ROTARY COMPRESSOR

Filed Oct. 3, 1963 3 Sheets-Sheet 1

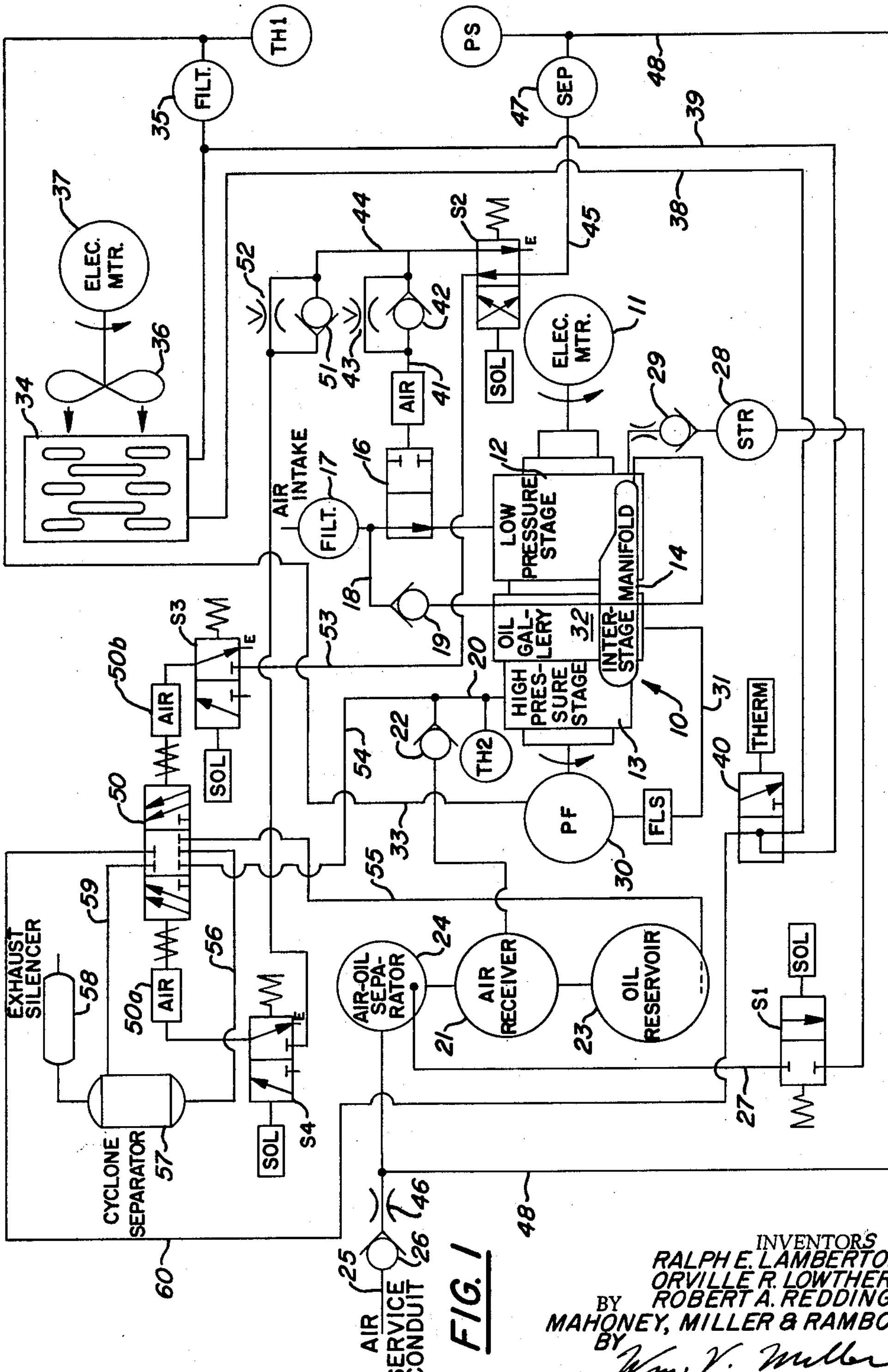

FIG. 1

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June 1, 1965 R. E. LAMBERTON ETAL 3,186,631

ROTARY COMPRESSOR

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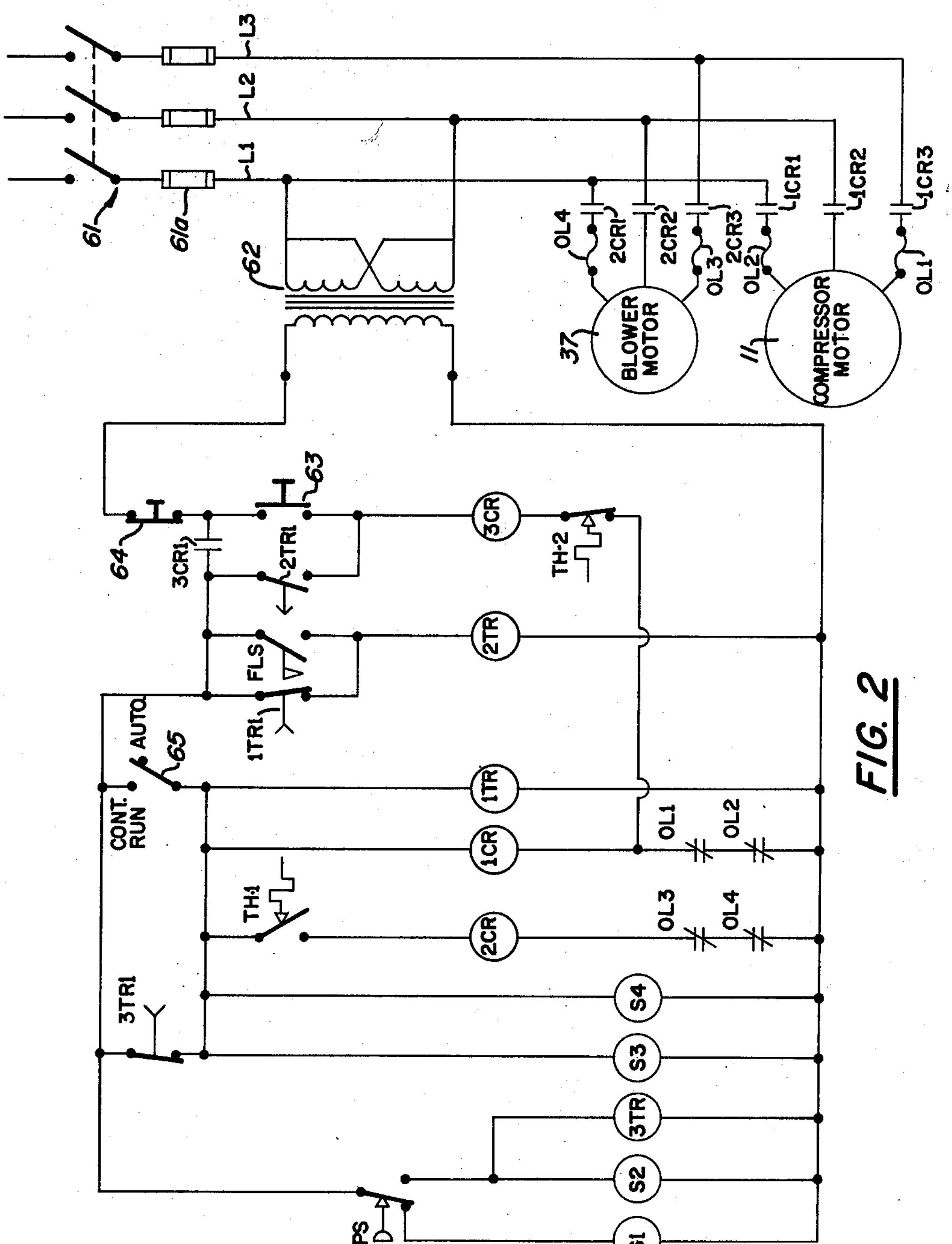

