Dec. 23, 1930. J. W. SANFORD 1,785,979

AUTOMATIC COMPRESSOR CONTROL SYSTEM

Original Filed Nov. 14, 1927 2 Sheets-Sheet 1

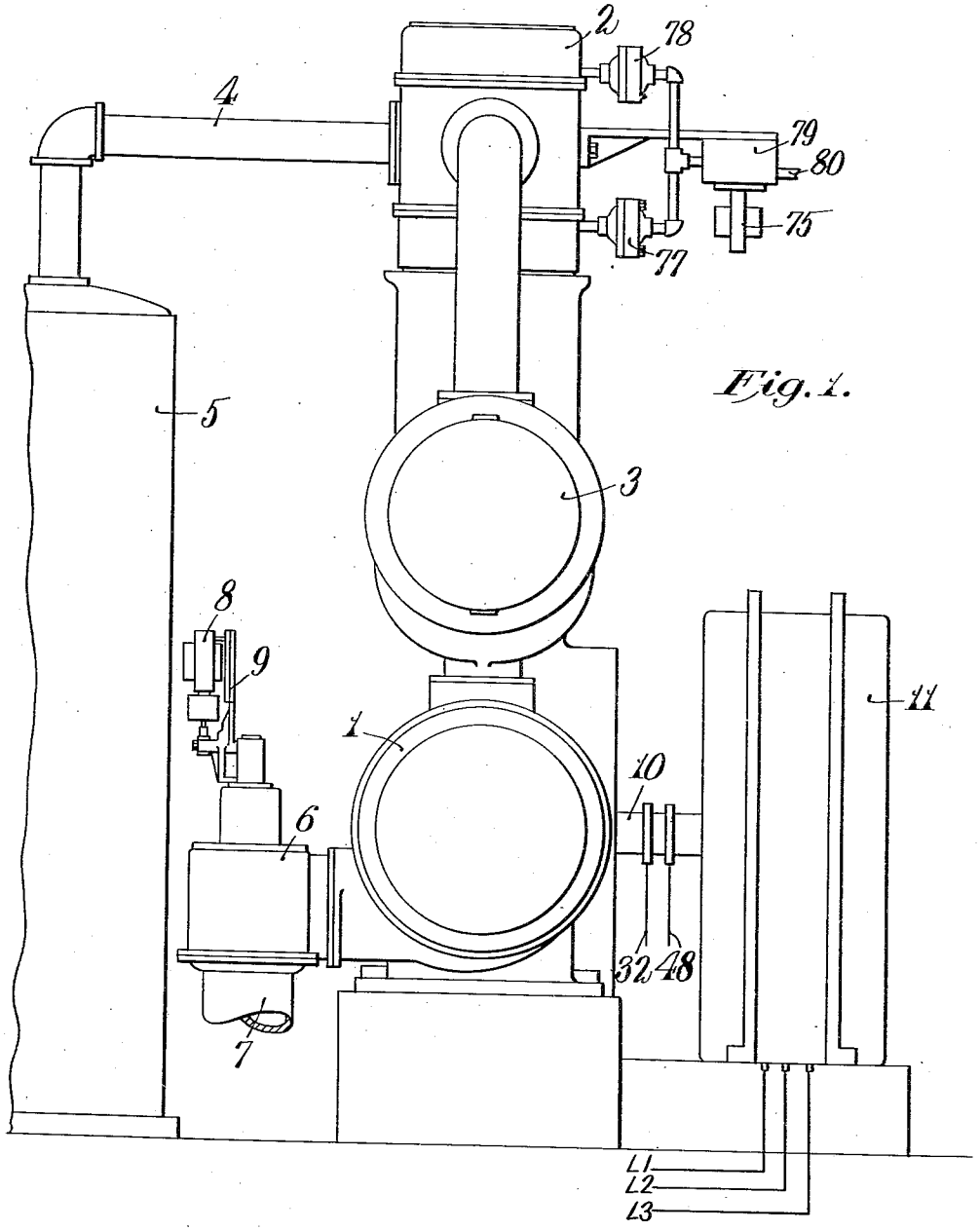


Fig. 1.

