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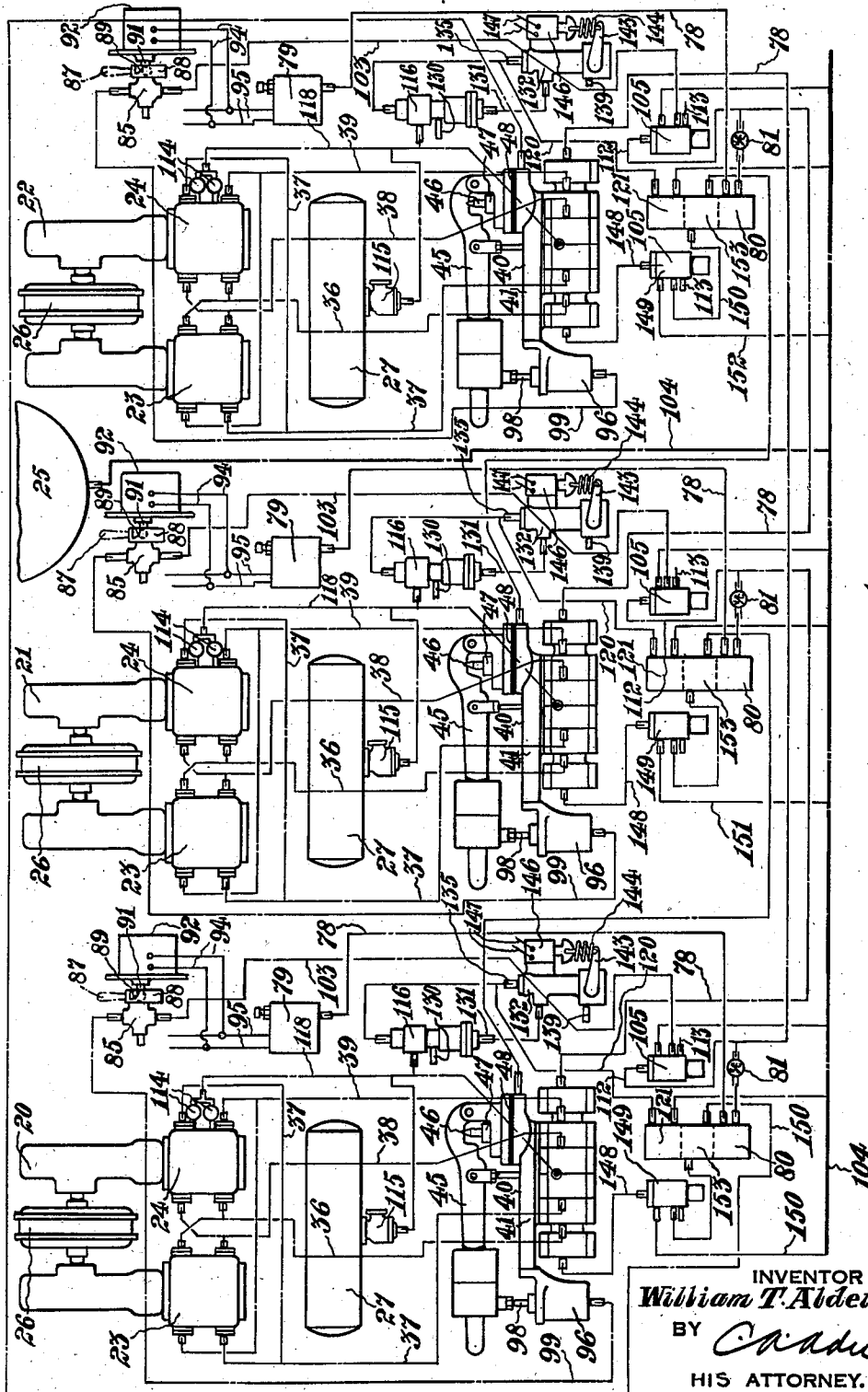
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LOAD CONTROLLING APPARATUS FOR COMPRESSORS