FIG. 2

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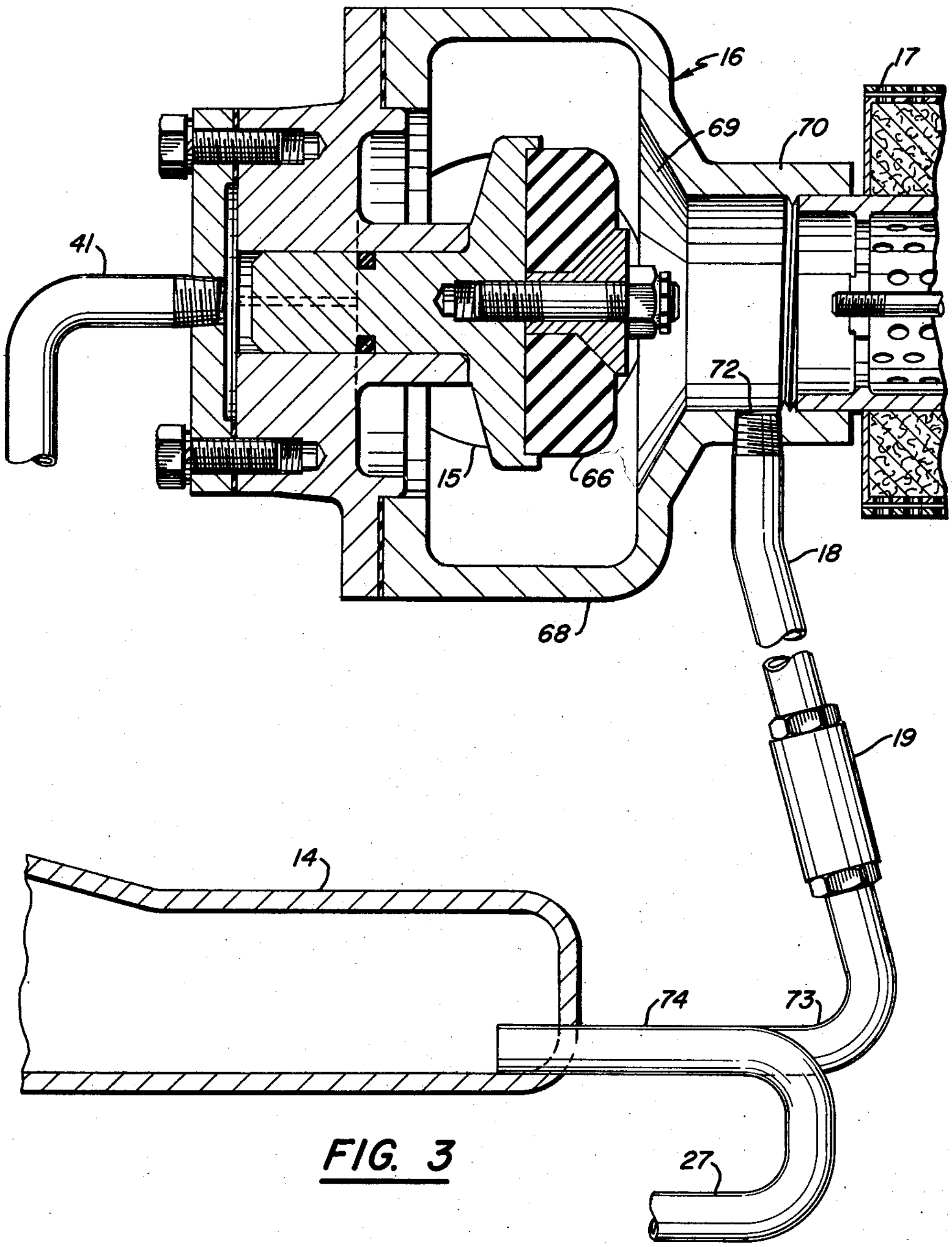

FIG. 3

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ROTARY COMPRESSOR

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19 Claims. (Cl. 230—26)

Our invention relates to a rotary compressor. It deals, more specifically, with an unloading system for a rotary compressor whereby the power required to drive the compressor while it is running in an unloaded state is greatly reduced as compared to power requirements of prior art compressors now commonly in use in a similar state.

This invention deals mainly with compressors of the internally oil-cooled, sliding-vane rotor, positive-displacement type. It is applicable, particularly, to a rotary compressor of this general type which is driven by an electric motor although it is not necessarily limited to an electrically-driven compressor.

At the present time, compressors of the general type indicated are provided with unloading systems but by these systems only the intake valve of the compressor is closed so that atmospheric air to be compressed will not be taken into the compressor and a very high vacuum will result at the intake side of the compressor unit. The rotor continues to rotate in the unloaded state of the compressor, even if there is no need to compress air, to provide for proper circulation of the lubricant-cooling oil in the system. However, even in the unloaded state, the rotor is working against the pressure in the air receiver which is reflected back to the discharge chamber of the high-pressure cylinder. Since no air is entering the low-pressure cylinder, all sectors of both rotors bounded by the sliding vanes are operating at a partial vacuum. As each sector of the high-pressure rotor is exposed to the receiver backpressure, air expands into this cavity and must be recompressed back to a pressure slightly greater than that of the receiver, as the rotor vanes pass the discharge port. This alternate expansion and recompression results in a high power consumption for driving the rotor in the unloaded state of the compressor as compared to the power consumption required to drive it in the loaded state of the compressor, ordinarily amounting to about 75% of the energy required to drive it in the loaded state. This is particularly true of the electrically-driven compressors in which the electric motor drives at constant speed. Even in connection with rotary compressors driven by internal combustion engines, where the throttle is moved to a minimum speed position during the time the compressor is unloaded, a substantial amount of power and, therefore, fuel is required to drive the rotor while the compressor is unloaded.

It is the main object of this invention to provide an unloading system for a compressor of the type indicated which may be termed a "free" unloading system in that the rotor will not be required to work against the pressure of the compressed air in the receiver part of the compressor unit and, therefore, the amount of power required to drive the rotor during that unloaded state will be a minimum.

Another object of our invention is to provide a free-unloading system of the type indicated in an internally oil-cooled compressor wherein an unloading point in the system is selected where the air is sufficiently free of circulating lubricating-cooling oil to allow it to be exhausted to the atmosphere without excessive loss of oil.

Another object of our invention is to provide a free-unloading system of the type indicated by which the unloading of the compressor is accomplished without venting substantial amounts of previously-compressed air from the receiver part of the compressor system, such as from the air receiver tank and associated air-oil separator.

A further object of our invention is to provide a control system for a compressor of the type indicated which preferably will automatically control starting and stopping of the compressor as well as loading and unloading of the compressor in accordance with our invention.

A further object of our invention is to provide a free-unloading system of the multi-stage type wherein an interstage manifold connects the stages of the compressor having an oil-scavenging system associated therewith for preventing the accumulation of excessive amounts of oil in the manifold while the compressor is operating in the unloaded state.

Various other objects will be apparent as this description progresses.

In the accompanying drawings, we have illustrated one embodiment of our invention, the embodiment shown being a compressor which is electrically driven, but it is to be understood that many specific variations are possible without departing from basic principles of our invention.

In these drawings:

FIGURE 1 is a schematic diagram of the fluid system of a rotary compressor embodying our invention with certain electrical members indicated in association therewith.

FIGURE 2 is a schematic diagram of the electrical system used on the compressor in accordance with our invention.

FIGURE 3 is a schematic sectional view illustrating details of the oil-scavenging system associated with the free-unloading system.

With reference to the drawings, in FIGURE 1 we have illustrated schematically a rotary compressor system to which our invention is applicable, but it is to be understood that we are not limited to this specific compressor system. The structure of the rotary compressor itself may be generally like that disclosed in the patent to Lamberton No. 2,739,758 issued March 27, 1956, but its drive is shown herein as being an electric motor. The general arrangement and positioning of the various units of the compressor system may be similar to that disclosed in the copending application of Paugh Ser. No. 215,390 filed August 7, 1962.

In FIGURE 1, we indicate a compressor **10** of the rotary type which is driven by an electric motor indicated at **11**. The compressor may be of the multi-stage type and is shown as having a low-pressure cylinder **12** and a high-pressure cylinder **13**. These cylinders are connected together by an interstage manifold **14** so that low-pressure air discharged from the cylinder **12** will be conducted into the cylinder **13** for further compression. The low-pressure cylinder **12** houses a rotor (not shown) preferably of the sliding vane type which is coupled to and is driven by the motor **11**. The rotor in the low-pressure cylinder is coupled to and drives the rotor (not shown) which is in the high-pressure cylinder **13**. The low-pressure cylinder **12** is provided with an air intake conduit **15** having a two-way unloading valve **16** connected therein which is of the piston type and is adapted to be actuated by air-pressure. A filter **17** is also provided for the intake conduit **15** so that air taken into the low-pressure cylinder **12** from the atmosphere will be filtered. Also connected to the filter **17** is an air conduit **18** which is adapted to inspirate air into the interstage manifold **14**, to the low-pressure end of which it is connected as shown. This condiut **18** is provided with the check valve **19**. The conduit **18** functions in a manner to be described in detail later to aid in preventing undue accumulation of oil in the manifold **14**.