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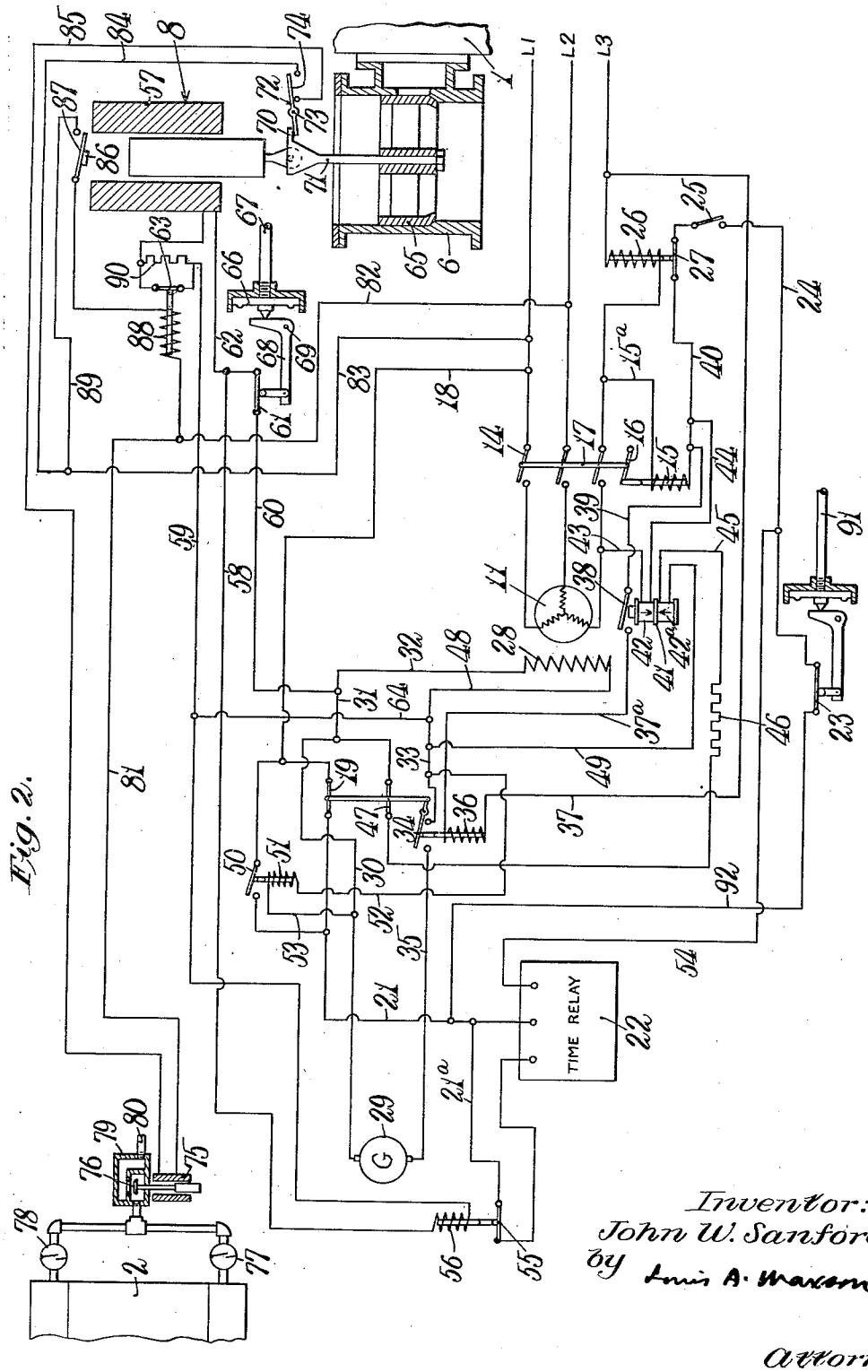


Fig. 2.

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UNITED STATES PATENT OFFICE

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AUTOMATIC COMPRESSOR-CONTROL SYSTEM

Application filed November 14, 1927, Serial No. 233,223. Renewed April 4, 1930.

