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COMPRESSOR SYSTEM

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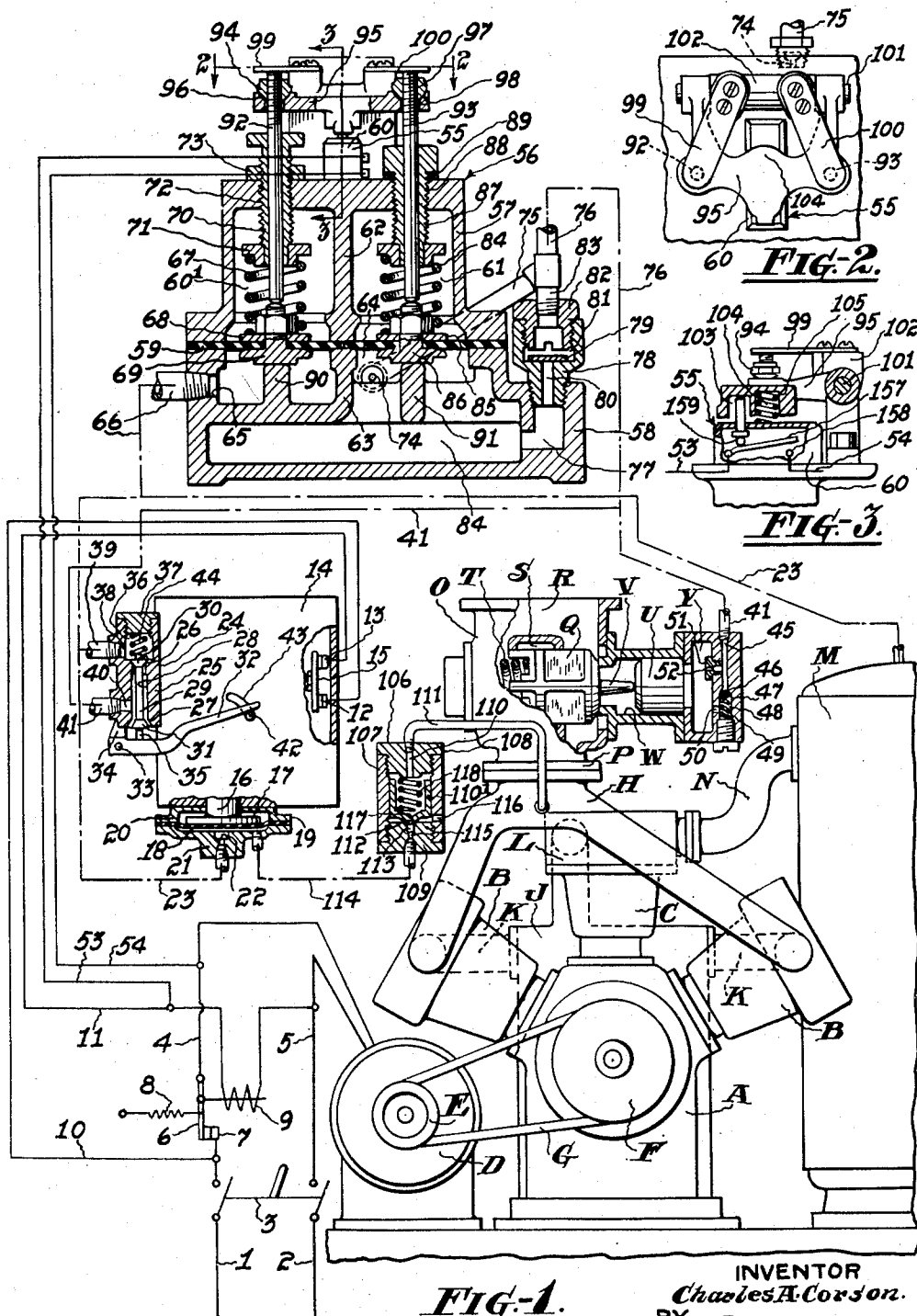


FIG-1.

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COMPRESSOR SYSTEM

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This invention relates to compressor systems and, more particularly, to a system of regulation for air or gas compressors.

