switch will be held closed by the spring 134 to maintain this portion of the circuit complete. The other contacts 110, 111, 112 and 113 of the switches are connected continuously through the solenoids 97, 98, 99 and 100, conductor 101, switch 103 and conductor 105 to the power line L₁.

When the pressure in the compressor discharge line 5 increases to 94 pounds, the pressure switch 64 closes and energizes the solenoid 97, causing the valve member 93 to move from its seat and the valve member 94 to engage its seat. Pressure fluid then flows from conduit 81 through chamber 72, port 74, chamber 76, conduit 83 and branch conduits 84 and 85 to the unloading devices 27 and 36 for unloading the head ends of the low and high pressure cylinders 11 and 12. If the pressure continues to increase, the pressure switches 65, 66 and 67 close successively at 96, 98 and 100 pounds pressure and energize the solenoids 98, 99 and 100 for operating the valves 61, 62 and 63. When the valve 61 is operated by its solenoid, pressure fluid is supplied from the conduit 81 and the branch conduit 78 through the valve to the conduit 86 which conducts it to the branch conduits 87 and 88 leading to the unloading devices 27 and 36 in the head ends of the low and high pressure cylinders 11' and 12'. As the valves 62 and 63 are operated by their solenoids, pressure fluid is supplied through the conduits 89 and 90 to close the intake closure valves in the intake connections for the low pressure cylinders. If the pressures in the supply line drop to values at which the pressure switches 64, 65, 66 and 67 open, the valves 60, 61, 62 and 63 operate to vent fluid from the unloading connections through the vent ports 82.

Each of the control circuits 7, 8 and 9 provides a circuit for the motor starting device 140 of its respective compressor. This circuit includes the conductor 141 connecting the power line L₁ to one side of the device 140, and the conductor 142, the conductor 145, the switch 147 and the conductor 148 connecting the other side of the device 140 to the power line L₂. The switch 147 will be open, however, until its solenoid 154 is energized.

If, with the switches 70 engaging the contacts 126, the pressure in the compressor discharge line is such that the pressure responsive switches 68 associated with compressors 2, 3 and 4 engage the contacts 124 and 171, current will flow in each control system from the power line L₁ through the solenoid 168 of the time relay 163, through the conductor 170, the pressure switch 68, the conductor 125, the switch 70, and the conductor 144 to the power line L₂. Thus the time relay 163 will be closed and complete circuits through the solenoids 152, 153 and 154 for the switches 133, 118 and 147. As current flows through the solenoid 152, the switch 133 will occupy its open position and break the circuit to the pressure responsive switches 64, 65, 66 and 67. When the solenoid 153 is energized, the switch 118 is closed and completes circuits from the valve solenoids 97, 98, 99 and 100 to the contact 121 of the pressure responsive switch 68, thus establishing a condition in which an increase to a predetermined value of compressor discharge pressure can effect complete unloading. With the energizing of the solenoid 154, the switch 147 is closed

and completes the circuit through the motor starting device 140 so that the motor 56 is caused to run and the switch 103 is closed.

If the demand for air is less than the amount supplied by the compressor system, the pressure in the supply line will increase and, at a pressure of 102 pounds, cause the pressure switch 68 of the control system 7 to operate and break the connection between contacts 124, 171 and to connect the contacts 121, 122. When the connection between contacts 124, 171 is broken, the supply of current through the solenoid 168 for the time relay 163 is cut off. The relay 163 remains closed, however, for a predetermined length of time and maintains the circuits through the solenoids for the switches 133, 118 and 147. Since the switch 118 will be held in a closed position by its solenoid 153, circuits will be established through the valve solenoids 97, 98, 99 and 100 as soon as the pressure switch 68 connects the contacts 121 and 122, and the compressor will be completely unloaded. The compressor driving motor will continue to operate since the switch 147 will be held closed by its solenoid 154. If the pressure in the supply line drops to 87 pounds, the pressure at which the switch 68 of control circuit 7 moves to a position connecting the contacts 124 and 171, before the end of the time period at which the time relay 163 opens, the compressor will be reloaded by the breaking of the circuits through the solenoid relays at the contacts 121 and 122 of the switch 68, and the solenoid 168 for the time relay will be re-energized to maintain the motor circuit closed. If, however, the pressure in the supply line remains above 87 pounds to the end of the time period, the time relay 163 opens and cuts off the flow of current through the solenoids for the switches 133, 118 and 147. The switch 133 closes and the switch 118 opens placing the circuits through the valve solenoids under the control of the pressure switches 64, 65, 66 and 67 so that the system may be changed, if desired, to step control by moving the switch 70 to contact 143. However, it should be noted that the switch 147 opens and cuts off the supply of current to the driving motor so that it stops and remains stopped until the solenoid for the time relay is again energized.