The high-pressure cylinder 13 is provided with an outlet or discharge chamber for the compressed air and oil mixture which connects by a discharge conduit 20 to the receiver tank, indicated at 21, and a check valve 22 is provided in this conduit. An oil tank is illustrated at 23 below the receiver tank 21 and is connected thereto. An air-oil separator is indicated at 24 above the tank 21 and is connected thereto. The separator 24 is connected to the air-service conduit 25 which has a check valve 26 therein and which supplies the air compressed by the compressor to the point of use. An oil bleeder conduit 27 leads from the lower portion of the separator 24 and connects to the low-pressure end of the manifold 14, being provided with a strainer 28 and a check valve 29, associated with a restricted passage to the manifold, connected therein in series. This conduit functions to return the separated oil from the separator 24 to the interstage manifold during normal loaded operation of the compressor as will be further explained in greater detail. According to the present invention, this conduit 27 has interposed therein a solenoid-actuated two-way valve S1 which is part of the free-unloading system of this invention. Valve S1 may be of the spool type spring offset to the position indicated.

Oil for lubrication and cooling is supplied by a pump 30 in the usual manner, this pump being coupled to the rotor in the cylinder 13. The discharge of this pump is connected by an oil conduit 31 to the oil supply system of the cylinders 12 and 13 which is indicated schematically as the gallery 32 and a flow switch FLS is interposed in this oil conduit 31 although a pressure switch may be used instead of this flow switch. The inlet side of the pump 30 is connected by an oil conduit 33 to an oil cooler indicated at 34 and a filter 35 is interposed in this conduit. Also, a thermally-actuated switch TH1 is associated with this conduit and is actuated by the temperature of the oil therein flowing to the pump 30. A blower is indicated at 36 as part of the oil cooler and is driven by an electric motor 37. An oil conduit 38 leads from a thermally-actuated by-pass valve 40 to the oil cooler 34. A by-pass oil conduit 39 is also connected to this valve 40 and connects to the oil conduit 33 leading from the oil cooler 34.

The unloading valve 16, as previously indicated, is part of the unloading system and is actuated by air pressure through a conduit 41 connected thereto and provided with a check-valve 42 which is by-passed by a restricted by-pass 43. The conduit 41 is connected to a conduit 44 which is connected to a four-way solenoid-actuated valve S2 which may be of the well known spool type and which is spring offset to a normal position as indicated when the solenoid is deenergized. This valve is connected by a conduit 45 to a conduit 48 through an air-liquid separator 47 and conduit 48 is connected to the air-service conduit 25. A restrictor 46 is interposed in conduit 25 between check-valve 26 and the separator 24 with the conduit 48 connection being on the high-pressure side to assure fast pressure built-up when starting for valve operation. A pressure-actuated electrical switch PS is connected to the conduit 48.

Connected in the system is a multi-path, directional flow control 50, termed herein as a five-way valve, which is also part of the unloading system according to this invention. This valve may be of the spool type as illustrated which is spring centered and operated by an air actuator, 50*a* and 50*b*, provided at each end of the spool. This valve is controlled by the four-way valve S2, previously mentioned, for operating the system in either the loaded state or the unloaded state. The valve actuator 50*a*, utilized for unloaded operation, is connected by conduit 44 to one port of the four-way valve S2 through a check valve 51 which is by-passed by a restricted by-pass 52. A solenoid actuated three-way valve S4 is interposed in conduit 44 between the air actuator 50*a* and the check valve 51 and restriction 52. The other valve actuator 50*b* is connected to a second port of the four-way valve S2 by a conduit 53 which has a solenoid actuated three-way valve S3 interposed therein. Valves S3 and S4 may be of the spool type which are spring offset to a normal position when the solenoid thereof is deenergized. The valve 50 includes three inlet ports, one of which is connected by a conduit 54 to the discharge conduit 20 leading from the high-pressure cylinder 13. A thermally-actuated switch TH2 is connected in the discharge conduit 20 so as to be affected by the temperature of the compressed air and oil mixture discharged from the high-pressure cylinder whether the air and oil mixture flows to the air receiver 21 or to the valve 50. The oil reservoir tank 23 is connected to a second inlet port of the valve 50 by a conduit 55 leading from the lower side or bottom of the oil tank. The third inlet port of the valve 50 is connected by a conduit 56 to the bottom or oil outlet of an air-oil separator 57 which may be of the cyclone type. This separator 57 has an air exhaust outlet at its upper end which may be provided with an exhaust silencer 58. Of the valve's two outlet ports, one is connected by a conduit 59 to the inlet of the separator 57 and the other is connected by a conduit 60 to the inlet port of the by-pass valve 40.

An electrical power and control circuit for operation of the compressor in accordance with this invention is diagrammatically illustrated in FIGURE 2. The control circuit, as illustrated, is adapted to not only automatically control operation of the compressor as to loaded and unloaded operation in accordance with service demands but to automatically start and stop the apparatus in accordance with predetermined operational conditions. It is the primary function of the control circuit to automatically operate the several components of the apparatus as to provide for free-unloaded operation of the compressor.

The electrical power circuit is connected to a three-phase, alternating current power distribution system of suitable voltage and includes the three power lines L1, L2 and L3. A three-pole disconnect switch 61 is interposed in the power lines along with the customary over-current protective devices such as the fuses 61*a*. Connected to the power lines L1, L2 and L3 are the electric motors 37 and 11, previously referred to, for operating the oil cooler blower 36 and driving the rotary compressor 10. Each respective motor 11 and 37 is connected to the power lines through a magnetic contactor of the type having a set of normally open contacts, 1CR1, 1CR2 and 1CR3 and 2CR1, 2CR2 and 2CR3, controlled by their respective electromagnetic solenoids or operating coils 1CR and 2CR. Also incorporated in each magnetic contactor are the usual overload protective devices consisting of the associated thermally-responsive elements and normally closed contacts OL1, OL2, OL3 and OL4. As will be noted from the circuit diagram, the overload devices OL1 and OL2 are associated with the compressor motor 11 and the overload devices OL3 and OL4 are associated with the blower motor 37. Also connected to the power lines L1 and L2 is a control circuit voltage transformer 62 which provides the desired voltage for operation of the control circuit.

The control circuit includes a start-stop circuit having manually-actuated start and stop switches 63 and 64 which may be of the pushbutton type. The stop switch 64 is normally closed while the start switch 63 is normally open with the contacts of each being serially connected across the secondary output conductors of the transformer 62. Also connected in series with the switches 63 and 64 is the coil 3CR of a circuit-maintaining relay which is operable to by-pass the start switch 63, once the compressor apparatus has been started and is operating normally. Completion of the start and stop circuit is through the serially-connected contacts of the thermostatically-operated switch TH2, previously mentioned, and the normally closed contacts of the overload devices OL1 and OL2 associated with the compressor motor 11. The thermostatic switch TH2 is provided with a normally closed contact which will open when the temperature of the oil-air mixture discharged from the high-pressure stage 13 of the compressor exceeds a predetermined value. In this present embodiment, the switch TH2 is set to open at about 240° F. and will break the start-stop circuit, thus protecting the compressor apparatus from damage due to high temperatures. Serially connecting the contacts of the overload devices OL1 and OL2 in the start-stop circuit provides further protection for the compressor apparatus in the event that an overload should occur in the compressor motor 11. An overload of this form would also break the start-stop circuit thus deenergizing the control circuit and disconnecting the compressor and blower motors 11 and 37 from the power lines L1, L2 and L3.

A holding circuit is connected in shunt relationship with the start-stop circuit which automatically operates to deenergize the control circuit and disconnect the compressor and blower motors 11 and 37. This circuit includes the normally open contacts 3CR1, actuated by the relay coil 3CR, which are serially connected with the parallel connected contracts 1TR1 of a time delay relay and the flow switch FLS, previously mentioned, and the operating coil 2TR of a time delay relay connected in series therewith. The contacts 1TR1 of the time delay relay are normally closed while the contacts of the flow switch FLS are normally open. As previously indicated, the flow switch FLS is interposed in the discharge conduit 31 of the oil pump 30 and is responsive to a minimum desired oil flow necessary for operation of the compressor. The flow switch FLS assures that oil is being continuously pumped into the compressor 10 and operates to deenergize the control circuit at any time the oil flow decreases to such an extent that it is below the minimum.