It has been customary to operate air or gas compressors by driving them by electric or other motor controlled by an automatic pressure operated switch, so that when some predetermined maximum discharge pressure is reached the motor will automatically shut down to be restarted automatically when the pressure drops to a predetermined minimum speed. This system has an advantage over other systems in which the compressor is unloaded while the motor and compressor continue to idle, in that no electric current is used during the stopped period. This advantage disappears, however, if the stopping and starting occur very frequently for the reason that during the starting period the motor draws excessive current. It is thus seen that there is a point at which it would be advantageous to merely unload the compressor without stopping it. This latter method of operation is known as "constant-speed" operation, while the other is usually called the "stop-start" system. The "stop-start" method is generally found desirable when the demand for air is relatively low and the "constant-speed" system is more advantageous during periods of greater demand and when the compressor loads and unloads frequently.

It is an object of this invention to provide a compressor system which is adapted to operate on both the constant speed and the start-stop system, and in which the system to be used is automatically selected.

It is a further object of the invention to provide a system of this character in which a minimum stopping period for the motor is pre-established so that the most economical of these types of operation may result.

Other objects and advantages of the invention will become in part obvious and in part pointed out hereinafter.

In the drawing in which similar reference characters refer to similar parts and in which is shown a preferred embodiment of the invention,

Figure 1 is an end elevation of a compressor and its regulating apparatus, certain portions of the regulator being shown in vertical section and other parts being broken away to show more clearly the internal construction and the operation of the various parts, the electric wiring and piping being shown schematically;

Figure 2 is a top plan view taken along the line 2—2, looking in the direction of the ar-

rows in Figure 1 and showing portions of the switch and the controller; and

Figure 3 is a section taken along the line 3—3 of Figure 1 looking in the direction of the arrows and showing the internal construction of the switch mechanism of the controller.

Referring to the drawing, a compressor of a standard construction is shown at A having low pressure cylinders B and a high pressure cylinder C. In this instance, the compressor A is shown driven by a suitable electric motor D and the driving connection consists of a pulley E on the electric motor D and a pulley F on the compressor A and a driving belt G.

The compressor A is provided with an intake manifold H leading to the low pressure cylinders B. From these cylinders the air is discharged into an intercooler J through suitable piping K and thence by piping connection L to the high pressure cylinder C. High pressure air is conducted therefrom to a receiver M through a discharge pipe N.

At the intake manifold H is provided a suitable unloading device which consists of a casing O flanged as at P for attachment to the manifold and provided internally with a balanced valve Q controlling communication between an outer chamber R connected with atmosphere, and an inner chamber S leading to the manifold H.

Valve Q is biased to its open position shown in the drawing by a spring T. The valve is closed by pressure of a fluid actuated piston U bearing against a projection V on the valve. A suitable cylinder W is provided for the piston U into which pressure fluid is adapted to be admitted from a chamber Y suitably connected, as will be described hereinafter, to the source of pressure fluid M.

A suitable source of current is provided from the electric mains 1 and 2 having a main switch 3 for connection with the motor leads 4 and 5. Interposed between the switch 3 and lead 4 is a magnetic starting switch comprising the armature 6 and the stationary contact 7. As is customary, the armature 6 is biased to its open position by a spring 8. Tension of the spring 8 is overcome upon closing of the switch 3 by a solenoid 9 included in a circuit bridged across the leads 4 and 5, preferably between the switch 3 and the contact 7 in respect of the lead 4, the bridged circuit include the conductors 10 and 11 leading to contacts 12 and 13 of a pressure switch 14 adapted to control stopping and starting of motor D. Cooperating with the contacts

12 and 13 there is provided a circuit closing member 15 operated by the switch. The pressure operated switch 14 is of conventional design and is operated by a plunger 16 cooperating with a plate 17 against which a diaphragm 18 is adapted to exert pressure. The diaphragm 18 is housed within a casing 19 consisting of a flanged upper half 20 and a corresponding flanged lower half 21, between which the diaphragm is clamped. Pressure fluid is admitted to the space between the lower half 21 and the diaphragm 18 at an orifice 22 which, in this instance, may be the size of a #60 drill. Orifice 22 communicates by means of a suitable conduit 23 with the receiver M so that the diaphragm 18 is at all times exposed to pressure from the discharge line of the compressor.