Whenever the pressure in the supply line increases to 103 pounds, the control system 8 operates in the same manner as the control system 7 to unload its compressor, and, if the pressure doesn't drop to 88 pounds before the end of the time period for which its time relay 163 is adjusted, to stop its driving motor. At 104 pounds pressure in the supply line, the control system 9 operates in the same manner as control systems 7 and 8 to unload its compressor and to stop the motor if the pressure doesn't drop to 89 pounds within a predetermined time period.

There is shown in Fig. 5 a modification of the invention in which the solenoid controlled valves 60', 61', 62' and 63' are held in positions for effecting an unloading of the compressor when their windings are de-energized, and are moved to positions for venting the unloading means when their windings are energized. It will be understood that, as in the first form of the invention, each of a plurality of compressors in a system is provided with a control similar to that of Fig. 5. It will be seen that with this arrangement the compressor will be unloaded if the power should be inadvertently cut off and the compressor will gradually come to a stop. To effect this control, pressure fluid is supplied from

the discharge line 5 through the conduit 81 and the conduits 77, 78, 79 and 80 to the chambers 73 in the casings 71 of the valves, and the chambers 72 in these valve casings are vented to atmosphere. Pressure responsive switches 64', 65', 66', 67' and 68' are arranged to open circuits leading to the solenoid windings of the valves 60, 61, 62 and 63 when the discharge pressure reaches predetermined maximum values instead of closing these circuits as in the first form of the invention. The switch 68' also acts to close the circuit through the winding for the solenoid 163' when the discharge pressure reaches a predetermined maximum value instead of opening it. A time relay 163' is normally held in closed position by the spring 167 and is opened after the solenoid 168' has been energized a predetermined period of time, this being directly opposite to the control of the relay 163 in the first form of the invention. Other than the changes mentioned above, this second form of the invention is the same as the first. In this case, however, the motor starting device 140 has been shown more in detail, though still in diagrammatic form, there being a solenoid 180 connected to the conductor 142 and to the conductor 105 leading to the power line L₁ for controlling the switch 103 and switches 181 and 182 connecting the motor 56 across the power lines L₁ and L₂.

When the manually controlled switch 70 is moved to a position engaging contact 143, a circuit is completed from the power line L₁ through conductor 105, the solenoid 180, conductor 142, switch 70 and conductor 144 to the power line L₂. Current flowing through the solenoid 180 causes the switches 103, 181 and 182 to close connecting the motor across the power lines L₁ and L₂, and connecting one end of each solenoid winding for the valves 60', 61', 62' and 63' to the power line L₁. If the compressor discharge pressure is low, the pressure switches 64', 65', 66' and 67' are closed, connecting the opposite ends of the solenoid windings through the conductor 131, the switch 133 and the conductor 136 to the power line L₂. Under these conditions the valves 60', 61', 62' and 63' are held by their energized solenoids in positions to vent the compressor unloading devices and cause the compressor to operate loaded. As the discharge pressure increases, the pressure switches 64', 65', 66' and 67' operate successively to open the circuits de-energizing the valve solenoids and permitting the valves to move to positions for supplying pressure fluid to the unloading devices thereby effecting a step by step unloading of the compressor.

When the switch 70 is moved to the contact 126 and the discharge pressure is low, circuits will be established immediately from the power line L₁ through the windings of the solenoids 152, 153 and 154, through conductor 161, time relay 163', conductor 165, switch 70, and conductor 144 to the power line L₂. The energized solenoid 152 causes switch 133 to open and break the circuits controlled by the pressure switches 64', 65', 66' and 67'. Solenoid 153 causes switch 113 to be closed connecting the solenoid windings for the valves 60', 61', 62' and 63' through the conductors 114, 115, 116 and 117 to the conductor 120 which leads to the contact 121 of the switch 68'. With low discharge pressure, the switch 68' assumes a position connecting contacts 121 and 122 so that conductor 120 is connected through conductors 123 and 125, switch 70, and conductor 144 to the power line L₂. The

solenoid windings for the valves are then energized and hold the latter in positions for venting the unloading devices. If the discharge pressure increases to a point where the switch 68' breaks the contacts 121, 122 and connects the contacts 124, 171, the circuits through the solenoid windings for the valves are broken causing the latter to move to positions for supplying pressure fluid to the unloading devices, and a circuit is completed through the solenoid 168' for the time relay 163'. If the solenoid 168' is energized for a predetermined period of time, the relay 163' opens, breaking the circuits through the windings of the solenoids 152, 153 and 154. This causes the compressor motor to stop with the compressor cylinders held unloaded until the pressure drops to a value at which the pressure switch operates to break the contacts 124, 171. If the pressure drops so that the switch 68' breaks the contact between 124, 171 before the time period of the relay 163' elapses, the relay 163' remains closed and causes the motor to drive the compressor unloaded until the contacts 121, 122 are again connected, at which time the compressor reloads.