Filed Oct. 14, 1939

3 Sheets-Sheet 1



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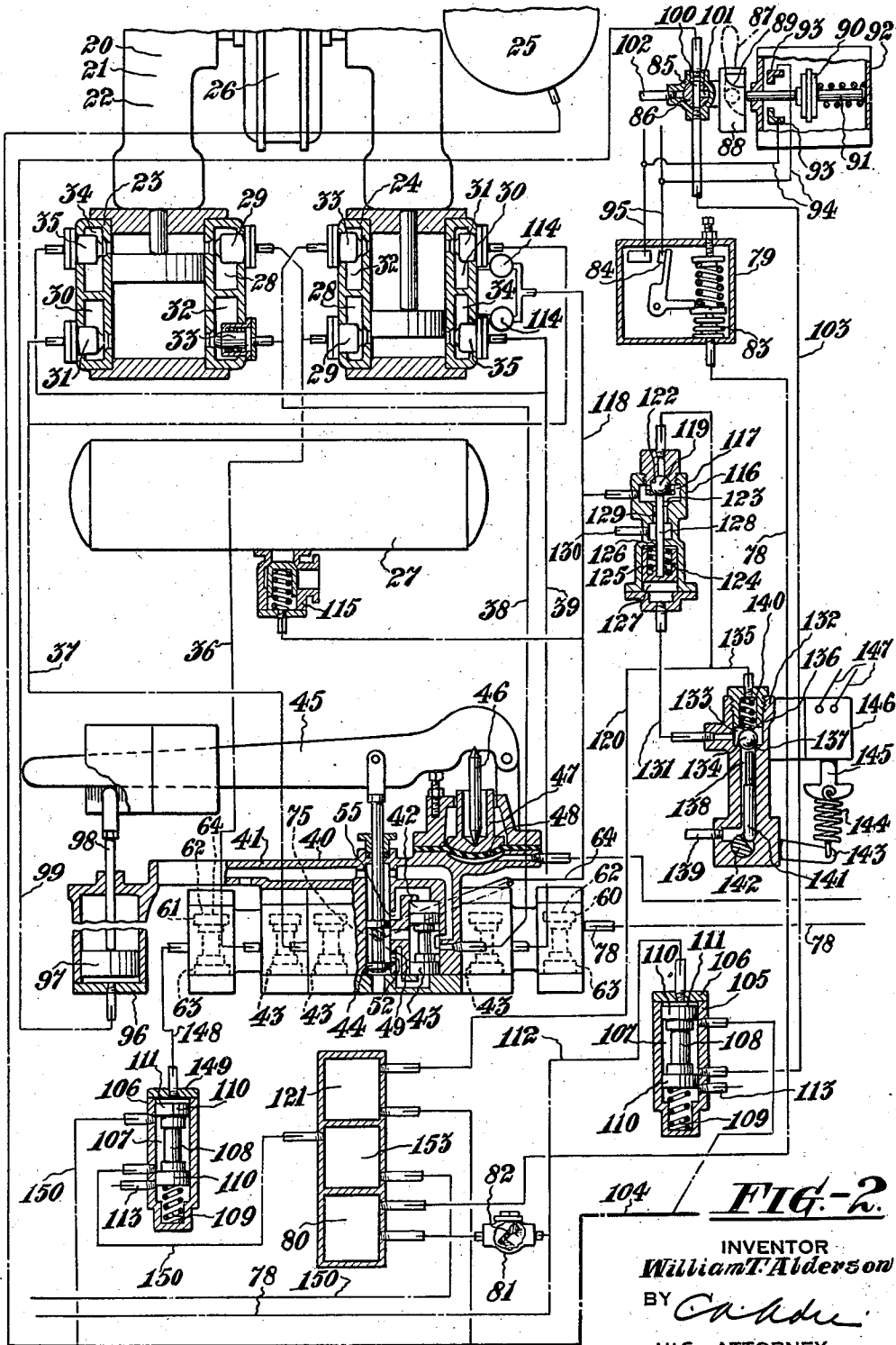
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## UNITED STATES PATENT OFFICE

2,225,291

## LOAD CONTROLLING APPARATUS FOR COMPRESSORS

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18 Claims. (Cl. 230-17)

This invention relates to compressors, and more particularly to load controlling apparatus for machines of this character.

5 The invention is particularly applicable for use in connection with compressor systems employing a plurality of compressors discharging into a common receiver and where the demand of the work for which the pressure fluid is intended may vary to a considerable degree.

10 In installations of this type if the demand for pressure fluid is moderate only one machine need be operated and whenever the demand for pressure fluid exceeds the capacity of one compressor other compressors may be brought into operation.

15 In accordance with the present invention, the initiation of operation of an additional compressor or compressors, as necessitated by the increasing demand upon the pressure fluid in storage, is effected automatically and in such wise that whenever the consumption of pressure fluid  
20 lowers the storage pressure to a predetermined degree certain devices will operate responsively to such reduction for initiating the starting of another compressor to assist in maintaining the required pressure value.

It is accordingly an object of the present invention to effect sequential starting and stopping of a plurality of compressors discharging into a common receiver.

30 Another object is to effect the automatic starting and stopping of units of a group of compressors in accordance with the demand upon the supply of storage pressure.

A further object is to confine the load controlling function to the last of a group of compressors to be set in operation, irrespective of the number of compressors included in the group.

Other objects will be in part obvious and in part pointed out hereinafter.

40 In the drawings accompanying this specification and in which similar reference numerals refer to similar parts,

Figure 1 is a diagrammatic view of a group of compressors equipped with load controlling apparatus constructed in accordance with the practice of the invention for effecting sequential starting and stopping of the compressors.

Figure 2 is a diagrammatic view, partly in section, of one of the compressors and its load controlling apparatus shown in Figure 1, and

50 Figure 3 is a longitudinal elevation, partly broken away, of a detail.

Referring to the drawings, and at first more particularly to Figure 1, 20, 21 and 22 are multi-stage compressors which accordingly have low

and high pressure cylinders 23 and 24, respectively, and may be suitably connected to discharge into a common storage receiver 25. Each compressor has an individual driving motor 26, and an intercooler 27 through which the fluid passes from the low pressure cylinder 23 to the high pressure cylinder 24 for removing the heat generated by compression.