As is usual in pressure switches of this type, pressure switch 14 is of the "snap" variety and there is some set difference between the pressures at which the plunger 16 is actuated upwardly and downwardly. For instance the plunger 16 may be adapted to operate at a receiver pressure of 100 pounds and to be restored at a predetermined low pressure of 80 pounds. It is understood, of course, that the upward motion of the plunger 16 operates to open the circuit at switch points 12 and 13 tending to de-energize the solenoid 9 thereby breaking contact between the armature 6 and stationary contact 7. Normally, this will tend to stop the motor D by opening its circuit. Upon dropping of the plunger 16 at the predetermined low line pressure, the contact member 15 is adapted to restore the circuit at the switch contacts 12 and 13 to re-energize the solenoid 9 and to close the motor circuit.

The pressure switch 14 is also designed to operate a three way pilot valve 24 which consists of a body portion 25 provided with upper and lower valve seats 26 and 27 respectively, connected by bore 28. Within the bore 28 is disposed a valve stem 29 provided at its ends with upper and lower valve heads 30 and 31 respectively. The stem 29 is of sufficient length so that only one of the valve heads 30 and 31 can be seated on the seatings 26 and 27 respectively, at any one time. The stem 29 is arranged to be shifted so that these valves seat on their respective seatings by means of a lever 32 pivoted as at 33 on a bracket 34 formed integrally with the body 25. The lever 32 is adapted to press against an extension 35 of the stem 29 so that as the lever 32 moves upwardly, valve 31 seats and the valve 30 is unseated, and as the lever drops the valve 30 seats and the valve 31 is unseated.

The upper part of the body 25 is provided with a chamber 36 closed by a plug 37 and communicating through a passage 38 and a suitable pipe 39 with the source of pressure fluid in the receiver M. The pipe 39 may, in this instance, connect with the conduit 23 for this purpose.

The bore 28 in the pilot valve 24 is in communication with a tapped hole 40 to which is attached a pipe or conduit 41 leading to the unloader at the chamber Y. It will thus be seen that the pilot valve 24 is adapted to alternatively connect the chamber Y and the unloader with the source of pressure fluid from the receiver M or with exhaust, depending upon the seating of the valves 30 and 31.

To operate the lever 32 the pressure switch 14 is provided with a pin 42 extending to the

exterior of the switch casing to engage the lever 32. The pin is actuated by the plunger 16 to move in the arcuate slot 43 so that when the pressure switch 14 operates to open the circuit of the solenoid 9, lever 32 is raised. Upon dropping of the pressure to the predetermined minimum, the lever 32 is correspondingly dropped. A biasing spring 44 is provided within the chamber 36 bearing against the plug 37 and the valve head 30 so as to tend normally to seat that valve.

Conduit 41 is connected at the unloader to a passageway 45 formed in the wall of the chamber Y, provided at one end with a seat 46 cooperating with a ball check valve 47 disposed in a counterbore 48 and pressed to its seat by a light biasing spring 49. Counterbore 48 communicates with the chamber Y by hole 50. The valve 47 is adapted to be unseated by fluid admitted from the conduit 41 under pressure, but is adapted to prevent escape of pressure fluid from the chamber Y. Exit from the chamber Y is provided by plug 51 having a very small orifice 52 delaying emission of pressure fluid from the chamber.

Operation of the solenoid 9 is also controlled by a circuit bridged across the conductor 11 and the motor lead 4 and including the conductors 53 and 54 respectively, and a switch 55 forming a part of a second controller 56. Switch 55 is shown in section in Figure 3 and includes a swinging contact 157 connecting with the conductor 53 and a stationary contact 158 to which the conductor 54 is attached. The swinging contact 157 is actuated by extremely small movement of a plunger 159 extending through the switch casing 60.