The coil 2TR controls the normally open contacts 2TR1 connected in series with the holding relay contacts 3CR1 and in shunt relationship to the start switch 63. This time delay relay is of the type wherein the contact action is retarded upon deenergization of the operating coil. Thus, when the start switch 63 is momentarily closed, a circuit is completed through contacts 1TR1 and coil 2TR causing contacts 2TR1 to close instantaneously. With contacts 2TR1 closed the start switch 63 may be opened and the control circuit will proceed to automatically operate the compressor and blower and other associated apparatus even though a momentary interruption should occur in the holding circuit. Should the circuit including the timer coil 2TR be opened at any subsequent time, such as would result from a momentary fluctuation in the oil flow in conduit 31, the contacts 2TR1 will remain closed until expiration of the delay interval. Energization of coil 2TR at any time including during a timing interval will reset the mechanism for subsequent operations. A delay of approximately five seconds time has been found sufficient to prevent intermittent operation of the automatic circuit due to fluctuation of lubricant-cooling oil flow.

Connected in the control circuit in dependent relationship to the holding and start-stop circuits are the operating coils 1CR and 2CR for the magnetic motor contactors. Each coil, 1CR and 2CR, is connected in series with its respective serially-connected overload contacts, OL1 and OL2, OL3 and OL4. The coils 1CR and 2CR with their respective overload contacts are connected in shunt relationship and may be connected to the holding circuit through either a manually actuated selector switch 65 or through the normally closed contacts 3TR1 of a time delay relay. The connection of the operating coils 1CR and 2CR to the holding circuit is made at the juncture of the parallel connected timer contacts 1TR1 and flow switch contact FLS whereby the relay contacts 3CR1 will be effective to control the operation of the blower and compressor motors 11 and 37. The selector switch 65 is of the two-position type and is adapted to complete the circuit to the operating coils 1CR and 2CR in a first position and is open-circuited in the second. As will be noted from the circuit diagram, the selector switch 65 is connected in shunt relationship to the timer contacts 3TR1 and is effective to by-pass these contacts when in the first position. Interposed in the circuit of the operating coil 2CR are the contacts of the thermal switch TH1, previously mentioned. These contacts are of the normally-open type with the switch being set to close the contacts at about 110° F. and to open the contacts at about 100° F. The thermally-responsive element of the switch is installed in the oil cooler outlet conduit 33 and is effective to maintain the temperature of the oil within predetermined limits by controlling the operation of the oil cooler blower motor 37.

Also connected in shunt relationship to the operating coils 1CR and 2CR is the operating coil 1TR of the time delay relay. This relay is of the type wherein the contact action is retarded upon energization of the operating coil. In the present compressor system, it has been determined that a delay of about 10 seconds time in opening of the contacts 1TR1 is desirable for optimum operation of the system. At any time the coil 1TR is deenergized, the coil and contacts 1TR1 will be instantaneously reset to their normal position.

An automatic free-unloading circuit is provided by this invention to simultaneously open the compressor high-pressure stage discharge to the atmosphere, isolate the oil separator and air receiver tanks, and to close the unloader valve 16 preventing further intake of air. The free unloading circuit includes the solenoid-actuated valves S1, S2, S3, and S4. Selective energization of the solenoids of the valves S1 and S2 is effected through a pressure switch PS. This switch is responsive to the pressure in the air service conduit 25, through the interconnecting conduit 48, and is of the single pole, double-throw type. In the first or low-pressure position, the pressure switch PS, the pole of which is also connected to the holding circuit so as to be in series with the relay contacts 3CR1, completes a circuit through the solenoid of the valve S1. In the second or high-pressure position, a circuit will be completed through the solenoid of the valve S2. The operating pressure limits of the switch PS, in the present embodiment, are set to maintain a circuit through the solenoid of the valve S1 at any time the pressure in the air service conduit 25 drops below 90 p.s.i.g. and remains below 105 p.s.i.g. and to maintain a circuit through the solenoid of the valve S2 at any time the pressure in the air service conduit reaches 105 p.s.i.g. and remains above 90 p.s.i.g. The solenoids of valves S3 and S4 are connected in parallel with the timer coil 1TR and the operating coils 1CR and 2CR of the magnetic motor contactors and will be energized at any time the compressor motor is operating.

Connected in parallel with the solenoid of the valve S2 is the operating coil 3TR of the third time delay relay. This relay is operative to effect automatic start and stop of the compressor and blower motors 11 and 37 in accordance with the air pressure in the air service conduit 25. This relay is also of the type wherein the contact action is retarded upon energization of the operating coil. Since the coil 3TR is connected in parallel with the solenoid of the valve S2, it will be energized simultaneously therewith when the air service conduit pressure reaches 105 p.s.i.g. The contacts 3TR1 will not open, however, until the time delay of the relay has elapsed. At the expiration of the time delay, the contacts 3TR1 will open and deenergize the operating coils 1CR and 2CR causing the blower and compressor motors 37 and 11 to stop and deenergize the solenoids of the exhaust valves S3 and S4. The delay, which may be of the order of 15 minutes, has been found advisable in order that the number of starts will be limited to four in any one-hour time interval. This is necessary to prevent overheating of the compressor motor 11 due to the relatively large starting current. When the air service conduit pressure drops to 90 p.s.i.g., thus resetting the pressure switch PS and deenergizing the solenoid of the valve S2, the timer coil 3TR will also be deenergized and will be reset in preparation for another timing interval. Instantaneously upon resetting of the operating coil 3TR, the contacts 3TR1 will close, if previously opened, permitting restarting of the compressor and blower motors 11 and 37.

As previously indicated, the conduit 18 is part of an oil scavenging system according to our invention which prevents the accumulation of oil in the manifold 14 during the unloaded operation of the compressor 10. This system is shown more in detail in FIGURE 3 and functions during the time the compressor is operating in the freely unloaded state. This scavenging system is an air-inspiring system which is connected to the manifold 14 and which operates on a pressure differential between the manifold and atmospheric air at the compressor intake to draw air from the atmosphere, during the unloaded cycle and to jet it through the manifold in the direction of normal flow through the manifold and thereby to scavenge the oil therefrom.

The bleed or drain conduit 27 running from the oil separator 24 functions to return separated oil from the separator 24 to the circulating oil system via the interstage manifold 14 during loaded operation of the compressor. During loaded operation, the pressure within the interstage manifold 14 will be substantially less than that within the separator 24 thereby assuring return of the separated oil to the oil system. For this purpose, it is necessary to select a point of reentry having a lower pressure.

While the compressor is loaded, the oil passing from the low-pressure cylinder 12 with the air will pass into the high-pressure cylinder 13 and out to the air receiver 21. The compressed air flows from the receiver 21 into the separator 24 and any oil vapors remaining in the air are retained in the filtering elements in the oil separator and are passed from the separator into the drain or bleed line 27. The check valve 29 in the conduit 27 will prevent oil from being forced back up into the separator when the compressor is started. As soon, after starting of the compressor, as air pressure in the discharge end of the oil separator 24 exceeds the pressure in the manifold 14, any oil collected by the oil separator 24 will be forced into the manifold 14. The main stream of oil and air, as indicated, during loaded operation of the compressor will flow through the manifold 14 and there will be no tendency for oil to accumulate therein at this time. The oil and air returned from the separator 24 by the conduit 27 will merely be added to that main stream.

The compressor air inlet is controlled by the valve 16 which may be a common type of unloading valve, an example of which is illustrated in FIGURE 3. It comprises a piston type valve member 66 which is actuated by receiver pressure reaching it through the conduits 41, 44, 45 and 48 controlled by the valve S2 previously mentioned. This valve member 66 is disposed in a housing 68 mounted on the low-pressure cylinder 12 over its inlet 15 and communicating therewith. The housing is provided with an inlet sleeve 70 leading thereinto having a valve seat 69 at its inner end with which the valve member 66 cooperates. On the outer end of the inlet sleeve 70, the filter unit 17 is mounted. Atmospheric air will be drawn through the filter unit 17 and be filtered before it enters the housing 68 through the inlet sleeve 70.