This invention relates to automatic compressor control systems and more particularly to means for automatically controlling the entire operation of a synchronous motor driven compressor.

There are a number of characteristics of a synchronous motor which make it very desirable for use in driving air and gas compressors. The advantages of its constant speed with variable load, its high efficiency, and its non-inductive load on the power supply with accompanying reduction in power rates, make it especially adaptable to this field. The comparatively low torque of this motor at starting and until the machine is synchronized on the line make it desirable that the compressor be completely unloaded during this interval. It is therefore one of the principal objects of my invention to provide an improved means for insuring that the compressor will remain in a completely unloaded state until the motor is synchronized and is capable of carrying its full load. It is a further object of my invention to provide electrically operated unloading means for the compressor adapted either to be controlled by or to be supplied with current from a circuit connected in parallel with the motor field.

It often happens that the demand for compressed air or gas is very low over a considerable period of time. A typical example of this would be found in the case of a mine using compressed air driven tools where practically no air is needed during the intervals between shifts or in an extensive mine where a "booster" compressor is often installed; the capacity of which is needed only in periods of greatest demand for air and at all other times may be shut down. In accordance with my invention I utilize equipment which will load and unload the compressor so as to maintain the desired air pressure during normal operation; stop the machine by disconnecting the motor from the line after the compressor has run continuously unloaded for a definite length of time; maintain the compressor unloaded when it is at a standstill so that it is in proper condition to be started up again when desired; throw the motor on the line and start up the machine when the air pressure in the receiver tank drops below the desired minimum; hold the compressor unloaded until the motor comes up to synchronous speed and automatically allow the same to pick up its load at the proper time. Other phases and objects of my invention will hereinafter more fully appear.

In the accompanying drawings I have shown for purposes of illustration one form which my invention may assume in practice.

In these drawings,—

Fig. 1 is a front elevation of an angle compound compressor and its driving motor to which my invention may be applied.

Fig. 2 is a wiring diagram of a complete equipment which I may employ for carrying out the objects of my invention.

In Fig. 1 I have shown an angle compound compressor having a low pressure cylinder 1, a high pressure cylinder 2 and an intercooler 3. The compressed air or gas discharges by way of a pipe 4 into a receiver tank 5. A valve 6 is mounted on the low pressure cylinder to control the inlet of air or gas through a pipe 7 to effect loading and unloading of the low pressure cylinder. This valve is automatically operated by means of a solenoid mechanism 8 mounted by means of a bracket 9 on the valve casing. The compressor is driven through a shaft 10 by means of a motor 11, herein of the alternating current synchronous type. Direct current is supplied to the revolving field coils of this motor by means of an exciting set (not shown in Fig. 1, but indicated at 29 in Fig. 2) through the lines 32 and 48. The main power supply to the motor is carried by the three lines designated L—1, L—2 and L—3, and controlled by switch 14. This switch is automatically operated by a solenoid 15 through an arm 16 and a bar 17 which carries the main line contactors, the switch being closed when the solenoid is energized and opened when the solenoid is de-energized. Current for operating the control system is supplied from the main line through a wire 18, a switch 19, line 21, and through a time relay 22 or a pressure switch 23 to the wire

24 in a manner to be more fully described later on. The time relay and pressure switch are connected in parallel across the wires 21 and 24. This control circuit is completed across one phase of the main line by way of the manually operated switch 25 and through the coil of the solenoid 15 back to L—3. An overload relay 26 is interposed in the main line for breaking the control circuit through a switch 27 and shutting down the motor in the event of an excessive load.

The motor field 28 is supplied with direct current from an exciter 29 through a circuit which includes the wires 30, 31, 32, 33, the solenoid operated switch 34, and a wire 35. The switch 34 is operated by means of a solenoid 36 and this solenoid is adapted to be energized by a circuit from the main line through wires 37 and 37ª, switch 38, wires 39 and 40, switch 25, wires 24, 21 and 18. The switch 38 is controlled by a differential relay 41 having one coil 42 connected in a circuit which includes the wires 43 and 44, switch 25, wires 24, 21 and 18. The opposed coil of this differential relay which tends to prevent the closing of the switch is connected in a closed circuit through wire 45, resistance 46, switch 47, wire 32, the motor field 28, wires 48 and 49. A switch 50 is adapted to be automatically opened, when not held closed by a solenoid coil 51, to break the control circuit in the event that the voltage from the exciting set fails. It will be noted that this coil 51 is connected across the generator 29 through the wires 52 and 53.