The second controller 56 comprises a casing formed in two portions—an upper casing portion 57 and a lower casing portion 58, joining at two flat faces adapted to receive between them a flexible diaphragm 59 of any suitable material such as, for instance, rubber. Within the casing formed by the portions 57 and 58 are two chambers 60' and 61 divided by a partition 62 formed integrally with the upper half 57 and continued by the lower partition 63 and the lower half 58. The chambers are divided horizontally by the diaphragm 59. The lower part of the chamber 61 is relatively large as indicated at 64. The chamber 60' below the diaphragm 59 is provided with an aperture 65 which communicates by conduit 66 leading into the conduit 23 with the source of discharge pressure fluid in the receiver M. The diaphragm 59, therefore, is at all times within the lower part of chamber 60' exposed to the discharge pressure of the compressor A.

The pressure against the diaphragm 59 is opposed in chamber 60' by a spring 67 bearing against a washer 68 overlying the diaphragm 59 and held in place by a bolt 69. Tension on the spring 67 is adjustable by means of a screw 70 provided with a cap 71 fitting the upper end of the spring 67. The screw 70 is threaded in the upper wall of the upper casing half 57 at the threaded aperture 72. Adjustment of the screw is maintained by a lock nut 73.

Chamber 64 is adapted to receive pressure fluid through an orifice 74 in the wall of the chamber and connected by a pipe 75 and a conduit 76 to the conduit 41. Chamber 64 thus receives pressure fluid under the control of the pilot valve 24 and the controller 14. Likewise under the control of the pilot valve 24 pressure fluid is ex-

hausted from the chamber 64 through a passageway 77 in the side wall of the chamber 64 in which is provided a plug 78 having a check valve 79 controlling a passageway 80 leading to a chamber 81. A reducing pipe plug 82 in chamber 81 is provided with a nipple 83 leading to the conduit 76. Pressure on diaphragm 59 within the chamber 64 is opposed by a coil spring 84 bearing against washer 85 bolted to the diaphragm 59 by means of the large headed bolt 86.

The compression of spring 84 is regulated by means of the threaded screw 87 passing through the threaded aperture 88 in the top wall of the casing half 57. In this instance the adjustment is set by means of shims 89 under the head of the screw 88.

At such times as the pressure under the diaphragm 59 is unable to withstand the pressure of the springs 67 and 84, the bolts 69 and 86 rest upon stops 90 and 91, respectively, which are formed integrally with the lower casing half 58.

Motion of the diaphragm 59, due to the pressures thereunder, is adapted to be transmitted to the switch 55. For this purpose the screws 70 and 87 are hollow and provided with push rods 92 and 93, respectively, bearing against the stems of the bolts 69 and 86, respectively. At its upper end push rod 92 is provided with a nut 94 cooperating with a U shaped lever member 95 at an aperture 96. Likewise, push rod 93 is provided with a nut 97 cooperating with the lever 95 at an aperture 98.

Push rod 92 bears against the top of the stem of bolt 69 and is held in contact therewith by a light leaf spring 99. Likewise, the push rod 93 is held in contact with the corresponding bolt 86 by means of a light spring 100.

The U shaped lever 95 is journaled at the ends of its arms on a bearing rod 101 mounted in a bracket 102 at the top of the upper casing half 57 upon which bracket also are mounted the leaf springs 99 and 100. Motion of the U shaped lever 95 is adapted to transmit motion of the diaphragm 59 to the plunger 159 on the switch 55. To this end the lever is provided with a recess 103 to receive the plunger.

The weight of the lever 95 is counterbalanced by a light coil spring 104 seated on the top of the switch 55 and contained in a pocket 105 of the U shaped lever 95.

As can be readily understood from the above description, the actuating force for the switch 55 is the pressure of the springs 99 bearing downwardly. When this pressure is overcome by upward motion of the push rods 92 and 93, the switch is released by the spring 104. The switch 55 is extremely sensitive and the contacts 157 and 158 are closed by an extremely slight motion of the plunger 159 of the order of one or two thousandths of an inch.