Without our scavenging system, if the compressor runs for long periods unloaded, an excessive amount of oil will accumulate in the interstage manifold 14. Should there be a demand for additional compressed air subsequent to an accumulation of oil in the manifold thus returning the compressor to loaded operation, the accumulated oil will instantly be drawn into the high-pressure cylinder 13 and, if a sufficiently large volume of oil has accumulated, causes a hydraulic jam between the vanes of the high-pressure rotor. Such an accumulation of oil could damage or distort the vanes. Also, if the air compressor is a portable compressor and is used for work on very irregular terrain, the compressor may be operating at very steep angles which could possibly cause an excessive accumulation of oil in the lowest end of the manifold with resulting serious damage or breakage of the vanes of the rotor in the high-pressure cylinder. Since during the unloaded state of the compressor there is no substantial flow of air through the manifold 14 from the low-pressure cylinder to the high-pressure cylinder but on the other hand there is a very low-pressure or vacuum condition in the manifold, which tends to cause accumulation of oil in the manifold, especially at the downstream end thereof, the jet of scavenging air created by our scavenging system and acting in the same direction as the normal flow through the manifold, will prevent the accumulation of oil therein.

According to our invention, we provide the conduit 18 as a means to prevent accumulation of oil in the interstage manifold 14 during the periods when the compressor is unloaded. This conduit 18 constitutes a piping system, between the interstage manifold and the air intake of the compressor, which provides for the inspiration of air through the intake filter 17 to the manifold 14 to produce a jet therein which will aid in forcing the oil from the manifold into the high-pressure cylinder 13. For this purpose, we connect the conduit 18 at one end to the unloading valve unit 16 and at its other end to the upstream end of the manifold 14. Thus, the inlet end 72 of the conduit 18, as shown in FIGURE 3, is connected to the valve unit 16 at the inlet sleeve 70 at a point intermediate the filter 17 and the valve seat 69. The air taken into the conduit 18 will, therefore, be filtered air. The other or outlet end 73 of the conduit is connected to the manifold 14 at its upstream end and directly above the bottom of the manifold to direct the air flow parallel to the bottom wall, as best shown in FIGURE 3. The outlet end 74 of the bleeder pipe or conduit 27 is also preferably connected to the manifold 14 in a similar manner. The outlet ends 73 and 74 of the conduits 18 and 27 are directed toward the opposite or downstream end of the manifold 14. The conduit 18 is provided with a check valve 19 previously mentioned which closes when sufficient positive pressure develops in the manifold 14 to prevent flow from the manifold to the inlet of the unloader valve 16.

When the compressor is running in an unloaded state, very little air is in circulation within the compressor. Therefore, if it were not for the provision of our scavenging system, there could be a rapid build up of oil in the interstage manifold 14. Since at this time the manifold 14 is under high vacuum, there is a substantial pressure differential between the manifold and the compressor filter 17 which communicates with the atmosphere, it being understood that the unloading valve 16 is closed at this time. Also, at this time, as will later appear, the valve S1 is closed blocking the bleeder conduit 27. The pressure differential between atmospheric air at the inlet and the low pressure in the manifold 14 is utilized according to our invention, to inspire atmospheric air into said manifold and use it as a scavenger jet to act in a downstream direction on any oil tending to accumulate therein and to cause the oil to flow toward and into the high-pressure cylinder 13. This jet will scavenge from the manifold any oil which tends to accumulate therein during the unloaded operation of the compressor.

Thus, with this arrangement, since the unloader valve 16 is totally closed when the compressor is running in an unloaded state, air will be inspired from the chamber in the sleeve 70 between the valve seat 69 and the intake filter 17. Consequently, only filtered air is drawn into the interstage manifold 14 through the conduit 18. This inspired air is drawn into the manifold **14** along the bottom thereof thereby aiding in moving oil therein from the low-pressure cylinder discharge to the high-pressure cylinder intake. When the compressor reassumes the pumping load, the valve **16** is opened by atmospheric pressure since holding pressure has been exhausted from the conduit **41**, a positive pressure develops in the manifold **14** and the check valve **19** is closed thereby preventing air and oil flow-back through the conduit **18** into the compressor intake.

The operation of the oil-scavenging system of this invention has been described above in detail. This system will function whenever the compressor is operating unloaded.

The general operation of the compressor and especially as it relates to the free-unloading operation is briefly described herein as related to the schematic diagrams of FIGURES 1 and 2. In these diagrams, the several elements or components are shown in their normal positions as when the compressor system is not operating. In this condition, the disconnect switch **61** will be open and the pressure in the air service conduit **25** may be at atmospheric pressure or at least below the minimum desired operational pressure of the system. The separator oil conduit valve **S1** will be closed since its solenoid will be deenergized. Also, the solenoid of the control valve **S2** is deenergized and this valve will be positioned as shown to exhaust or vent the conduit **44** to the atmosphere and connect conduit **53** to conduit **45**. The solenoids of the exhaust valves S3 and S4 are deenergized and the valves are positioned so as to block conduits **44** and **53** and vent the respective air actuators to the atmosphere through an exhaust port. The directional flow control valve **50** will thus be spring centered with all ports blocked. The unloader valve **16** will thus be in its normally open position as its actuating air cylinder is not pressurized. Since the temperature of the lubricating and cooling oil in the system will be below the minimum desired for operation, the thermal by-pass valve **40** will be positioned by its thermal element to connect the conduit **60** from the directional flow control valve **50** to both lines **38** and **39**. In the following description of the operation, it is to be assumed that the selector switch **65** will be placed in the open position denoted as "AUTO" for automatic start-stop operation as well as automatic free-unloading. As will be apparent from the electrical circuit of FIGURE 2, placing the selector switch **65** in the closed position denited "CONT. RUN" will eliminate the automatic start-stop features of the system but not the free-unloading operation.

Initial starting of the compressor system is preceded by closing the disconnect switch **61** which will energize the control circuit transformer **62** and the control circuit connected thereto and also connect the contactors of the compressor motor **11** and the blower motor **37** to the power source. Subsequent to closing of the disconnect switch **61**, the start switch **63** is momentarily depressed to complete the starting circuit as has been previously described in detail and cause relay contacts 3CR1 to close. While the compressor motor **11** will be immediately started, the blower motor **37** will not start until the temperature of the oil in the system has risen to a desired maximum, 110° F. for example, causing switch TH1 to close. A subsequent decrease in the oil temperature to a predetermined value, such as 100° F., will cause switch TH1 to open and the temperature of the oil will thus be maintained within the desired limits through continued operation of switch TH1.

Simultaneously with starting of the compressor motor **11**, the directional flow control valve **50** will be actuated to place the system in loaded operation. The control valve S2 is not actuated at this time and conduit **53**, which is connected through valve S2 and conduits **45** and **48** to the air service conduit **25**, will therefore carry this pressure. The exhaust valve **S3** interposed in conduit **53**, since its solenoid will be energized simultaneously with starting of the compressor motor **11**, will be operated to open conduit **53** to the air actuator **50*b*** of the valve **50** and thereby pressurize this actuator. The other exhaust valve S4 will also be simultaneously operated to connect conduit **44** to the air actuator **50*b***. As the air actuator **50*a*** will be vented to the atmosphere through conduit **44** and the exhaust port of valve S2, the pressurized actuator **50*b*** will cause the spool of valve **50** to shift and thus provide the indicated porting arrangement. It will be noted that the check valve **51** is installed in conduit **44** to permit free flow from the actuator **50*a*** and the valve **50** will be quickly shifted to the loaded position thereby permitting the compressor **10** to immediately take up the load.

With the valve **50** thus shifted to the loaded position, conduit **54** will continue to be blocked and the compressor **10** will necessarily pump into the air receiver **21** through conduit **20**. Conduits **56** and **59** will be connected forming a closed path from the oil outlet to the inlet of the cyclone separator **57**. The conduit **55** leading from the oil tank **23** will be connected to conduit **60** completing the oil supply circuit through the thermal by-pass valve **40**.