In order to enable the load on the compressor cylinders to be changed or controlled gradually, each cylinder is provided with suitable load controlling devices consisting, in the present instance, of clearance chambers and valves for controlling them. The valves and the clearance chambers are brought into action in pairs and one chamber and associated valve of a pair is located in the low pressure cylinder while the other chamber and its valve are located in the high pressure cylinder. Thus, a clearance chamber 28 and a valve 29 controlling it are located adjacent the crank end of the low pressure cylinder and a valve 20 and a chamber 28 are located adjacent the outer end of the high pressure cylinder.

Similarly, a clearance chamber 30 and a valve 31 are located at the outer end of the low pressure cylinder and a similarly designated clearance chamber and a valve lie adjacent the crank end of the high pressure cylinder. In like manner, a clearance chamber 32 and its clearance valve 33 are arranged adjacent the outer end of the low pressure cylinder, as for example diametrically opposite the chamber 30, and a chamber 32 and its valve 33 are located adjacent the crank end of the high pressure cylinder opposite the chamber 30 and at the outer end of the high pressure cylinder. In the longitudinal plane of the chamber 30 is a chamber 34 and a valve 35 and the other chamber 34 of the last mentioned pair and its valve 35 lie adjacent the crank end of the low pressure cylinder in the longitudinal plane of the adjacent clearance chamber 30.

The pairs of clearance valves 29, 31, 33 and 35 are connected, respectively, by conduits 36, 37, 38 and 39 which lead to a regulator 40 of the type illustrated in United States Patent No. 1,430,578 to C. W. Metzgar, dated October 3, 1922, and comprises a casing 41 having a series of valve chambers 42 containing main valves 43 which control the supply of pressure fluid to the clearance valves in the compressor cylinders. The main valves are in turn controlled by an auxiliary valve 44 connected to a weighted lever 45 pivoted at one end to the casing 41 and resting upon a pin 46 of which an end seats in a hollow plunger 47 supported by a diaphragm 48 in the casing 41.

The diaphragm 48, plunger 47, pin 46 and lever 45 of each regulator constitute an actuator therefor so that when the diaphragm 48 is subjected to storage pressure the lever 45 and attached valve 44 are caused to rise and fall in accordance with the variations in the pressure in the storage receiver. Thus, when the demand for fluid substantially equals the discharge output of the compressor the valve 44 assumes a low position in the casing 41. In this position the valve 44 communicates its chamber 49 with ports or passages 50, 51, 52 and 53 leading to the lower ends of the valve chambers 42. The main valves 43 will then be raised to admit pressure fluid through the conduits 36, 37, 38 and 39 to the clearance valves for holding them closed to prevent the passage of fluid from the compressor cylinders into the clearance chambers.

The various elements controlling the clearance chambers remain in substantially the positions described until the pressure fluid in the storage receiver 25 rises above the predetermined value. The pressure fluid acting against the diaphragm 48 then raises the lever 45 and thus the valve 44. As the valve 44 proceeds upwardly it uncovers, first, the port 53 to exhaust the pressure fluid beneath the main valve 43 controlling the conduit 39.

Simultaneously, with the uncovering of the port 53 the valve 44 places the lowermost port 54 of a group of ports, leading to the upper ends of the valve chambers 42, to admit pressure fluid above the main valve 43 controlling the conduit 39. This main valve is then shifted to a new position to exhaust the pressure fluid from the clearance valves 35. The valves 35 will then open to communicate the chambers 34 with the high and low pressure cylinders and the load of the compressor will thereby be reduced by one-quarter.

Upon the continued increase in pressure of the fluid acting against the diaphragm 48 the valve 44 will be raised to new positions and will successively uncover the ports 52, 51 and 50 to communicate the lower portions of the main valves 43 with the atmosphere, and to successively place other ports 55, 56 and 57, of the group including port 54, in communication with pressure fluid supply to shift the main valves 43 downwardly for exhausting the pressure fluid from the clearance valves which they control. This operation of the regulator may continue until all the clearance valves have been released and the compressor will then be fully unloaded.

In so far as the regulation of the clearance valves is concerned each regulator operates in its characteristic manner, as described in the aforementioned patent and again somewhat briefly in the above description. However, in accordance with the practice of the invention, the regulators perform additional duties including those of effecting the starting and the stopping of compressors other than those for which they control the load. To this end each regulator casing 41 is provided with valve chambers 58 and 59 containing, respectively, valves 60 and 61 which may be replicas of the valves 43 and accordingly have end heads 62 and 63, the outer ends of which constitute pressure surfaces 64 and 65, respectively.

The spaces between the heads 62 and 63 serve as supply chambers 66 and are in constant communication with the valve chamber 49 through passages 67 in the casing 41. Each valve 60 and 61 carries a bridge 68 having a channel 69 for

effecting communication between a port 70, in the casing 41, and an exhaust passage 71 leading through the casing 41 to the atmosphere. The bridges 68 are spaced suitable distances from the heads of the valves and the spaces 72 between the lowermost ends of the bridges 68 and the heads 63 serve as passages for communicating the chambers 66 with the ports 70.