Under certain conditions, as will be described hereinafter, it is desirable that the switch or controller 14 be operated at a close range of pressures in the receiver M instead of at the wider range as above referred to. To this end, a range changing device 106 is provided, whose purpose is to change the operational pressure range of the plunger 16. This is accomplished by reducing the effect of the high pressure on the diaphragm 18. The range changing device 106 consists of a cylinder 107 provided with an upper head 108 and a lower head 109 and a piston 110 fitting the bore of the cylinder. The upper head 108 is provided with a passage 111 communicating by

means of a pipe 111 with the manifold H. The lower head 109 is provided with a valve seat 112 in bore 113, which communicates with the space in the casing 19 under the diaphragm 18 by means of a pipe 114. A restrictive orifice 115 is provided in the bore 113 for the purpose of controlling the flow of pressure fluid through the pipe 114. The bore of the cylinder 117 is provided with a vent 116 to atmosphere by means of which pressure fluid entering the bore may escape to the open air when the valve seat 112 is opened at a valve 117 formed integrally with the piston 110. Normally, the piston 110 is biased by means of a spring 118 to its closed position.

The apparatus above described has been adapted to permit the compressor A to operate at "constant-speed" during the periods of normal demand, that is to say, without shutting down. Additionally, it enables the compressor to convert automatically to operation at "start-stop" during periods of low demand such as would be found perhaps at night.

Under all circumstances it will be noted that when the pressure in the receiver M rises to some predetermined value, as for instance 100 pounds, the diaphragm is forced upwardly to cause the controller 14 to open the circuit including contacts 12 and 13. Simultaneously, the pilot valve 24 is operated to open communication between the supply conduit 23 and conduit 41 thereby admitting motive fluid through the passageway 45 past the check valve 47 and through aperture 50 into the chamber Y, whereupon the piston U is forced against the pressure of the spring T to move the intake valve Q to closed position. Admission to the inlet manifold H is thereby cut off from atmosphere and the compressor A is thereby unloaded. The motor D, however, does not immediately stop because its circuit is not opened by operation of the controller 14. The switch points 6 and 7 are held closed by the solenoid 8 since its circuit is still closed at the switch 55.

As has been indicated above, operation of the pilot valve 24 by the controller 14 also controls the second controller 56 in the following manner: Motive fluid from the receiver M is constantly in communication with the chamber 60' under the diaphragm 59, which at a predetermined high pressure would tend to overcome pressure of spring 67 and to lift the push rod 92 upwardly to release the U shaped lever. This lever is, however, normally prevented from moving upward by pressure of holding the lever down through the medium of the push rod 93 and the nut 97. Therefore, if the U shaped lever 95 is to release the switch 55 at all, pressure holding the push rod 92 in raised position must be maintained until the push rod 93 is raised. The mechanism operating the push rod 93 is, therefore, a timing mechanism which, in conjunction with the operation of the push rod 92, determines whether the switch 55 is to open or not. To this end, the chamber 64 is adapted to be filled slowly at some predetermined rate, with pressure fluid from the receiver M. This is accomplished through the medium of the pilot valve 24 which, while admitting motive fluid to operate the unloader, also admits through the conduit 76 and pipe 75 motive fluid to the chamber 64. The size of the orifice 74 through which the motive fluid passes is suitably selected so that in some given time the chamber 64 will build up pressure to a suitable value to raise the diaphragm 59 thereby lifting the push rod 93 to release the U shaped lever 95.

Assume that the operating range of the controller 14 is set at 20 pounds, that is to say, to operate the pilot valve 24 at 100 pounds per square inch and to restore it at 80 pounds receiver pressure, the second unloader may be set so that the push rod 92, upon a drop in pressure from 100 pounds to 98 pounds, will re-engage the lever 95 so as to prevent its operation. Simultaneously, by suitable selection of the size of the nozzle 74 and tensioning of the spring 84, the pressure may be regulated to build up within 30 seconds in the chamber 64 so as to start raising the push rod 93. Thus it will be seen that if the switch 55 is to be open under these conditions, the receiver pressure will have to drop somewhat less than 2 pounds in 30 seconds, in which case both push rods 92 and 93 will be in raised position simultaneously to release lever 95. In that case the circuit of the holding coil 9 will be open both at the switch 55 and at the contacts 12 and 13 which causes the switch to open at contacts 6 and 7 to stop motor D.