Since the pressure in the air service conduit **25** at the time of initially starting will be below the minimum operational pressure, which may be 90 p.s.i.g., switch PS will be maintained in its first position energizing the solenoid of the valve **S1**. When thus energized, valve **S1** will be open, permitting the separated oil to flow from the separator **24** through conduit **27** and into the interstage manifold **14**, along with any air that may be mixed therewith. Continued operation will permit the oil pump **30** to induce an oil flow through conduit **31** into the oil gallery **32** of the compressor **10**. After establishment of a minimal oil flow, the flow switch FLS will be actuated closing its contacts and thus by-pass contacts 1TR1. The contacts 1TR1 will remain by-passed as long as oil is flowing through conduit **31** for proper cooling and lubrication of the compressor **10**. Simultaneously with starting the compressor, **10**, the operating coil 1TR of the time delay relay will be energized and will open its associated contacts 1TR1 after a predetermined time interval of, for example, five to ten seconds. Opening of the contacts 1TR1 places continued operation of the compressor system under control of the flow switch FLS. At any subsequent time, should the oil flow from the pump **30** be insufficient for cooling and lubrication, the flow switch FLS will open to deenergize relay coil 2TR. After a predetermined time interval, five seconds for example, contacts 2TR1 will open causing contacts 3CR1 to open and thus disconnect the remainder of the control circuit from the transformer **62**. Should there be an interruption in the oil flow through conduit **31** of momentary duration at any subsequent time, the time delay relay coil 2TR and its associated contact 2TR1 will prevent stopping of the compressor **10**. If the interruption of oil flow should be prolonged, more than 5 seconds, the contact 2TR1 will open to stop the compressor and thereby prevent damage. This relay will effect a deenergization of the complete control circuit necessitating manual operation of the start switch **63** for a subsequent restart. It will be apparent that this delay relay is a safety device which will require the operator to make the necessary repairs or adjustments before operation of the compressor may be continued.

Assuming that the compressor **10** and its oil pump **30** are operating normally, air will be drawn through the air intake filter **17** and the open unloader valve **16** into the low-pressure stage **12** of the compressor during a loaded operational cycle. The air will be compressed and discharged through the conduit **20** into the air receiver **21** and other connected tanks and conduits to build up the compressed air supply. The contacts of the pressure switch PS will remain in the illustrated first position during loaded operation of the compressor 10 for a continued supply of compressed air. A loaded operational cycle will continue as long as there is a continued demand for compressed air and the pressure in the air service conduit 25 does not reach the maximum operating pressure which may be about 105 p.s.i.g.

When the compressed air requirements have been fully met, or the capacity of the compressor is such that the output thereof exceeds the current air requirements, the compressor system of this invention will automatically revert to free-unloaded operation to minimize power consumption. Where the maximum desired operational pressure may be approximately 105 p.s.i.g., as in the usual compressed air systems, the pressure switch PS is set to be actuated at this maximum pressure and the pole thereof will be switched to the second position to energize the solenoid of valve S2. Simultaneously, the solenoid of valve S1 will be deenergized and this spring-biased valve will be closed, preventing further flow of separated oil from the separator 24. Energization of the solenoid of valve S2 causes displacement of the movable member thereof to connect the conduits 44 and 41 to conduit 45. Pressurization of the air pilot actuator of the unloader valve 16 is thus effected as the pressure in conduit 41 will be that of the air service conduit 25 to which conduit 45 is connected and the air may flow freely through the check valve 42 into the air pilot actuator of the unloader valve 16. The unloader valve 16 will thus be closed preventing further flow of air into the low-pressure stage 12.

Conduit 44 being connected to the pressurized conduit 45 will also pressurize the air actuator 50*a* of valve 50 through the exhaust valve S4 which remains energized. The exhaust valve S3 also remains energized and the air actuator 50*b* will be vented to the atmosphere through the exhaust port of the control valve S2 which is now connected to conduit 53. Pressurization of the air actuator 50*a* will therefore shift the spool of valve 50 to the unloaded position having the indicated porting arrangement. There is a delay on shifting of the valve spool to the unloaded position since the check valve 51 prevents free flow in this direction and the restriction 52 will retard the flow. The delay is desirable to assure that the unloader valve 16 will be closed before the remainder of the system is reconnected by the directional flow control valve 50.

In the unloaded position, conduit 54 is connected to conduit 59 and the high-pressure stage 13 of the compressor will discharge into the cyclone separator 57. During unloaded operation, the air-oil mixture discharged from the compressor 10 is predeterminantly oil as there is very little air that enters the compressor, only the air coming from the scavenging system conduit 18, and the separator 57 must have an adequate capacity rating for the unloaded operation. The oil flow through the compressor remains substantially the same for either loaded or unloaded operation. Air separated from the compressor discharge will be vented to the atmosphere through the exhaust silencer 58. Oil separated by the separator 57 is returned to the system through the conduit 56 which is now connected to conduit 60 through the valve 50.

The oil supply conduit 55 leading from the oil tank 23 is blocked by the porting arrangement of the directional flow control valve 50 and completes the isolation of the compressed air receiver system. The oil bleeder pipe 27 is blocked by the closed valve S1 and conduit 20 is blocked by the check valve 22. With this system, the previously compressed air in the several tanks will not be lost when the compressor 10 is fully unloaded for free-unloaded operation as in accordance with this invention. Retention of the compressed air in the tanks is of particular advantage in large capacity air compressors. These tanks are necessarily of a correspondingly large volume and require some time to pressurize. This represents a time lag which is undesirable and which is eliminated by this system. Assuming that the tanks were pressurized prior to the unloaded operation or the compressor 10 was stopped, return of the compressor to loaded operation will be accompanied by an almost immediate assumption of the compressed air load as only conduit 54 and the portion of conduit 20 between the high-pressure stage 13 and the check valve 22 will require pressurization.

Free-unloading operation of the compressor 10 with the unloader valve 16 closed and the high-pressure side of the compressor opened to the atmosphere through the valve 50, separator 57 and exhaust silencer 58 will continue until the pressure in the air service conduit 25 has dropped to the minimal operating pressure of approximately 90 p.s.i.g. At this pressure, the switch PS will be reset to its first position for further loaded operation, as previously described. Valve S1 will accordingly be actuated by energization of its solenoid to open conduit 27 and the control valve S2 will return to its normal position as its solenoid will be deenergized. Conduit 44 will again be vented to the atmosphere through valve S2 and conduit 53 will be pressurized again as it will be connected to conduit 45 through valve S2. The pressurized air within the actuating cylinder of the unloader valve 16 will exhaust through the restricted by-pass 43 and conduit 41 to the atmosphere. The restricted by-pass 43 prevents instantaneous operation of the unloader valve 16 for protection of the valve and the compressor 10. Air actuator 50*b* is also pressurized again and will shift the spool of valve 50 to the loaded position as air actuator 50*a* is now vented to the atmosphere through conduit 44, check valve 51 and the exhaust port of the control valve S2. The directional flow control valve 50 thus connects the several conduits of the system as previously described for operation of the compressor in a loaded state.

During this free-unloaded operation of the compressor, the scavenging system comprising the jet produced by the conduit 18, as previously described, and directed into the manifold 14 will function to prevent accumulation of oil in the manifold.

An automatic starting and stopping circuit is also incorporated in the compressor system, as previously indicated. During free-unloaded operation, the operating coil 3TR of the third time delay relay will be energized simultaneously with the solenoid of valve S2. This time delay relay, which may have a delay of approximately 15 minutes in the actuation of its contacts 3TR1, will control the stopping of the compressor motor 11 and blower motor 37. The timing interval begins at the start of the free-unloaded cycle and the contacts 3TR1 will open at the expiration of this timing interval. Upon opening of contacts 3TR1, the operating coils 1CR and 2CR of the motor contactors will be deenergized and thereby disconnect the motors 11 and 37 from the power supply lines L1, L2 and L3. The operating coil 1TR of the first time delay relay will also be deenergized at the expiration of this timing interval. Contacts 1TR1 will instantaneously close and the flow switch FLS will subsequently open when the oil flow through conduit 31 has sufficiently decreased. The operating coil 2TR of the second time delay relay will thus remain energized and maintain the associated contact 2TR1 closed which in turn maintains relay 3CR energized. The contact 3CR1 of this relay will remain closed to permit a subsequent restart of the compressor motor 11.