The pressure fluid supply to the valves 60 and 61 is also controlled by the auxiliary valve 44, 10 and to this end the casing 41 is provided with a passage 73 that extends from the lowermost part of the valve chamber 58 to a point in the valve chamber 49 below the lowermost of the ports leading to the valve chambers 42. Owing 15 to this arrangement, when the auxiliary valve moves below the port 53 the passage 73 will be open to the pressure fluid supply between the heads of the auxiliary valve, and at the beginning of the upward movement of the auxiliary valve 44 the passage 73 will be communicated 20 with the atmosphere before the port 53 is uncovered.

The lowermost end of the valve chamber 59 is supplied in a similar manner but the passage 25 74 which conveys pressure fluid thereto opens into the valve chamber 49 at a point above the port 50 so that the said passage 74 will be uncovered by the valve to communicate it with pressure fluid supply before the valve uncovers 30 the port 50 to supply pressure fluid to its associated main valve 43. More specifically, the passage 74 lies intermediate the passages leading to the main valves 43 and the supply port 75 of the valve chamber 49.

Passages are also provided in the casing 41 for conveying pressure fluid to the upper ends of the valve chambers 58 and 59 from the valve chamber 49. The passage serving this function for the valve chamber 58, and which is designated 76, communicates with the valve chamber 49 below the lowermost of the ports supplying the upper ends of the valve chambers 42. In this way, when the auxiliary valve 44 is positioned to supply pressure fluid to the lower ends 45 of the main valves, and the valves 60 and 61, the passage 76 will be uncovered to communicate it with the atmosphere through the upper end of the valve chamber 49. The passage designated 77 and leading to the upper end of the valve chamber 59, on the other hand, opens into the valve chamber 49 at a point above the group of passages controlling the upper ends of the main valves so that when the auxiliary valve descends said passage 77 will be the first to be communicated 55 with the atmosphere and when the auxiliary valve 44 rises it will be the last one of the passages opening into the valve chamber 49 to be communicated with pressure fluid supply.

The valves 60 and 61 are structurally identical and serve, respectively, as initial steps in the automatic starting and stopping of the compressor. Thus, the valve 60 of compressor 20 initiates the starting apparatus of an idle compressor and controls, in the arrangement shown, a supply conduit 78 leading to a pressure actuated starting switch 79 of another motor, say, the motor 26 driving the compressor 21. A time delay tank 80 is interposed in the conduit 78, and in the branch of the conduit 78 leading from the casing 41 to the delay tank 80 is a check valve 81 which permits the unrestricted flow of pressure fluid from the valve chamber 58 to the switch 79 but is provided with an orifice 82 to 75

assure a slow exhaust of fluid from the pressure switch 79.

From the foregoing it will be apparent that when the valve 60 of an operating compressor is positioned to admit pressure fluid into a conduit 78 the pressure switch 79 of the motor intended to be started, shown in somewhat fuller detail in Figure 2 as comprising a spring opposed bellows 83 for actuating the movable contactor 84, will be closed to complete the circuit to its motor. This action of the switch 79 will take place automatically since it is controlled by the regulator of its associated compressor and said regulator itself is constantly subjected to and acts in response to the value of the storage pressure.

Any of the motors 26 of the compressors may be started by the action of a regulator but means are also provided to effect manual starting of the motors. These means preferably comprise starting devices, for each motor, of the character forming the subject matter of United States Patent No. 1,761,578, granted to C. W. Metzgar, June 3, 1930. Each starting device comprises a valve mechanism including a casing 85 containing a rotary valve 86 having a handle 87 for its manipulation. The handle 87 has a head 88 which, as may be ascertained by reference to the last mentioned patent, is so related with the valve 86 that both will turn in unison.

In the outer side of the head 88 is a cam surface 89 to control the action of a spring-pressed movable contactor 90 carried by a rod 91 which is slidable in a casing 92 and abuts with one end against the adjacent end of the head 88. The casing 92 also contains stationary contactors 93 for cooperation with the movable contactor 90 to close the circuit between leads 94 which are connected to the wires 95 leading from the pressure switch 79 to the motor.

The arrangement is such that when the valve 86 occupies one position the rod 91 will seat against the end of the head 88 to retain the contactor 90 out of engagement with the contactors 93, and in another position of the valve 86 the cam surface 89 will be in a position permitting the contactor 90 to engage the contactors 93.

The valve 86 is of the three-way type and its function, in the present instance, is to control the flow of pressure fluid employed to retain the auxiliary valve 44 of the regulator of the associated compressor, when idle, in a position to maintain a full supply of pressure fluid in the upper ends of all the valve chambers in the regulator casing 41 to press the valves therein to their lowermost limiting positions. The device employed for this purpose comprises a cylinder 96 shown, for simplicity of illustration, as being attached to the casing 41, and within the cylinder 96 is a piston 97 having a rod 98 on its upper end to engage the lever 45 of the regulator. A conduit 99 leads from the cylinder 96, beneath the piston 97, to the valve casing 85 and is controlled by the valve 86 which has a port 100 extending diametrically therethrough and a lateral port 101 branching from the port 100.

The valves 86 control both the admission to and the exhaust of fluid from the cylinders 96, the latter taking place through an exhaust pipe 102 attached to each casing 85. Pressure fluid is conveyed to a casing 85 by a conduit 103 attached to a supply line 104 which is in constant communication with the storage receiver 25, and in the conduit 103 is a reversing valve mechanism 105

for controlling communication between the supply conduit 104 and the valve 86.