Conditions just described may be considered those of low demand and they determine, by means of the controller 56, a minimum stopping period for the motor D. Under these specific conditions, that is, with the pressure dropping at the rate of something less than 2 pounds in 30 seconds, it will be seen that the minimum stopped period for the motor D will be 5 minutes for a pressure range of 20 pounds, the assumed setting of the controller 14.

It will be noted that while the relative motions of the push rods 92 and 93 may effect the operation of the switch 55 to open the circuit of the holding coil 9, they cannot under any condition operate to close the circuit of that coil, inasmuch as the circuit including the switch 55, also includes the switch contacts 6 and 7. Therefore, the switch 55 can never start up the motor D once it has stopped. In other words, when the controller 56 has operated to shut down the motor D, restarting of the motor can only be effected by the controller 14 which, as one of its functions, closes the circuit of the holding coil 9 to close the motor switch at the contacts 6 and 7.

Assuming conditions of relatively greater demand for air, it will be seen that the pressure drop under the diaphragm 59 will release the push rod 92 so as to hold the U shaped lever 95 down before the pressure in the chamber 64 has had time to build up to release the lever. The switch 55, therefore, stays closed. It may be said, therefore, that the controller 56 is operated by the rate of drop in pressure per unit of time to open and close the circuit of motor D.

Under such conditions, the controller 14 has the effect of operating only the intake unloader, which is effected entirely through the pilot valve 24. Thus, during periods of great demand, the motor D operates continuously while the intake unloader performs the function of loading and unloading the compressor A.

It will be seen that the motor D is stopped by operation of controller 56 at some definite period after operation of the controller 14. Correspondingly, the compressor is also first unloaded by the intake unloader. It is considered desirable, as it well known in the art, that the unloader should keep the compressor unloaded while the motor D is starting, since it is uneconomical to start any motor under load. Accordingly, upon operation of the controller 14 to restart the motor D, the pilot valve 24 operates to release the mo-

tive fluid from the chamber Y. Under these conditions, the check valve 47 is held closed by the spring 49 and the exhaust of motive fluid is permitted only through the small orifice 52 of a size which would allow the lapse of several seconds before the pressure in the chamber Y will drop sufficiently to permit the compression of the spring T to throw the valve Q to its open position.

While the chamber 64 is arranged to be filled with pressure fluid very slowly by way of the orifice 74, it is preferably exhausted rapidly by way of the check valve 79 when the pilot valve 24 is restored to its normal position exhausting the air in the line 41.

During the periods of great demand for pressure fluid it is often convenient to operate the compressor A at a closer pressure range than when running "start-stop" and this is the purpose of the range-changing device 106. While the compressor A is running unloaded, the pressure in the manifold H is subatmospheric. This suction is transmitted to the bore of the cylinder 107, lifting the piston 110' to uncover the valve seat 112 and permitting air to escape through the pipe 114 slowly through the orifice 115 to atmosphere by way of the port 116. The escape of air in this manner has the effect of reducing, to a certain extent, the pressure under diaphragm 18 since admission to the space under the diaphragm is also restricted by the orifice 22. Thus, while the plunger 16 may have been forced upwardly by a pressure of 100 pounds per square inch to actuate the controller 14, subsequent action of the intake unloader and the range-changer 106 may immediately drop the pressure under the diaphragm 18 to a value, for instance of 90 pounds. Then, upon reduction of the pressure in the receiver M to 90 pounds, there will be a corresponding reduction in the pressure under the diaphragm to, let us say, 80 pounds, which will cause the controller 14 to operate, thereby reloading the compressor A. In this manner, the pressure operating range may be changed from, for instance 20 pounds to 10 pounds.

As will be obvious, the range-changing device 106 is not in effect when the motor D is operating on the "stop-start" conditions for, in such cases, the intake manifold H does not remain under vacuum for any great length of time while the motor D is stopped.

The change of range above referred to is desirable inasmuch as during large demand periods it is desirable to keep the pressure in the receiver M fairly constant, while under "stop-start" conditions constant pressure is not so desirable as it causes more frequent starting and stopping of the motor D.