Simultaneously with the deenergization of operating coils 1CR, 2CR and 1TR, the solenoids of the exhaust valves S3 and S4 will be deenergized. The porting of each valve is such that, when the solenoid is deenergized, the air actuators 50*a* and 50*b* will be vented to the atmosphere through an exhaust port of the respective valve S4 and S3. Conduit 44, which is pressurized at this time through the control valve S2, is blocked by the exhaust valve S4 to maintain pressure. Removing air pressure from the air actuator **50***a* through the exhaust valve S4 when stopping the compressor **10** as a result of operation of delay relay 3TR permits the flow control valve **50** to center. The air actuator **50***b* is vented to the atmosphere through an exhaust port of the exhaust valve S3. Since the directional flow control valve **50** is spring centered and both air actuators are open to the atmosphere, the spool of the valve will be returned to the center position with all ports blocked. In its center position, the flow control valve **50** will prevent further fluid flow in the system, such as a reverse flow of oil through conduit **60**, and will require a minimum of time to be shifted to its loaded position for a subsequent operating cycle.

The exhaust valves S3 and S4 are of particular advantage in the stopping of the compressor **10**, whether a normal stop as has been described or an emergency stop. In either case, it is desirable to have the directional flow control valve **50** return to its center position as soon as possible. All ports of the valve **50** will be blocked in the center position to prevent further fluid flow, either oil or air or a mixture, in the system. Regardless of whether the compressor system is operating in a loaded or unloaded cycle, the valve **50** will be permitted to return instantly to its center position.

At any subsequent time that the pressure in the air service conduit **25** decreases to 90 p.s.i.g., switch PS will be reset, deenergizing the solenoid of valve S2 and the operating coil 3TR of the time delay relay and energizing the solenoid of valve S1. Contacts 3TR1 of this relay will be instantaneously closed to reconnect coils 1CR, 2CR and 1TR and the solenoids of the exhaust valves S3 and S4 into the circuit. The compressor motor **11** and blower motor **37** will thus be restarted, as previously described, in conjunction with the initial starting phase.

It will be apparent from the above that our invention provides in an internally oil-cooled, positive displacement type rotary compressor, means for greatly reducing the power required to run the compressor in an unloaded state, that is, when it is not pumping a substantial volume of fluid at an elevated pressure. The unloading of the intake side of the compressor is accomplished at the intake valve whereas the unloading of the receiver or high-pressure discharge side of the compressor is accomplished by venting the air therefrom through an oil separator where the oil is removed from the air and the oil is returned to the system while the air is to be exhausted to the atmosphere without a loss of circulating oil. Unloading of the high-pressure discharge side of the compressor in this manner prevents loss of compressed air from the receiver system tanks to permit immediate assumption of the load by the compressor upon restart or return to loaded operation from unloaded operation. Thus, the power to drive the rotors during the unloaded state of the compressor is greatly reduced. Furthermore, this invention provides oil scavenging means which functions in association with the unloading system for preventing the accumulation of oil in the interstage manifold which otherwise might cause damage to the rotors. The control system for the unloading and loading operations as well as all other operations of the compressor are completely automatic. This control system includes timing means which limits the number of starts of the electric motors to prevent damage thereto.

The oil tank **23**, the received **21** and the separator **24** are shown as separate tanks but it is to be understood that the oil could collect in the bottom of the receiver tank so that the separate oil tank could be eliminated. Also, the oil separator tank could be disposed within the receiver tank. Our free unloading system and the associated oil scavenging system would work equally as well with such modifications of the compressor system.

According to the provisions of the patent statutes, the principles of this invention have been explained and have been illustrated and described in what is now considered to represent the best embodiment. However, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

Having thus described this invention, what we claim is:

1. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating-cooling system for said stages and connected thereto, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said pressure lubricating-cooling system including a supply tank connected in said receiver system and an air-oil separator vented to atmosphere, said supply tank and air-oil separator being connected to said flow control valve whereby actuation thereof to a first position will operatively connected said supply tank in said lubricating-cooling system and actuation to a second position will operatively connect the separator to the discharge port of said high-pressure stage, said valve when in said second position also preventing further outflow from said supply tank.

2. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating-cooling system for said stages and connected thereto, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said air and oil mixture receiver system including an air-oil separator, a conduit connecting the separator with said pressure lubricating-cooling system at a point which is substantially lower in pressure, and a two-way valve interposed in said conduit and operatively connected to said control means, said valve having a first position wherein said conduit is blocked and a second position permitting fluid flow through said conduit.

3. A rotary compressor according to claim 2 in which said low and high-pressure stages are connected by an interstage manifold and said conduit leading from said receiver system is connected to said manifold.

4. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating cooling system for said stages and connected thereto, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said inlet valve and said flow control valve being air-actuated, and said control means including a control valve having an electromagnetic solenoid for the actuation thereof, a conduit interconnecting said inlet valve and said flow control valve through said control valve to a source of pressurized air, and an electric circuit having a power source and switch means connected in circuit with said control valve solenoid, said switch means being of the pressure-actuated type having a pressure-responsive element which is pneumatically connected to said air service conduit for actuation of said switch means in accordance with the pressures in said service conduit.

5. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating-cooling system for said stages and connected thereto, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said air compressing rotors being coupled to a drive motor for the operation thereof and said control means including control apparatus for selectively starting or stopping said rotor drive motor, said control apparatus

being operative to start said rotor drive motor when the pressure in said air service conduit reaches said selected lower limit and to stop said rotor drive motor when the pressure in said air service conduit reaches and is maintained at said selected upper limit for a predetermined time interval.

6. A rotary compressor according to claim 5 wherein said control apparatus includes timing means connected therein for ascertaining said predetermined time interval.

7. A rotary compressor according to claim 6 wherein said pressure lubricating-cooling system includes a heat exchanger of the forced circulation type having a drive motor and said control apparatus is operative for selectively starting and stopping said heat exchanger drive motor.

8. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating-cooling system for said stages and connected thereto, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said low and high-pressure stages being connected by an interstage manifold and including means for scavenging oil from said manifold during unloaded operation, said means comprising a fluid conduit connected to said manifold at the upstream end thereof and connected to a source of fluid under greater pressure than that in the manifold during unloaded operation of the compressor.

9. A rotary compressor comprising low-pressure and high-pressure stages having air-compressing rotors, a pressure lubricating-coiling system for said stages and connected thereto, an inlet valve connected to said low-pressure lubricating-cooling system for said stages and air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said high-pressure stage to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said high-pressure stage for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said high-pressure stage when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said high-pressure stage when the pressure in said service conduit reaches a selected low limit to thereby load the compressor, said low and high-pressure

stages being connected by an interstage manifold and including means for scavenging oil from said manifold during unloaded operation, said means comprising a fluid conduit connected at one end to the upstream end of said manifold and open at the opposite end to the atmosphere, said fluid conduit having a check valve interposed therein to prevent fluid flow therethrough from said manifold during loaded operation of the compressor.

10. A rotary compressor comprising interconnected low-pressure and high-pressure stages having air-compressing rotors, a drive motor coupled to said rotors, an inlet valve connected to said low-pressure stage for controlling the inlet of air thereto, an air and oil receiver system connected to a discharge port of said high-pressure stage for receiving the air and oil mixture discharged therefrom and including an air-oil separator, an air service conduit connected to said receiver system, a conduit interconnecting said receiver system with said high-pressure stage having a check valve interposed therein to prevent fluid flow from said receiver system to said high-pressure stage, an oil bleeder conduit connected to said air-oil separator for removal of oil separated therefrom and including means for restricting the outflow of fluid, a two-way valve interposed in said oil bleeder conduit and operative to block said conduit in a first position and permit fluid flow through said conduit in a second position, means for actuating said two-way valve, a pressure lubricating-cooling system for said stages and connected thereto including an oil supply tank communicating with said receiver system for accumulating oil received by said receiver system during loaded operation of the compressor, a second air-oil separator vented to the atmosphere, and an oil supply conduit connected to said stages, a directional flow control valve connected to said oil supply tank, said second air-oil separator, said oil supply conduit and the discharge port of said high-pressure stage between said discharge port and the check valve in the conduit connecting with said receiver system for selectively controlling the flow of the air and oil mixture discharged from said high-pressure stage and to control the flow of oil in said pressure lubricating-cooling system, and control means connected to said inlet valve, said directional flow control valve and the actuating means of said two-way valve for closing the inlet valve, operating the flow control valve to vent said high-pressure stage while maintaining a flow of oil through said lubricating-cooling system and closing said two way valve to block the bleeder conduit for maintaining said receiver system under pressure, said control means being responsive to the pressure in said air service conduit to close said inlet valve, operate said flow control valve to vent said high-pressure stage and to cause said two-way valve to close when the pressure in said air service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve, operate said flow control valve to prevent venting of said high-pressure stage and to cause said two-way valve to open when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor.