For the purpose of shutting down the motor after it has run unloaded for a definite length of time, I have provided the time relay 22 adapted to break the control circuit through the main line contactor holding coil 15. As before noted, the pressure switch 23 and the time relay are connected in parallel across the wires 21 and 24 of the control circuit. This time relay may be of any standard type which will normally close the circuit between the wires 21 and 54 and yet break the circuit if the time relay is energized for the predetermined period for which it is set, and which will automatically reset itself in the event that the compressor does not run unloaded for the definite time for which the relay is set. This time relay is controlled by an automatic switch 55 which is normally closed when its coil 56 is not excited. It will be noted that this coil 56 is connected across the direct current lines which lead to a solenoid coil 57, by way of wires 58 and 59. The solenoid 57 is connected in parallel with the motor field 28 by way of wires 60 and pressure switch 61, wire 62, switch 63, wires 59 and 64. With this arrangement it will be obvious that the solenoid 57 cannot be energized until the motor field 28 is connected to the exciting set, or in other words, when the motor is synchronized. The solenoid 57 operates on the unloader valve 65 on the low pressure cylinder 1. In the de-energized position of this solenoid the valve drops to its lower or closed position as illustrated in Fig. 2 and the low pressure cylinder is unloaded. The pressure switch 61 is adapted to automatically energize and de-energize the solenoid 57 in response to variations in the receiver tank pressure. This switch comprises a diaphragm 66 which communicates with the receiver tank by way of a pipe 67; and this diaphragm operates on a bell crank lever 68 pivoted at 69 in such manner as to open the switch 61 when the pressure reaches the predetermined maximum and close the switch when the pressure reaches a predetermined minimum.

The means for unloading the high pressure cylinder until the motor has reached synchronous speed will now be described. When the solenoid controlled unloading valve 65 of the low pressure cylinder approaches its lower position, a stop 70 on the valve stem 71 engages one arm of a lever 72 pivoted at 73 and operates a switch 74 to open a circuit through the solenoid 75, thereby de-energizing same and allowing the valve 76 to drop by gravity to open position and vent both ends of the high pressure cylinder, the gas passing from the cylinder ends by way of check valves 77 and 78 and through the valve casing 79 to the atmosphere at 80. The power for operating this solenoid may be derived from any suitable source, and in this instance it is shown connected across one phase of the main line by way of wires 81, 82, 83, 84, switch 74 and the wire 85. When the solenoid valve 57 approaches its upward limit of travel, it engages a stop 86 on a switch 87 and closes a circuit through the coil 88 by way of wires 82, 83 and 89. The coil 88 opens the switch 63 and the direct current flowing through the solenoid 57 must then also flow through the resistance 90, the purpose being to cut down the current consumption of the solenoid when the compressor is operating normally.

The pressure switch 23 may be of any suitable type and is herein shown as being of the same construction as the pressure switch 61 and therefore the details of construction need not be further described except to say that the switch is connected to the receiver tank by way of the pipe 91. When the motor has been shut down through the operation of the time relay the pressure will gradually drop when there is again a demand for air until the pressure switch 23 automatically closes and again makes the control circuit between wires 21 and 24 by way of the wire 92.