Each valve mechanism 105 controls the flow of pressure fluid to and from a valve 86. It comprises a casing 106 having a chamber 107 to accommodate a valve 108 which seats upon a spring 109, in the lower part of the casing 106, for actuating the valve 108 toward the upper part of the casing 106. The valve has end heads 110 and the outer end of the upper head 110 constitutes an actuating surface 111 to and from which pressure fluid is conveyed by a conduit 112 connected to the conduit 78 between the check valve 81 and the valve 60 so that pressure fluid will flow unrestrictedly to and from the actuating surface 111.

The heads 110 of the valve 108 are suitably spaced to uncover the several branches of the conduit 103 in order to permit the flow of fluid through the valve chamber 107 from one branch to the other of said conduit and also to afford communication between the branch 103 leading from the valve mechanism 105 to the valve 86 with an atmospheric exhaust pipe 113 attached to the casing 106 below the conduit leading to the valve 86.

In accordance with a well known practice, each compressor unit is provided with devices, variously located, for further assuring the complete unloading of the compressors after the clearance valves have been opened to communicate the clearance chambers with the compressor cylinders. Included among these devices are cylinder relief valves 114, of a well known type, attached to the high pressure cylinder to permit the exhaust therefrom of such pressure fluid as may leak from storage into the cylinder. The receivers are also provided with relief valves 115, of a well known type, to permit the partial exhaust of the fluid delivered to the receivers by the low pressure cylinders during the starting of a compressor, thereby preventing the imposition of a heavy load upon the motors while accelerating.

During the normal operation of the compressors both the relief valves 114 and 115 of a compressor are held closed, however, by pressure fluid controlled by a common valve means which also controls the supply of pressure fluid to the valve chamber 49 of the regulator. The valve mechanism illustrated to perform this service is of the three-way type comprising a casing 116 having a chamber 117 to which is connected a conduit 118 that leads to the relief valves 114 and 115 and to the port 75 in the valve chamber 49. In the chamber 117 is a valve 119, in the form of a ball, for controlling communication between the conduit 118 and a supply pipe 120 connected to the supply conduit 104 and having a drain tank 121 interposed therein for moisture separated from the pressure fluid passing through the conduits leading to the relief valves and the regulator.

In one end of the valve chamber 117 is a seating surface 122 for the valve 119 to prevent the flow of pressure fluid from the pipe 120 into the valve chamber, and at the opposite end of the valve chamber is a second seating surface 123 upon which the valve seats whenever the conduit 118 and the pipe 120 are in communication with each other. The valve 119 descends by gravity to the latter seat and is actuated into engagement with the seat 122 by a piston 124 containing a spring 125 which seats against a shoulder 126 in the casing 116 to move the piston 124 downwardly in the chamber 127 containing the piston. A rod 128 is interposed between the pis-

ton 124 and the valve 119 to actuate and hold the latter against the seat 122.

The rod 128 extends slidably through the wall 126 and loosely through an aperture 129 merging with the valve seat 123, and opening into the lower part of the aperture 129 is an exhaust pipe 130 to communicate the aperture 129 with the atmosphere.

Suitable means are provided for controlling the supply and exhaust of pressure fluid to and from the chamber 127 for actuating the valve 119 against the seat 122 and to permit the valve 119 to return to the seat 123. To this end the chamber 127 is provided with a conduit 131 which is attached to the casing 132 of a control valve mechanism having a chamber 133 to accommodate a valve 134. The conduit 131 opens into an intermediate portion of the chamber 133, and opening into the upper end of the chamber 120. The valve 134 is of the ball type adapted to engage a seat 136 in the upper end of the chamber 133 to cut off communication between the conduits 131 and 135 and also to engage a seat 137 in the bottom of the chamber 133 at the end of a bore 138 extending downwardly through the casing 132 and communicating with the atmosphere through a pipe 139.

The valve 134 is held against the seat 137 by a spring 140 disposed above the valve and is actuated against the seat 136 by a plunger 141 extending loosely through the bore 138. The lower end of the plunger rests upon a rocker 142 rotatable in the casing 132 and having an arm 143 which is yieldably connected, as by a spring 144, to the armature 145 of a solenoid 146. The wires 147 of the solenoid are wired into the motor field switches, in a well understood manner, so that the energization and deenergization of the solenoids takes place automatically in accordance with the operation of the motor switches. In this way the energization of the solenoids will not occur during the initial starting of the motors when they are operating as induction motors. This delay is desirable because it prevents the loading of the compressors until their motors have attained a speed at which it may be considered practical to apply the load.

The function of the valves 61 is, more particularly, that of initiating the first step in the stopping of a compressor other than that of which the regulators controlling the valves 61 form a part. For example, the valve 61 of the compressor 20 performs this service for the compressor 20, the valve 61 of the compressor 21 performs a like service for the compressor 21 and the valve 61 of the compressor 22 acts as the first step in the stopping of the compressor 21. Each valve 61 controls a conduit 148 that conveys pressure fluid to and from a reversing valve 149, similar in all respects to the valve mechanism 105.