11. A rotary compressor according to claim 10 wherein said directional flow control valve is of the three-position type having a first position in which flow of oil in said lubricating-cooling system is prevented and said high-pressure stage is not vented, a second position in which said high-pressure stage is not vented and said oil supply tank is connected in said lubricating-cooling system and a third position in which said high-pressure stage is vented to atmosphere through said second air-oil separator, said second oil separator is connected in said lubricating-cooling system and further flow of oil from said oil supply tank is prevented.

12. A rotary compressor according to claim 10 in which said inlet valve and said directional flow control valve

are air-actuated and said two-way valve is actuated by an electro-magnetic solenoid, and said control means includes a control air valve having an electromagnetic actuating solenoid, a conduit interconnecting said inlet valve actuator and said flow control valve actuator through said control valve to a source of pressurized air, and an electric circuit having a power source and switch means connected in circuit with said control valve solenoid and said two-way valve solenoid, said switch means being of the pressure-actuated type having a pressure-responsive element which is pneumatically connected to said air service conduit for actuation of said switch means in accordance with the pressures in said service conduit.

13. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween, a pressure lubricating-cooling system for said compressing means and connected thereto, an inlet valve forming part of said inlet system for controlling the inlet of air to said compressing means, said receiver system being connected to a discharge port of said compressing means for receiving air and oil mixture discharged therefrom and including a service conduit leading therefrom, said receiver system being connected to said discharge port by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system, a directional flow control valve connected to said discharge port to vent said compressing means to atmosphere, and control means connected to said valves for closing the inlet valve and operating the flow control valve to vent said compressing means for freely unloading the compressor, said control means being responsive to the pressure in said air service conduit for actuation to close said inlet valve and operating the flow control valve to vent said compressing means when the pressure in said service conduit reaches a selected upper limit to thereby freely unload the compressor while maintaining said receiver system under pressure and to open said inlet valve and operate said flow control valve to prevent venting of said compressing means when the pressure in said service conduit reaches a selected lower limit to thereby load the compressor, said pressure lubricating-cooling system including a supply tank connected in said receiver system and an air-oil separator vented to atmosphere, said supply tank and air-oil separator being connected to said flow control valve whereby actuation thereof to a first position will operatively connect said supply tank in said lubricating-cooling system and actuation to a second position will operatively connect the separator to the discharge port of said compressing means, said valve when in said second position also preventing further outflow from said supply tank.

14. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween, a pressure lubricating-cooling system for said compressing means and connected thereto, an inlet valve forming part of said inlet system for controlling the inlet of air to said compressing means, said receiver system being connected to a discharge port of said compressing means for receiving air and oil mixture discharged therefrom by a conduit having a check valve interposed therein to prevent fluid flow from said receiver system when the compressing means is loaded, a directional flow control valve connected to said discharge port of said compressing means, said pressure-lubricating cooling system including an air-oil separator having an inlet connected to said flow valve and having an air outlet connected to atmosphere and an oil outlet connected to said flow valve, said receiver system also including oil-accumulating means having an oil outlet line connected to said flow valve, said pressure lubricating-cooling system also including an oil inlet line leading from said flow valve to said compressing means which connects with said oil outlet line through said flow valve when the compressing means is loaded, and control means connected to

said valves and to said receiver system and responsive to a predetermined pressure in said receiver system to close the inlet valve to unload the compressing means and to operate the flow control valve to connect said discharge port of the compressing means to said inlet of the separator and to connect said oil outlet of the separator to said oil inlet line and also to block said accumulating means oil outlet line to prevent flow of fluid from the receiver system.

15. A compressor according to claim 14 in which said receiver system also includes an air-oil separator, a bleed line leading from said last-named separator to said compressing means, and a control valve in said bleed line connected to said control means and actuated thereby in response to said predetermined receiver pressure to block said line.

16. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween, a pressure lubricating-cooling system for said compressing means and connected thereto, inlet valve means forming part of said inlet system for controlling the inlet of air to said compressing means, said receiver system being connected to a discharge port of said compressing means for receiving air and oil mixture discharged therefrom when said compressing means is loaded, directional flow control valve means connected to said discharge port of said compressing means, said pressure-lubricating cooling system also including an oil inlet line leading from said flow control valve means to said compressing means which connects with said oil outlet line through said flow valve when the compressing means is loaded, and control means connected to said valve means and to said receiver system and responsive to a predetermined pressure in said receiver system to close the inlet valve means to unload the compressing means and to operate the flow control valve means to connect said discharge port of the compressing means to said inlet of the separator and to connect said oil outlet of the separator to said oil inlet line and also to block said accumulating means oil outlet line to prevent flow of fluid from the receiver system.

17. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween and having a discharge outlet, a pressure lubricating-cooling system for said compressing means and connected thereto, inlet valve means forming part of said inlet system for controlling the inlet of air to said compressing means, said receiver system being connected to the discharge outlet of said compressing means for receiving air and oil mixture discharged therefrom when the compressing means is loaded, directional flow control valve means connected to said compressing means discharge outlet and to an exhaust outlet but interrupting communication therebetween when the compressing means is loaded, said receiver system having an oil outlet connected to said control valve means, said pressure-lubricating cooling system also including an oil inlet leading from said flow control valve means to said compressing means, which communicates with said oil outlet through said valve means when the compressing means is loaded, and control means connected to said valve means and responsive to a predetermined pressure in said receiver system to close the inlet valve means to unload the compressing means and to operate the flow control valve means to connect said discharge outlet of the compressing means to said exhaust outlet and to block said oil outlet to prevent flow of fluid from the receiver system.

18. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween and having a discharge outlet, a pressure lubricating-cooling system for said compressing means and connected thereto, said inlet system including unloading means for unloading the compressing means, said receiver system comprising a first section connected to said discharge outlet through a check valve for receiving the air and oil mixture discharged through said discharge outlet from said compressing means while it is loaded and a second section for receiving the air and oil mixture discharged through said outlet when the compressor is unloaded, said second section being connected to atmosphere, said pressure-lubricating cooling system including an oil inlet line connected to said compressing means, said first receiver section having an oil return line and said second receiver section having an oil return line, flow valve means connecting said oil return line of the first receiver section to said oil inlet line and disconnecting the oil return line of the second receiver section from said oil inlet line when the compressing means is loaded, and control means connected to said flow control valve means and to said unloading means to operate both of said means upon receiver pressure reaching a predetermined amount, said control means actuating said valve means to connect said discharge outlet of the compressing means to said second receiver section and to disconnect said oil return line of said first receiver section from said oil inlet line but to connect said oil return line of the second receiver section to said oil inlet line.

19. A rotary compressor having a fluid inlet system and a fluid receiver system with fluid-compressing means connected therebetween and having a discharge outlet, a pressure lubricating-cooling system for said compressing means and connected thereto, said inlet system including unloading means for unloading the compressing means, said receiver system comprising a first section for receiving the air and oil mixture discharged through said discharge outlet from said compressing means while it is loaded and a second section for receiving the air and oil mixture discharged through said outlet when the compressing means is unloaded, said second section having venting means adapted to be connected to the discharge outlet of said compressing means, each of said receiver sections having oil collecting and return passages adapted to be connected to said compressing means, valve means for normally disconnecting the return oil passage of the second receiver section from the compressing means and for connecting the return oil passage of the first receiver section to the compressing means and disconnecting said discharge outlet from said venting means, and control means responsive to receiver pressure for actuating said unloading means and actuating said valve means to disconnect the return oil passage of the first receiver section from said compressing means and to connect the return oil passage of the second receiver section to said compressing means and also to connect the discharge outlet of the compressing means to said venting means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,186,631 June 1, 1965

Ralph E. Lamberton et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, lines 15 and 16, for "air-inspiring" read -- air-inspirating --; column 11, line 52, for "predeterminantly" read -- predominately --; column 13, line 66, for "received" read -- receiver --; column 16, line 51, for "lubricating-coiling" read -- lubricating-cooling --; line 53, strike out "lubricating-cooling system for said stages and" and insert instead -- stage for controlling the inlet of air thereto, an --; line 74, for "low" read -- lower --; column 20, line 18, after "flow" insert -- control --.

Signed and sealed this 21st day of December 1965.

'AL)

'st:

EST W. SWIDER
'ing Officer

EDWARD J. BRENNER
Commissioner of Patents