The operation of the apparatus shown in the wiring diagram will now be briefly described, the parts being assumed to be in the positions illustrated. The switch 25 will be closed by hand, thereby establishing a con-

trol circuit through the wire 15*a*, coil 15, wire 40, switch 27, wire 24 and either through the pressure switch 23 or time relay 22 to the wire 21 through the switch 19, and wire 18 to the line L—1. The coil 15 will thus be energized to close the main line contactors 14, which sends current through the motor armature, and the motor is started in any of the common methods of starting synchronous motors. One of the usual methods is to provide a squirrel cage winding on the rotor and start the motor as an induction machine. As soon as the main line contactors are closed, a revolving magnetic field will be induced by the armature current and an alternating current will be generated in the motor field coils 28, which will flow through a closed circuit by way of wires 32, 31, switch 47, resistance 46, coil 42*a* and wires 49 and 48. This current continues as long as there is relative movement between the field coils and the revolving field induced by the armature current, the frequency of this current gradually diminishing as the rotor approaches synchronous speed. The effect of current in this circuit is to energize the coil 42*a* and oppose the closing of switch 38. However, when the rotor attains synchronous speed this current automatically dies out, allowing the coil 42 which is energized, after the main line contactors are closed, through the wires 43, 44, 40, 24, 21 and 18 to close the switch 38. Assuming now that the motor has reached synchronous speed, the switch 38 will be closed under the influence of coil 42 and a circuit will be thus established through the coil 36 by way of wires 37, 37*a*, switch 38, wires 39, 40, 24, 21 and 18. The switch 34 will now be automatically closed and at the same time the switches 19 and 47 opened since they are connected to the same shaft as the switch 34. The closing of switch 34 connects the motor field directly with the exciter 29 through the wires 35, 33, 48, 32 and 30. The motor is now synchronized on the line and is capable of carrying its full load.

On the closing of switch 34, a circuit is also established, providing the pressure switch 61 is closed, through the solenoid 57 in a manner which should be obvious from the above description. The loading and unloading of the compressor will now be controlled through the switch 61 during the normal operation of the machine. At any time that this switch is opened, as when the compressor is running unloaded, the circuit through the coil 56 will be broken and will allow the switch 55 to close, thereby setting the time relay into operation, the source of current for this purpose being derived from the control circuit through wires 18, 21, wire 21*a*, 54, 24, 40 and 15*a*. If the compressor runs unloaded continuously for the definite length of time for which the relay is set, the latter will automatically function to open the circuit between the wires 21 and 54 and, since the pressure would be high and the pressure switch 23 open, the control circuit between the wires 21 and 24 will be interrupted. This de-energizes the coil 15 and allows the main line contractors 14 to open, thereby shutting down the motor.

As soon as the switch 34 is closed, it will be noted that a circuit is established through the coil 51 and this coil is so designed as to hold the switch 50 in closed position, providing the voltage on the exciter 29 is sufficient for proper operation of the motor. The control circuit between the wires 18 and 21 is interrupted through the opening of switch 19, but a parallel circuit is automatically completed at the same time through the switch 50. The function of this arrangement is to break the control circuit and shut down the motor in the event that the voltage of the exciter fails for any reason.

As a result of my invention it will be apparent that I have provided a very simple arrangement for insuring that the compressor will run in a completely unloaded state until the motor is synchronized. I have also provided an arrangement of controlling mechanism which will shut down the motor in case the compressor runs unloaded for a certain interval of time and automatically start the machine up again when the pressure drops, hold the compressor unloaded until the motor attains synchronous speed, and then load the compressor and cause it to operate to maintain the pressure for which the pressure regulating switches are set. The necessary equipment is standard for the most part and its detailed construction need not be illustrated nor described since it is well known by those familiar with the art.

While I have in this application specifically described one form which my invention may assume in practice, it will be understood that this form of the same is 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 combination, a compressor, a synchronous motor for driving the same, electrically actuated unloading means for said compressor, and means for controlling both the synchronizing of said motor and the loading of said compressor, said controlling means causing the flow of current simultaneously to the field of said motor and to said unloading means.

2. In combination, a compound compressor, a synchronous motor for driving the same, unloading means for both the high and low pressure cylinders of said compressor, and means for controlling the synchronizing of

said motor adapted also to control both of said unloading means.

3. In combination, a compressor, a synchronous motor for driving the same having a field, means controlling said field, unloading means for said compressor, and electro-magnetic means for controlling said unloading means having a controlling circuit in parallel with the motor field and controlled by the means controlling the latter.