The reversing valves 149 are interposed in conduits leading from the supply conduit 104 to the several diaphragms 48 of the regulators. One of these conduits, designated 150 and controlled by the reversing valve 149 associated with compressor 20, leads to the diaphragm 48 of compressor 22. The conduit controlled by reversing valve 149 of compressor 21 and designated 151 leads to the diaphragm 48 of compressor 20, and the conduit designated 152 controlled by reversing valve 149 of compressor 22 leads to the diaphragm 48 of compressor 21.

Interposed in each conduit 150, 151 and 152 are volume tanks 153 to maintain ample volumes

of pressure fluid closely adjacent the diaphragms 48 of the regulators.

In practice, whenever it is intended to set the first one of the group of compressors in operation, the valve 86 of, say, compressor 20 is rotated manually into a position in which the passage in the valve 86 establishes communication between the conduit 89 and the exhaust pipe 102, thereby opening the cylinder 96 to the atmosphere and permitting the lever 45, together with the auxiliary valve 44 attached thereto, to descend. During the rotation of the valve 86 the cam surface 89 of the head 88 is moved into the longitudinal plane of the rod 91. The contactor 90 will then be actuated, by its spring, against the contactors 93 and close the circuit 94 for starting the motor 26 of compressor 20.

When the motor attains synchronous speed the solenoid 146 will become energized to move the armature 145 upwardly and tilt the rocker 142. This movement of the rocker raises the ball valve 134 against the seat 136, thereby opening the chamber 127 to the atmosphere through the conduits 131 and 139 and the associated passages in the casing 132.

Upon the exhaust of pressure fluid from the chamber 127 the spring 125 shifts the piston 124 to permit the valve 119 to drop to the seat 123. Pressure fluid then flows from the conduit 120 to the valve chamber 117 and conduit 118 to the relief valves 114 and 115 and to the valve chamber 49. The relief valves 114 and 115 will be closed by such pressure fluid to prevent the further passage of fluid from the compressor through these elements. During the ensuing descending movement of the lever 45 of the regulator the auxiliary valve 44 will successively place the upper ends of the valve chambers 42, 59 and 58 in communication with the atmosphere and successively place the ports below the supply port 75 in communication with pressure fluid supply.

In the present instance, the port first uncovered is that designated 74. When this port is uncovered pressure fluid is admitted beneath the valve 61 which will be raised to place the space 72 in position to admit pressure fluid into the adjacent port 70. Pressure fluid will then flow through the conduit 148 into the casing 106 of reversing valve 149 and move its valve 108 to communicate the conduit 150 with the atmosphere through pipe 113 so that the diaphragm 48 of compressor 22 will be open to the atmosphere.

Upon further descending movement of the auxiliary valve 44 the ports leading to the lower ends of the chambers 42 are successively communicated with pressure fluid supply in the valve chamber 49. The clearance valves of the high and low pressure cylinders will then be closed by the pressure fluid valved to them by the main valves 43 accordingly as one main valve after the other is actuated upwardly in their chambers 42.

With the various elements in the positions described, the compressor is fully loaded and its discharge output delivered to the storage receiver 25. As long as the compressor 21 maintains the required pressure within the receiver the pressure beneath the diaphragm 48 will maintain the auxiliary valve 44 in position to communicate the passage 73 with the atmosphere.

When, however, the consumption of pressure fluid causes the pressure in the receiver and, therefore, beneath the diaphragm 48 to fall below

a predetermined minimum value the auxiliary valve 44 descends to a position in which it communicates the passage 73 with supply in the valve chamber 49 and opens the passage 76 to the atmosphere. The valve 60 will then be raised to admit pressure fluid into the conduit 78 leading to compressor 21. The admission of pressure fluid into said conduit will immediately cause the pressure switch 79 to be actuated for closing the motor circuit 95 of compressor 21. Simultaneously, with the actuation of switch 79 pressure fluid is admitted into the associated valve mechanism 105 to press valve 108 downwardly to a position for communicating the branch of conduit 103 leading to valve 86 with the exhaust pipe 113. With the valve 86 in a position to communicate conduits 103 and 99 with each other pressure fluid passes from cylinder 96 of compressor 21 to the atmosphere. The auxiliary valve 44 may then descend to supply pressure fluid to the various valves which it controls to cause the actuation of the devices that serve to apply the load to compressor 21.

During its downward movement the auxiliary valve uncovers first the passage 74 leading to the associated valve 61 to admit pressure fluid thereto for raising said valve. Pressure fluid will then flow from the chamber 66 through the space 72, the port 70 and the conduit 148 into the upper end of reversing valve 149, the valve 108 of which will be moved into a position in which it communicates the branch of the conduit 151 leading from the reversing valve to diaphragm 48 of compressor 20 with the atmosphere.

The pressure fluid beneath the diaphragm 48 of compressor 20 will then be exhausted to the atmosphere and the regulator remains in position to maintain full loading of said compressor 20 and to maintain pressure fluid beneath the valves 60 and 61 but will not take any part in varying the load on the compressor 20 or on the combined load of the compressors.

Thereafter, this service will be performed only by the regulator of compressor 21 and said regulator will maintain a partial or full load on its compressor until the consumption of pressure fluid creates a value in the storage receiver 25 below the predetermined minimum.