I claim:

1. A compressor system including a compressor, a driving motor therefor, a controller operated by the compressor discharge pressure adapted to stop the motor at a predetermined high pressure and to restart the motor at a predetermined low pressure, a compressor unloader operated by pressure fluid controlled by said controller to unload the compressor at said predetermined high pressure and to reload the compressor at the predetermined low pressure, and a second controller to delay the stopping of the motor after operation of the first controller and to pre-establish the minimum stopping period of the motor.
2. A compressor system including a compres-

sor, a driving motor therefor, a controller operated by the compressor discharge pressure adapted to stop the motor at a predetermined high pressure and to restart the motor at a predetermined low pressure, a compressor unloader operated by pressure fluid controlled by said controller to unload the compressor at said predetermined high pressure and to reload the compressor at said predetermined low pressure, means to delay operation of said unloader to reload the compressor for a given period after said predetermined low pressure is reached, and a second controller adapted to delay stopping of said motor at said predetermined high pressure, said controller including means for pre-establishing the minimum stopping period of said motor controlled by the rate of drop in the compressor discharge pressure when the compressor is unloaded by said unloader.

3. A compressor system, including a compressor, a device for unloading the compressor, a motor for driving the compressor, a pressure fluid operated controller for stopping and restarting the compressor motor and having a predetermined pressure range, a second pressure fluid operated controller for the motor having a shorter pressure range than the first said controller and provided with a timing mechanism controlled by the first controller to pre-establish the minimum stopping period of the motor.

4. A compressor system, including a compressor, an electric driving motor therefor, a magnetic switch mechanism for controlling said motor, a controller operated by the compressor discharge pressure for said switch mechanism for stopping and restarting the motor, and means associated with said switching means for pre-establishing the minimum stopping period of the motor, said means being controlled by the rate of drop in the compressor discharge pressure.

5. A compressor system, including a compressor, an electric driving motor therefor, a magnetic switch mechanism for controlling said motor, a controller operated by the compressor discharge pressure for said switch mechanism for stopping and restarting the motor, a compressor unloader operated by the controller, and means associated with the switch mechanism for pre-establishing the minimum stopping period of the motor, said means being controlled by the rate of drop in the compressor discharge pressure when the compressor is unloaded.

6. A compressor system, including a compressor, an electric driving motor therefor, a controller for said switch mechanism operated

by the compressor discharge pressure to stop the motor at a predetermined high pressure and to restart the motor at a predetermined low pressure, a compressor unloader operated by pressure fluid and controlled by said controller to unload the compressor at said predetermined high pressure and to reload the compressor at the predetermined low pressure and a second controller associated with said switch mechanism to delay stopping of the motor after operation of the first said controller and to pre-establish the minimum stopping period of the motor.

7. A compressor system including a compressor, an electric driving motor therefor, a switch mechanism for controlling the operation of said driving motor, a controller for said switch mechanism operated by the compressor discharge pressure to stop the motor at a predetermined high pressure and to restart the motor at a predetermined low pressure, a compressor unloader operated by pressure fluid controlled by said controller to unload the compressor at said predetermined high pressure and to reload the compressor at said predetermined low pressure, means to delay reloading operation of said unloader for a given period after said predetermined low pressure is reached, and a second controller associated with said switch mechanism adapted to delay stopping of said motor at said predetermined high pressure, said controller including means for pre-establishing the minimum stopping period of said motor and controlled by the rate of drop in the compressor discharge pressure when the compressor is unloaded by said unloader.

8. A compressor system, including a compressor, an electric driving motor therefor, a switch to control the circuit of said motor, a holding coil for said switch, a controller for said holding coil operated by the compressor discharge pressure to stop the motor at a predetermined high pressure and to restart the motor at a predetermined low pressure, a compressor unloader operated by pressure fluid controlled by said controller to unload the compressor at said predetermined high pressure and to reload the compressor at said predetermined low pressure, and a second controller associated with said holding coil adapted to delay stopping of said motor at said predetermined high pressure, said second controller including means for pre-establishing the minimum stopping period of said motor and controlled by the rate of drop in the compressor discharge pressure.

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