4. In combination, a compressor, a synchronous motor for driving the same having a field, means controlling said field, unloading means for said compressor, and electro-magnetic means for controlling said unloading means having a controlling circuit in parallel with the motor field and controlled by the means controlling the latter, said controlling circuit including means for opening and closing the same in response to variations in compressor discharge pressure.

5. In combination, a compressor, a synchronous motor for driving the same having a field, means controlling said field, unloading means for said compressor, and electro-magnetic means for controlling said unloading means having a controlling circuit in parallel with the motor field and controlled by the means controlling the latter, said controlling circuit including means for opening and closing the same in response to variations in compressor discharge pressure, said controlling circuit including a pressure operated switch adapted to open the circuit to unload the compressor when the discharge pressure reaches a predetermined maximum.

6. In combination, a compressor, an electric motor for driving the same, unloading means for said compressor, electrical controlling means for said unloading means, and an electrically operated time relay cooperating with said controlling means for stopping said motor after the compressor has run unloaded a predetermined length of time.

7. In combination, a compressor, an electric motor for driving the same, unloading means for said compressor, electrical controlling means for said unloading means causing unloading when the compressor discharge pressure exceeds the desired maximum, an electrically operated time relay cooperating with said controlling means for stopping said motor after the compressor has run unloaded a predetermined length of time, and means for automatically starting said motor after the pressure drops below the desired minimum.

8. In combination, a compressor, an electric motor for driving the same, unloading means for said compressor, electrical controlling means for said unloading means, an electrically operated time relay cooperating with said controlling means for stopping said motor after the compressor has run unloaded a predetermined length of time, and means for automatically starting said motor after the pressure drops below the desired minimum, said electrical controlling means delaying said unloading means in loading the compressor until the latter comes up to speed and causing said unloading means to unload the compressor when the compressor discharge pressure exceeds the desired maximum.

9. In an automatic compressor control system, means for controlling loading and unloading of said compressor in response to variations in receiver tank pressure during normal operation, means for automatically stopping the compressor when it has run unloaded continuously for a predetermined length of time, and means for automatically starting the same when the receiver tank pressure drops below the desired minimum.

10. In an automatic compressor control system, means for controlling loading and unloading of said compressor in response to variations in receiver tank pressure during normal operation, means for automatically stopping the compressor when it has run unloaded continuously for a predetermined length of time, means for automatically starting the same when the receiver tank pressure drops below the desired minimum, and means for holding the compressor unloaded until it comes up to speed.

11. In combination, a compressor, electrically actuated unloading means for said compressor, a synchronous motor for driving said compressor, means for controlling loading and unloading of said compressor in response to variations in receiver tank pressure during normal operation, means for automatically stopping the compressor when it has run unloaded continuously for a predetermined length of time, means for automatically starting the same when the receiver tank pressure drops below the desired minimum, said unloading means being operated by power from the exciting set of said motor, and means for controlling the synchronizing of said motor which also controls said unloading circuit to prevent loading of the compressor until the motor is synchronized.

12. In combination, a compressor, an electric motor for driving the same, a receiver tank, unloading means for said compressor, a switch for controlling operation of said motor, electromagnetic means for controlling said switch, means for controlling loading and unloading of said compressor, a-time relay associated with said unloading means for causing said electro-magnetic means to open said switch when said compressor has run unloaded for a predetermined length of time, and pressure responsive means for causing said electro-magnetic means to close said switch when the pressure in the receiver tank drops below a predetermined minimum.

13. In combination, a compressor, an electric motor for driving the same, a receiver tank, unloading means for said compressor, a switch for controlling operation of said motor, electro-magnetic means for controlling said switch, means for controlling loading and unloading of said compressor, a time relay associated with said unloading means for causing said electro-magnetic means to open said switch when said compressor has run unloaded for a predetermined length of time, and pressure responsive means for causing said electro-magnetic means to close said switch when the pressure in the receiver tank drops below a predetermined minimum, said time relay and pressure responsive means being connected in parallel with each other in a circuit including said electro-magnetic means.