When the pressure acting against the diaphragm 48 of compressor 21 reaches this minimum value the auxiliary valve 44 of the active regulator descends and uncovers passage 73 to admit pressure fluid beneath the associated valve 60 for raising it. Pressure fluid then passes through the connected conduit 78 to the pressure switch 79 and to the valve mechanism 105 of compressor 22. After a short period of acceleration of compressor 22 the remaining devices, including the solenoid 146, will act in their proper order to apply the load to the compressor and to communicate the diaphragm 48 of compressor 21 with the atmosphere in the manner previously explained.

The function of load controlling will thereafter be assumed entirely by the regulator of compressor 22 and the regulators of compressors 20 and 21 will occupy positions in which they maintain full loads on their respective compressors but will be otherwise inactive and, therefore, unable to cause any variation in the loading of their compressors.

In the event that the combined deliveries of all the compressors of the group raise the storage pressure in excess of the predetermined maximum value the pressure beneath diaphragm 48 of com-

pressor 22 raises the auxiliary valve 44 to cause unloading of the cylinders 23 and 24, either partially or fully, in accordance with requirements. If the compressor 22 becomes fully unloaded and the receiver pressure continues to rise the auxiliary valve 44 of compressor 22 will be elevated further to a position to communicate passage 77 with the valve chamber 49. Pressure fluid then flows against the pressure surface 64 of valve 61 and moves said valve downwardly to exhaust the pressure fluid acting against pressure surface 111 of the associated valve 108. This valve will then be moved in position to permit the flow of pressure fluid through conduit 152 and volume tank to the diaphragm 48 of compressor 21, thereby rendering its regulator operative. The auxiliary valve 44 of the latter diaphragm will then be raised above the associated passage 73 to open the lower end of valve chamber 58 to atmosphere.

Simultaneously with the shifting of valve 61, pressure fluid flows from valve chamber 49, through passage 76, into the upper end of valve chamber 58 and moves valve 60 downwardly to open conduit 78 to the atmosphere. Pressure fluid will then escape from pressure switch 79 and valve mechanism 105 of compressor 22 to stop said compressor. The valve 108 of valve mechanism 105 will then be actuated by its spring 109 to a position to admit pressure fluid from the supply conduit 104 through conduits 103 and 99 and valve 86 into cylinder 96 of compressor 22. The pressure fluid acting against piston 97 will raise lever 45 and auxiliary valve 44 to their uppermost positions for maintaining valve 61 in position to communicate reversing valve 149 with the atmosphere and thereby retain diaphragm 48 of compressor 21 in communication with pressure fluid supply.

Thereafter the regulator of compressor 21 will control the load of its compressor and if the receiver pressure continues to rise will cause unloading of the cylinders of compressor 21 in step-by-step fashion. The latter regulator will then act to effect full or partial loading and if the storage pressure still continues to rise above the predetermined maximum the auxiliary valve 44 is elevated to its extreme top position to cause actuation of the valves 61 and 149 for admitting pressure fluid beneath diaphragm 48 of compressor 20 and to open pressure switch 79 and admit pressure fluid beneath piston 97 of compressor 21, in the manner explained more fully in connection with the stopping of compressor 22.

Compressor 21 will then also be idle and only compressor 20 will continue to operate. The load will again be controlled by its regulator, and if the volume delivered by compressor 20 continues to exceed consumption so that the storage pressure rises above that which it is intended to maintain the auxiliary valve 44 of compressor 20 will rise and cause actuation of the various valves which it controls to unload the compressor and, finally, to cut off the power supply to the motor and valve pressure fluid to its piston 97 for raising the auxiliary valve 44 to its uppermost limiting position.

All the compressors will then be idle. Their cylinders will be fully unloaded and all the valve mechanisms 149 will be in position to admit pressure fluid beneath the diaphragms 48. Thus, whenever it is intended to again start operation of a compressor any one of the valves 86 may be actuated manually to a position for exhausting pressure fluid from the associated cylinder 96. The remaining steps in the starting, loading and

operation of the compressor will then follow as hereinbefore outlined.

After the pressure fluid has been exhausted from the cylinder 96 the starting valve 86 is moved into a position in which the port 100 communicates the conduits 99 and 103 and with the remaining valves 86 occupying like positions the subsequent starting operation of the remaining compressors and the stopping of all the compressors will take place entirely automatically without further manual attention.

Although, as has been stated in the description of the operation of the apparatus, a continued rise in the value of the storage pressure will cause the auxiliary valves of the regulators to ascend progressively to their topmost limiting positions and successively cause actuation of the various devices serving to unload the compressors, it will be readily appreciated that, upon increased consumption in pressure fluid, the regulators may again apply partial or full loads to their compressors, either in an intermediate position or topmost limiting position of the auxiliary valves as long as sufficient pressure remains in the pressure switches 79 to keep them from opening the circuits which they control. Thus, an auxiliary valve may be actuated to its topmost limiting position but, by reason of the restricted exhaust of pressure fluid from the switches, through the apertures 82 in the check valves 81, the opening of the switches will be delayed somewhat, and if the demand for pressure fluid is again increased before the pressure in the switches 79 has dropped below that value at which the switches open the regulators will again operate to apply loads to the compressors before the switch is opened and, therefore, while their respective motors are still in operation.