Any one or more of the control systems of either form of the invention may be adjusted to effect step controlled operation of their respective compressors by simply moving the respective switch 70 to contact 143, and the other systems may be adjusted to effect complete loading and unloading of their compressors with motor stopping and starting by moving their switches 70 to contacts 126. It will be noted that the maximum pressure in the compressor discharge line may vary one pound as the different control systems are connected one at a time to provide step control while the others provide complete control. When the control system 9 is adjusted to step control, the maximum pressure will be 103 pounds, the pressure at which the switch 68 for the control system 8 operates. When any one of the other control systems is adjusted to step control, the maximum pressure will be 104 pounds, the pressure at which switch 68 for control system 9 operates. The minimum pressures in the supply line may vary in the same manner between 86 and 87 pounds.

As a result of this invention there is provided an improved control of the operation of a plurality of compressors. By providing step control for one of the compressors, a very small quantity of air may be provided when needed, or slight changes in the demand for air may be easily taken care of even when the quantity of air needed is large. The complete loading and unloading of certain of the compressors takes care of the large changes in the demand for air, and the stopping and starting of the driving motors for these compressors assures efficient operation. Other advantages of the invention will be clearly apparent to those skilled in the art.

While I have, in this application, specifically described two forms which the invention may assume in practice, it will be understood that these forms of the same are shown for purposes of illustration and that the invention may be modified and embodied in various other forms without departing from its spirit or the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. In a compressor system, in combination, a plurality of compressors and power units for driving the same, a common discharge line for said

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compressors, unloading means for each of said compressors, and automatic control systems for controlling said unloading means, said control systems being responsive to compressor discharge pressures and selectively operative to effect automatically step unloading and reloading or complete unloading and reloading of any one of said compressors.

2. In a compressor system, in combination, a plurality of compressors and power units for driving the same, a common discharge line for said compressors, unloading means for each of said compressors, and automatic control systems for controlling said unloading means and said power units, said control systems being responsive to compressor discharge pressures and selectively operative to effect automatically step unloading and reloading with continuous driving or complete unloading and reloading with stopping and starting of any one of said compressors.

3. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, fluid actuated unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the flow of pressure fluid relative to its unloading means, said control system being selectively operative to control automatically the flow of fluid relative to said unloading means so as to effect step unloading or complete unloading of the compressor controlled thereby.

4. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, fluid actuated unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the flow of pressure fluid relative to its unloading means and the supply of operating medium to its driving motor, said control system being selectively operative to effect automatically step unloading with continuous operation, or complete unloading with stopping and starting, of the compressor controlled thereby.

5. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, fluid actuated unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the flow of pressure fluid relative to its unloading means and the supply of operating medium to its driving motor, said control system being selectively operative to effect automatically step unloading at predetermined discharge pressures with continuous operation, or complete unloading at a higher predetermined discharge pressure with a stopping of the compressor controlled thereby.

6. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, fluid actuated unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the flow of pressure fluid relative to its unloading means, said control system being selectively operative to effect step unloading at predetermined pressures in said discharge line or complete unloading at a higher predetermined pressure in said discharge line.

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7. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including valve means controlling the flow of fluid to each of the unloading devices of the compressor controlled thereby, and means including devices responsive to the pressures in the discharge line for controlling the operation of said valve means, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous operation of said valve means.

8. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including valve means controlling the flow of fluid to each of the unloading devices of the compressor controlled thereby, and means including devices responsive to the pressures in the discharge line for controlling the operation of said valve means, said last mentioned means being selectively adjustable to effect either a successive operation of said valve means at predetermined discharge pressures or a simultaneous operation of said valve means at a higher predetermined discharge pressure.

9. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including solenoid actuated valve means controlling the flow of fluid to each of the unloading devices of the compressor controlled thereby, and means including switch mechanisms responsive to the pressures in the discharge line for controlling the energizing of said solenoids.

10. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including solenoid actuated valve means controlling the flow of fluid to each of the unloading devices of the compressor controlled thereby, and means including switch mechanisms responsive to the pressures in the discharge line for controlling the energizing of said solenoids, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous energizing of said solenoids.

11. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the

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pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including solenoid actuated valve means controlling the flow of fluid to each of the unloading devices of the compressor controlled thereby, and means including switch mechanisms responsive to the pressure in the discharge line for controlling the energizing of said solenoids, said last mentioned means being selectively adjustable to effect either a successive operation of said valve means at predetermined discharge pressures or simultaneous operation of said valve means at a higher predetermined pressure.

12. In a compressor, in combination, a plurality of compressors delivering fluid to a common discharge line, motors for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, a control system for each compressor for controlling the flow of fluid relative to said unloading devices, said control system including means operating at different predetermined pressures in the discharge line for connecting said unloading devices successively to fluid supply and exhaust, means operating at a higher and a lower discharge pressure for connecting said unloading devices simultaneously to fluid supply and exhaust, the higher and lower discharge pressure for each control system being different, and means for selectively rendering one of said last two mentioned means effective and the other ineffective.

13. In combination, a compressor, a motor for driving said compressor, a plurality of fluid actuated unloading devices for said compressor, a control system for controlling the flow of fluid relative to said unloading devices, said control system including valve means controlling the flow of fluid to said unloading devices, and means for controlling the operation of said valve means in accordance with compressor discharge pressures, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous operation of said valve means.

14. In combination, a compressor, a motor for driving said compressor, a plurality of fluid actuated unloading devices for said compressor, a control system for controlling the flow of fluid relative to said unloading devices, said control system including valve means controlling the flow of fluid to said unloading devices, and means for controlling the operation of said valve means in accordance with compressor discharge pressures, said last mentioned means being selectively adjustable to effect either a successive operation of said valve means at different predetermined discharge pressures or a simultaneous operation of said valve means at a higher predetermined discharge pressure.

15. In combination, a compressor, a motor for driving said compressor, a plurality of fluid actuated unloading devices for said compressor, a control system for controlling the flow of fluid relative to said unloading devices, said control system including means operating at different predetermined compressor discharge pressures for supplying pressure fluid successively to said unloading devices, means operating at a higher predetermined discharge pressure for supplying pressure fluid simultaneously to said unloading devices, and means for selectively rendering one of said last two mentioned means effective and the other ineffective.

16. In combination, a compressor, a motor for driving said compressor, a plurality of fluid ac-

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tuated unloading devices for said compressor, a control system for controlling the flow of fluid relative to said unloading devices, said control system including means operating at different predetermined compressor discharge pressures for connecting said unloading devices successively to fluid supply and exhaust, means operating at higher and lower discharge pressures for connecting said unloading devices simultaneously to fluid supply and exhaust, and means for selectively rendering one of said last two mentioned means effective and the other ineffective.

17. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, power means for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including solenoid actuated valve means controlling the flow of fluid to each of said unloading devices and operative when energized to vent pressure fluid therefrom, and means including normally closed switch mechanisms responsive to the pressures in the discharge line for controlling the energizing of said solenoids, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous energizing and de-energizing of said solenoids.

18. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, power means for driving said compressors, a plurality of fluid actuated unloading devices for each of said compressors, and a control system for each compressor responsive to the pressures in said discharge line for controlling the flow of fluid relative to said unloading devices, said control system including solenoid actuated valve means controlling the flow of fluid to each of said unloading devices and operative when energized to supply pressure fluid thereto, and means including normally open switch mechanisms responsive to the pressures in the discharge line for controlling the energizing of said solenoids, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous energizing and de-energizing of said solenoids.

19. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, power means for driving each of said compressors, unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the operation of the unloading means for the compressor controlled thereby, said control system being selectively operative to effect step unloading and reloading or complete unloading and reloading of said compressor.

20. In a compressor system, in combination, a plurality of compressors delivering fluid to a common discharge line, power means for driving each of said compressors, unloading means for each of said compressors, and an automatic control system for each compressor responding to the pressures in said discharge line for controlling the operation of the unloading means for the compressor controlled thereby and for controlling its driving, said control system being selectively operative to effect step unloading at predetermined discharge pressures with continuous driving, or complete unloading at a higher predetermined

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discharge pressure with a stopping of said compressor after a predetermined time delay.

21. In combination, a compressor, power means for driving said compressor, a plurality of unloading devices for said compressor operative to effect either a stepped loading and unloading or a complete loading and unloading of said compressor, a control system for controlling the operation of said unloading devices, said control system including a plurality of means each operative to effect an operation of one of said unloading devices, and means for controlling the operation of said plurality of means in accordance with compressor discharge pressure, said last mentioned means being selectively adjustable to effect either a successive or a simultaneous operation of said plurality of means.

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