14. In combination, a compressor, an electric motor for driving the same, a receiver tank, unloading means for said compressor, a switch for controlling operation of said motor, electro-magnetic means for controlling said switch, means for controlling loading and unloading of said compressor, a time relay associated with said unloading means for causing said electro-magnetic means to open said switch when said compressor has run unloaded for a predetermined length of time, and pressure responsive means for causing said electro-magnetic means to close said switch when the pressure in the receiver tank drops below a predetermined minimum, said time relay being adapted automatically to reset itself provided the compressor does not run unloaded over the length of time at which it is set to operate.

15. In a compressor controlling mechanism, the combination of a compressor, a motor driving the compressor, an unloader for the compressor, a regulator responding to pumped pressure normally controlling the unloader, an electrically actuated device controlling the unloader independently of pumped pressure, and means for controlling current flow in said device to effect unloading during the period while said motor is coming up to speed.

16. In combination, a compressor, a synchronous motor for driving the same, an unloading valve for said compressor, a solenoid for controlling operation of said valve, a circuit for supplying power to said solenoid, said circuit being connected in parallel with the synchronous motor field, and a pressure operated switch for making and breaking said circuit in response to variations in receiver tank pressure.

17. In combination, a compound compressor, a synchronous motor for driving the same, an unloading valve for the low pressure cylinder, a solenoid for controlling operation of the same adapted to permit closure of said valve to unload the cylinder when said solenoid is de-energized, means for energizing said solenoid including a circuit in parallel with the synchronous motor field, a pressure switch for making and breaking said circuit in response to variations in receiver tank pressure, means for unloading the high pressure cylinder, and means operated mechanically by movement of said low pressure unloader valve for controlling said high pressure unloading means.

18. In combination, a compressor, an electric motor for driving the same, means responsive to compressor discharge pressure for automatically unloading said compressor, means for controlling the main current supply to said motor, means operating after the compressor has run unloaded for a predetermined length of time for opening said current control means, and means responsive to compressor discharge pressure and independent of said time responsive means for automatically closing said current control means.

19. In combination, a compressor, an electric motor for driving the same, a switch for starting and stopping said motor, unloading means for said compressor, and electrical controlling means for said switch and for said unloading means, said electrical controlling means including time responsive means for opening said switch only after the compressor has run unloaded for a predetermined length of time and means responsive to compressor discharge pressure and independent of said time responsive means for automatically closing said switch.

20. In combination, a compound compressor, means for unloading the low pressure cylinder, a relief valve for the high pressure cylinder, electric actuating means for said relief valve, means for supplying current thereto including a circuit, and a switch for controlling the flow of current through said circuit, said switch being controlled by said unloading means for the low pressure cylinder.

21. In combination, a compressor, a synchronous motor for driving the same having a field, and electrically operated unloading means for said compressor, said electrically operated unloading means having the electric operating means thereof controlled by a circuit in parallel with the field of the motor.

22. In combination, a compressor, a synchronous motor for driving the same having a field, and electrically operated unloading means for said compressor, said electrically operated unloading means having the electric operating means thereof controlled by a circuit in parallel with the field of the motor and controlling means for said circuit governed by variations in receiver pressure.

23. In a compressor control system, a compressor, a motor for driving the same, un-

loading means for the compressor, controlling means therefor operative to effect unloading at a predetermined compressor discharge pressure and reloading at a lower predetermined compressor discharge pressure, and means for automatically stopping the motor if said compressor discharge pressure remains above said lower predetermined compressor discharge pressure for a predetermined substantial period of time subsequent to unloading.

24. In a compressor control system, a compressor, a motor for driving the same, unloading means for the compressor, controlling means therefor operative to effect unloading at a predetermined compressor discharge pressure and reloading at a lower predetermined compressor discharge pressure, and means for automatically stopping the motor if said compressor discharge pressure remains above said lower predetermined compressor discharge pressure for a predetermined substantial time subsequent to unloading, said means functioning independently of variations in rate of air consumption during said time.

25. In combination, a compound compressor, means for unloading the low pressure cylinder, means for unloading the high pressure cylinder, means operative on movement to control a supply of power medium to control the operation of the unloading means for the high pressure cylinder, and means movable with the unloading means for the low pressure cylinder for moving said last mentioned means.

In testimony whereof I affix my signature.

JOHN W. SANFORD.