I claim:

1. The combination of a plurality of compressors, and pressure fluid actuated means acting in response to an increasing demand on the discharge output of an operating compressor to effect the starting of another compressor.
2. The combination of a plurality of compressors, load controlling devices for each compressor, and pressure fluid actuated means acting in response to an increasing demand on the discharge output of an operating compressor to effect the starting of another compressor and its load controlling device.
3. The combination of a plurality of compressors, loading devices for the compressors, means for controlling the loading devices, and means controlled by the first mentioned means for sequentially initiating the operation of the compressors.
4. The combination of a plurality of compressors, loading devices for the compressors, regulators for controlling the loading devices, and means controlled by the regulator of an operating compressor to initiate an operating period of another compressor and its regulator.
5. The combination of a plurality of compressors, loading devices for the compressors, regulators for controlling the loading devices, means controlled by the regulator of an operating compressor to initiate the operation of another compressor and its regulator, and means controlled by the regulator of such other compressor to render the regulator of the compressor first set in operation ineffective to vary the load of its associated compressor.
6. The combination of a plurality of compressors discharging into a common receiver, load

controlling means for each compressor, means for automatically initiating sequential operation of the compressors in response to an increasing demand upon the pressure fluid in the receiver, and means to render all but one of the load controlling means ineffective to vary the combined load of the compressors.

7. The combination of a plurality of compressors discharging into a common receiver, load controlling means for each compressor, pressure actuated means controlled by the load controlling means of an operating compressor upon an increasing demand for initiating the operation of another compressor and its load controlling means, and means actuated by pressure fluid valved by the load controlling means of such other compressor to render the load controlling device of the compressor first set in operation ineffective to vary its load.

8. The combination of a plurality of compressors discharging into a common receiver, load controlling means for each compressor, means for automatically initiating sequential operation of the compressors and their load controlling means in response to an increasing demand, and means controlled by the load controlling means and acting during the starting of a compressor to render the load controlling means of another operating compressor ineffective to vary the load of such other operating compressor.

9. The combination of a plurality of compressors discharging into a common receiver, regulators for controlling the loads of the compressors, pressure actuated valve means controlled by the regulator of an operating compressor for initiating the operation of another compressor, and a valve actuated by pressure fluid valved by the regulator of another compressor during the starting thereof for rendering the regulator of the said operating compressor ineffective to vary the load of said operating compressor.

10. The combination of a plurality of compressors discharging into a common receiver, regulators for controlling the loads of the compressors, manually operable means for initiating the operation of a compressor and its regulator, and pressure actuated valve means controlled by the regulator of such operating compressor for initiating the starting of another compressor.

11. The combination of a plurality of compressors discharging into a common receiver, motors for driving the compressors, power supply controlling means for the motors, and pressure fluid actuated means acting in response to a predetermined pressure value in such common receiver to effect the actuation of the power controlling means of an idle motor to start such idle motor.

12. The combination of a plurality of compressors discharging into a common receiver, motors for driving the compressors, pressure fluid actuated switches for the motors, pressure fluid actuated valves for admitting and exhausting pressure fluid to and from the pressure actuated switches, and means operating in response to an increasing demand on an operating compressor to effect actuation of a valve for admitting pressure fluid to a switch for starting the motor of another compressor.

13. The combination of a plurality of compressors discharging into a common receiver, motors for driving the compressors, pressure actuated switches for the motors, conduits for conveying pressure fluid to and from the switches, valves to control the conduits, load controlling means for the compressors operating in response to an

increasing demand on an operating compressor to effect actuation of a valve for admitting pressure fluid to a switch for starting the motor of another compressor, and means in the conduits for restricting the exhaust of fluid from the switches.

14. The combination of a plurality of compressors discharging into a common receiver, and means actuated by the pressure fluid discharged from the compressors acting automatically for sequentially stopping the compressors upon the attainment of a predetermined pressure value in such common receiver.

15. The combination of a plurality of compressors discharging into a common receiver, means for sequentially stopping the compressors, and means for controlling the loads of the compressors and to effect actuation of the first said means upon the attainment of a predetermined pressure value in such common receiver.

16. The combination of a plurality of compressors, a storage receiver for the compressors, means for sequentially effecting the starting of the compressors, means for sequentially effecting the stopping of the compressors, and pressure fluid actuated means acting responsively to the pressure within the storage receiver to effect actua-

tion of the first mentioned means whenever the pressure in the storage receiver reaches a predetermined minimum value and to effect actuation of the second mentioned means whenever the pressure in the storage receiver reaches a predetermined maximum value.

17. The combination of a plurality of compressors, a storage receiver therefor, means for sequentially effecting the starting of the compressors, means for sequentially effecting the stopping of the compressors, and regulators for controlling the loads of the compressors and for controlling both of said means.

18. The combination of a plurality of compressors, a storage receiver therefor, pressure actuated means for sequentially effecting the starting of the compressors, pressure actuated means for sequentially effecting the stopping of the compressors, and regulators acting in response to the pressure within the storage receiver to control the loads of the compressors and to effect the actuation of both said means respectively as the pressure within the storage receiver reaches a certain predetermined low value and a certain predetermined high value.

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